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127-1 AARON GOODMAN, AMG*; LAUREN ESPOSITO, LAE; California Academy of Sciences, California Academy of Sciences ; *agoodman@calacademy.org*

Spatial and Ecological Niche Partitioning in Congeneric Scorpions

Species in the scorpion genus Centruroides Marx, 1890 (Scorpiones: Buthidae) are good candidates to study ecological niche partitioning due to their habitat plasticity, widespread geographic distribution, and presence of cryptic species. Currently, three species belonging to three subgroups of Centruroides are distributed along the Isthmus of Tehuantepec in southern Mexico, presenting a rare opportunity to study niche partitioning within a single genus. We examined the environmental, substrate, and habitat preferences of *Centruroides flavopictus*, Pocock, 1890, *Centruroides gracilis*, Latreille 1904, and *Centruroides rileyi*, Sissom 1995 within La Estación Biología Los Tuxtlas west of the Isthmus of Tehuantepec. Our results demonstrate habitat partitioning occurs along humidity, temperature, and elevational gradients, with *C. gracilis* preferring habitats of low humidity and high temperature and is predominantly found on the substrate in human-mediated habitats, ""*C. flavopictus*"" exhibited a larger range of humidity and temperature preferences but was found within secondary and primary forest, and *C. rileyi* had the greatest specificity of low temperature and high humidity on trees within primary forest. Furthermore, *C. rileyi* was found significantly higher in trees than *C. flavopictus*. This study represents the first example of niche partitioning within a genus of arachnid, and the first description of the ecological niche in an arboreal-specialist scorpion.

56-5 ABBOTT, EA*; DIXON, GB; MATZ, MV; University of Texas; *evelyn.abbott@utexas.edu*

Disentangling coral stress and bleaching responses by comparing gene expression in symbiotic partners

Coral bleaching—the disruption of the symbiosis between a coral host and its endosymbiotic algae—is associated with environmental stressors. However, the molecular processes are not well understood, and no studies have disentangled the transcriptional bleaching response from the stress response. In order to characterize general stress response, specific stress responses, and the bleaching response, we isolated host and symbiont RNA from fragments of Acropora millepora which were exposed to 5 different stress treatments. We hypothesize that under stress conditions, the coral host, and not the symbionts, become stressed. If this hypothesis is correct we predict that the host may upregulate genes involved in oxidative stress, immune response, heat shock proteins, or lipid metabolism; we also expect that the symbiont would upregulate genes involved in growth and uptake of nutrients. Additionally, it is unknown whether the host or the symbiont initiates bleaching. Because symbionts are horizontally acquired, their success is not linked to the survival of the host. Thus, we hypothesize that when the host becomes stressed, the symbionts initiate bleaching. To capture the bleaching response, ambient conditions were reestablished after treatments and samples of RNA were taken at multiple time points, between 8-16 hours after the treatment. The RNA was sequenced with tag-based RNA sequencing and the data were analyzed using DESeq and WGCNA. If the symbionts initiate bleaching, we expect that the expression profile of the symbionts will resemble symbionts in the free-living state—such as upregulation of genes involved in sexual reproduction and motility. Conversely, if the host initiates bleaching we expect to upregulation of genes involved in immune response, exocytosis, or nutrient transport.

P1-56 ABBOTT, CP*; LOCKWOOD, R; SUES, H-D; HUNT, G; ANGIELCZYK, KD; The University of Chicago, Chicago, IL, William & Mary, Williamsburg, VA, Smithsonian Institution, Washington, DC, Smithsonian Institution, Washington, DC, The Field Museum, Chicago, IL; *cpabbott@uchicago.edu*

How useful are extant tetrapods as analogues for non-mammalian synapsid posture?

Reconstructing non-mammalian synapsid posture usually takes one of two approaches. One approach models range of motion and muscle moment arms from fossils, and another method compares fossils to extant tetrapod analogues. The former method is constrained by how well body fossils reflect in vivo biomechanics, while the latter is limited by the relevance of extant analogues to fossil synapsids. Non-mammalian synapsids lack both extant representatives and a tight phylogenetic bracket. The only extant synapsids are mammals, which are highly derived and disparate compared to most fossil synapsids. Extant reptilian and amphibian analogues also possess derived morphologies compared to their extinct relatives, despite superficially "primitive" postures. Does the high phylogenetic and morphological disparity of these analogues impact their usefulness? We collected long bone and girdle dimensions from skeletal material for of 45 extant mammal, reptile, and amphibian taxa, and compared these data with analogous measurements from *Diasparactus*, *Ophiacodon*, *Dimetrodon*, and *Aulacephalodon*. We used principal component analysis to visualize the distribution of the sampled taxa in morphospace, and phylogenetic flexible discriminant analysis to explore categorical estimates of synapsid posture compared to traditional extant locomotor grades. Results indicate that fossil synapsids lack informative locomotor analogues among extant tetrapods. Furthermore, our results suggest that the traditional sprawling-upright dichotomy not only masks the continuum of tetrapod posture, but also ignores phylogenetic and physical constraints relevant to their locomotor habits.

P3-2 ABDULELAH, SA*; CRILE, KG; ALMOUSELI, A; AWALI, S; TUTWILER, AY; TIEN, EA; MANZO, VJ; HADEED, MN; BELANGER, RM; University of Detroit Mercy; *abdullsa3@udmercy.edu*

DNA damage in the cells of lateral antennules of crayfish (Faxonius virilis) is increased following exposure to environmentally relevant concentrations of atrazine

Atrazine (ATR) is an herbicide commonly applied in agricultural regions in the Midwestern United States. Excess ATR can enter nearby aquatic environments through run-off and seepage, causing ATR concentrations to increase and placing non-target aquatic organisms, like crayfish, at risk of ATR exposure. It has been shown that acute exposure to 80 ppb (µg/L) ATR can cause chemosensory deficits in crayfish. Knowing that ATR causes impairments on olfactory-mediated behaviors, our aim for this study was to determine the effects of ATR in olfactory sensory neurons, located in the lateral antennules of crayfish. We exposed crayfish to environmentally relevant concentrations of ATR (0, 10, 40, 80, 100 and 300 ppb) for 10 days. Following exposures, the distal portion of the lateral antennule was cryosectioned, and a TdT mediated dUTP nick-end labelling (TUNEL) assay was done in order to determine if cells in the lateral antennules had DNA damage. We found a significant increase of TUNEL-positive cells as atrazine increased above 10 ppb. The data that we obtained showed that DNA damage is caused in the cells of lateral antennules, including olfactory sensory neurons, which ultimately compromises the chemosensory abilities of crayfish. This is concerning as crayfish rely heavily on chemosensory abilities for many aspects of their lives.

P2-69 ABERNATHY, A.L*; KLAR, E.A; JORDAN, C.H; JOSHI, M.M; NEWBREY, M.G; Columbus State University; *abernathy_abigail@columbusstate.edu*

Comparison of intersex severity between two types of histological sections using testes of Largemouth Bass (Micropterus salmoides) and Spotted Bass (M. punctulatus) from the Chattahoochee River, Georgia

Previous studies have not adequately quantified or compared the severity of feminization (intersex) between cross and longitudinal sections of testes. In previous studies, intersex severity was ranked on a scale of 0-4: 0 = no oocytes, 1 = one oocyte, 2 = more than one oocyte, 3 = a cluster of oocytes, 4 = multiple clusters of oocytes. This ranking system is ineffective for assessing intersex severity with high counts of oocytes. Our goal was to compare the severity of intersex between two sampling techniques, cross and longitudinal sections of testes. We collected Largemouth Bass (*Micropterus salmoides*) (n =37) and Spotted Bass (*M. punctulatus*) (n = 25) from Lake Oliver, a reservoir of the Chattahoochee River, Columbus, GA, USA. Testes from each fish were prepared histologically with one testis cut into three cross sections, while the other was cut longitudinally. After staining with hematoxylin and eosin, the two sectioning techniques showed different intersex severity values. Longitudinal sections of Largemouth Bass revealed an average severity index of 1.67, while cross sectioning yielded an average severity index of only 0.87. In Spotted Bass, the longitudinal sections had a severity index of 1.36, while the cross sections only found an average severity of 1.00. Cross sectioning is the most common sampling technique to assess intersex, but our data suggests that longitudinal sectioning is more descriptive for determining intersex severity. The implications of our findings suggest that assessment of severity in fish populations may be underrepresented in published studies.

58-5 ABZHANOV, A; Imperial College London and Natural History Museum, United Kingdom; *a.abzhanov@imperial.ac.uk*

Phylogenetic Principles and Morphogenetic Mechanisms for Evolvability in Adaptive Radiations

Understanding the origins of morphological variation is one of the chief challenges to the modern biological sciences. Cranial diversity in vertebrates is a particularly inviting research topic as animal heads and faces show many dramatic and unique adaptive features which reflect their natural history. We aim to reveal molecular mechanisms underlying evolutionary processes that generate such morphological variation. To this purpose, we employ a synergistic combination of geometric morphometrics, comparative molecular embryology and functional experimentation methods to trace cranial evolution in reptiles, birds and mammals, some of the most charismatic animals on our planet. Our research is revealing how particular changes in developmental genetics can produce morphological alterations for natural selection to act upon, for example in generating adaptive radiations.

29-7 ACHARYA, R*; CHALLITA, EJ; BHAMLA, MS; Georgia Institute of Technology; *racharya33@gatech.edu*

Ultrafast Finger Snap is Mediated by a Frictional Skin Latch

The snap of a finger is a ubiquitous motion that has been seen across cultures and times. Using high-speed imaging, we analyze finger snap dynamics for the first time. We find that the mechanics of the snap are strongly mediated by human skin friction, which acts as a latch to generate rapid motion. The skin frictional latch is optimally tuned to enable maximum kinematic performance as the angular accelerations observed during a snap are one of the fastest human motions known. A simple scaling relationship is found that links the latch geometry to the performance of snapping motion across multiple organisms from termites to humans. Ultimately, our work reveals how friction between surfaces can be harnessed as tunable and scalable latching mechanism, with applications ranging from increasing grip in biomedical prosthetic surfaces to generating high force and accelerations in tiny robots.

P3-14 ACKERLY, KL*; ESBAUGH, AJ; The University of Texas at Austin; *klackerly@utexas.edu*

Additive effects of oil exposure and hypoxia on aerobic performance in red drum, Sciaenops ocellatus

Crude oil exposure can impair cardiorespiratory function in fishes, which can reduce their ability to transport oxygen for production of energy to support aerobic performance. As a result, many fishes experience decreased maximum metabolic rate and overall aerobic performance, which likely influences ecological success. However, oil exposure is not the only environmental stressor that can affect metabolic performance, especially in areas affected by crude oil spills. Hypoxia (low dissolved oxygen) is also known to constrain maximum metabolic rate, yet there has been little effort to explore how hypoxia may influence the magnitude of metabolic injury following oil exposure. Therefore, our goal was to investigate the effects of acute oil exposure and hypoxia on the metabolic performance of red drum, *Sciaenops ocellatus*, an economically important fish common in the Gulf of Mexico. Here, sub-adult red drum were exposed to crude oil for 24h before being exposed to hypoxic conditions. Our results show that hypoxia exposure combined with crude oil exposure results in significantly reduced aerobic scope (the difference between standard metabolic rate and maximum metabolic rate), which was additive compared to the reductions caused by each stressor alone. Interestingly, our results showed no changes to hypoxia tolerance among individuals, regardless of exposure to hypoxia or oil. We are currently investigating parameters such as hematocrit, mitochondrial enzyme content, and blood oxygen binding affinity to determine the mechanisms driving these additive effects. These data will offer insight into metabolic constraints facing fishes exposed to oil while concurrently subjected to hypoxia, a notable climate change stressor.

52-3 ACKERLY, KL*; ESBAUGH, AJ; The University of Texas at Austin; *klackerly@utexas.edu*

Impacts of temperature acclimation and oil exposure on aerobic performance in red drum, Sciaenops ocellatus

Aerobic scope, the difference between minimum metabolic requirements and maximum metabolic capacity, is an important metric affecting ecological success in fishes. Crude oil exposure can impair cardiorespiratory function in fishes, which reduces maximum metabolic rate and aerobic scope, and may impair ecological performance. However, oil exposure is not the only environmental stressor that can influence aerobic scope, especially in areas affected by crude oil spills. Temperature fluctuations, even within an organism's thermal window, are also known to significantly impact overall metabolic performance, yet there has been little effort to explore how oil exposure impacts metabolic performance across temperatures. Our goal was to investigate the effects of 24h acute oil exposure on the metabolic performance of red drum, *Sciaenops ocellatus*, following 3wk chronic exposure to four ecologically relevant temperatures. Our results show that individuals acclimated to higher temperatures had significantly higher metabolic demands compared to individuals at lower temperatures, which resulted in significantly decreased tolerance to low oxygen conditions. As predicted, crude oil exposure resulted in significantly lower maximum metabolic rates at all temperatures except the lowest. These results suggest that acclimation to lower temperatures may mediate the insult of injury to metabolic performance following exposure to crude oil.

P2-90 ADAMS, DR*; GIFFORD, M; Vilonia High School, University of Central Arkansas; *davidreidadams@icloud.com*

Lizards Modulate Foarging Behavior in Response to Environmental Variation

Movement is an important determinant of an animal's fitness because it underlies all tasks necessary to survival, yet the basis on which animals choose varying speeds is still largely unknown. Speeds chosen by animals while preforming tasks, like predator evasion and foraging, are dependent on numerous external and internal factors. Environmental conditions and functional constraints should have influence over movement speeds of animals. Understanding the relationships between these factors and how they contribute to movement would help us better predict the speeds used during survival-dependent tasks. We video recorded Prairie Lizards (*Sceloporus consobrinus*) in experimental enclosures and analyzed the speeds and attack initiation distances lizards used while foraging. We predicted that, in more cluttered habitats, animals would use slower speeds and initiate prey capture attempts from shorter distances due to reduced visibility. Secondly, we predicted that average attack velocities during successful foraging attempts would be slower than unsuccessful attempts. Further, we predicted that increasing habitat complexity would reduce the difference of speeds between successful and unsuccessful attempts. Overall, attack speeds and distance were dependent on habitat type. Regardless of enclosure type, attack velocity was positively and significantly correlated with the attack distance, indicating that animals modulate attack speed based on distance prey is from them. Successful foraging attempts were significantly slower than unsuccessful ones, and the difference in successful and unsuccessful attempts was dependent on habitat configuration. Finally, this study emphasizes that functional constraints dominate in simple environments and that environmental constraints become more important with increasing habitat complexity.

P1-115 ADAMS, AN*; WOFFORD, SJ; Behavioral and Sensory Ecology Laboratory, Dept of Biology, Jacksonville State University; *aadams10@stu.jsu.edu*

Using a complex chemical landscape to find an ideal habitat under predation threat

Animals rely on information from their environment to detect predators, prey, and resources which can significantly increase fitness. Chemical signaling is widely used in aquatic animals and can influence decision making under stressful conditions. For example, aquatic animals, like crayfish, use chemical information to find mates, engage in contests over resources, and to manage access to resources (i.e. determine risks verses rewards). During this study, a habitat selection assay was used to study the relative importance of an attractive cue (i.e. shelter and food) to an aversive cue (e.g. predator odor). Crayfish were placed into a specialized arena with a gravel substrate and identical shelters on each side of the arena. Odors were delivered to each side of the arena using a gravity-fed system. Control trials used pre-conditioned, dechlorinated tap water as the odor. Treatment one trial introduced a predator odor into one side of the arena and tap water to the other. Treatment two introduced the same odors at random with a high protein diet located in the same habitat as the predator odor. Individuals were allowed to acclimate to the arena for 5 minutes prior to the start of odor delivery. Individuals were then allowed to explore for 15 minutes and were video recorded from above. Videos were scored for initial habitat choice and total time spent in each habitat section. As expected, the introduction of both an attractive and aversive stimulus influenced the crayfish's decision on habitat selection. These results support previous studies that suggest sensory landscapes can be complex and influence an individual's decisions.

55-3 ADDIS, AE*; JANZEN, FJ; BRONIKOWSKI, AM; Gonzaga University, Iowa State University; *addis@gonzaga.edu*

A Role of Insulin-Like Growth Factors in Mediating Trade-Offs Between Growth and Reproduction in Painted Turtles

A central tenet of life-history theory predicts the existence of energetic trade-offs. A classic example of these trade-offs is the energetic investment in reproduction versus self-care, including growth. Most studies investigating such trade-offs are of a demographic nature; many fewer investigate the physiological mechanisms that facilitate such trade-offs. Painted turtles (*Chrysemys picta*) are an excellent organism in which to investigate physiological mechanisms associated with the trade-off between reproductive effort and growth because they exhibit indeterminate growth, meaning, for one, that they continue to grow even after reaching reproductive maturity. In this study, we investigated the putative role of insulin-like growth factors (IGF-1 and IGF-2) as hormonal mediators of energetic investment. We collected blood samples from known-age females after oviposition; size and age are positively correlated in this population. We found that while age is positively correlated with clutch size, age does not affect IGF-1 or IGF-2 levels. However, we did find a three-way interaction among IGF-1, IGF-2, and age on clutch size. This complex interaction is not surprising considering the multitude of effects IGFs have. These results superficially suggest that that how IGFs influence reproductive output varies based upon age. These results will be explored in greater detail in this talk.

71-1 ADEOLA, FI*; LAILVAUX, SP; University of New Orleans, New Orleans, LA; *fiadeola@uno.edu*

The Influence of Dampened Locomotor Function on Calling Structure in the house cricket Acheta domesticus

Secondary sexual displays are important determinants of fitness in animals. Although variation in such displays are of keen interest to evolutionary biologists, the factors driving such variation are often poorly understood. Intrinsic factors such as individual condition, motivational state, or locomotor capacities in the case of dynamic displays could potentially affect aspects of male displays, which in turn can affect the probability of obtaining successful mating outcomes. We manipulated aggression and locomotor capacities in male house crickets, *A. domesticus* by synthetically blocking the octopamine receptors that influence aggression and skeletal muscle function. We then measured male courtship calls and analyzed the call structure to quantify the differences in the opportunity in selection based on the changes in dominant frequency, pulse duration intervals between chirp and trill in treated vs untreated males. By manipulating the ability of males to produce calls, which are driven by muscular contractions, we were able to reveal the influence of dampened locomotor function on male auditory displays

P3-62 AFKHAMI, M*; MASLY, JP; University of Oklahoma, Norman, OK; *mehrnaz.afkhami-1@ou.edu*

The genetics of co-evolved reproductive traits in Drosophila

Females in many species follow sensory clues received from males to make reproductive decisions. Although chemical clues (e.g., pheromones, seminal fluid proteins) have been studied extensively, much less is known about the role of tactile clues in directing male-female reproductive interactions. The epandrial posterior lobes (PLs) are male-specific cuticular projections of the external genitalia that have evolved recently among the four species of the *Drosophila melanogaster* complex and have diverged morphologically among these species. The PLs insert between two abdominal segments of the female during mating, and variation in PL size and shape affects female oviposition amounts. Using a collection of interspecific genetic introgression lines between *D. sechellia* and *D. mauritiana*, we test the hypothesis that the loci that specify male PL morphology and female egg-laying behavior are genetically linked, which facilitates their rapid divergence between species. We find that pure species *D. sechellia* females mated with introgression males possessing divergent PL morphology lay fewer eggs compared to matings with pure species control males. In contrast, introgression line females mated with males of the same introgression line lay normal numbers of eggs, a result that is consistent with either tight linkage of loci that specify male and female traits, or pleiotropic effects of a single locus. We have also identified a series of mechanosensory bristles at the PL insertion sites, which suggests that mechanical stimulation during copulation might be involved in directing female oviposition amounts. Interestingly, the neurons attached to these bristles express *fruitless*, an important effector of male courtship behavior in *Drosophila*. Adult expression of *fruitless* in the female genitalia bristles suggests that this gene could be important for reproductive processes in females post mating.

P3-186 AGUIAGA, J*; GOMULKIEWICZ, R; WATTS, H/E; Washington State University, Washington State University ; *jonathan.aguinaga@wsu.edu*

Modeling private versus social information in the assessment of environments

In order to arrive at a behavioral decision, individuals may use information they acquire themselves through direct sampling of the environment (private information), or by monitoring the behavior of others (social information). How individuals process private and social information to assess the quality of an environment, or the resources within it is not well understood. We developed a mathematical model to understand how combining private and social information affects an individual's assessment of their environment. In each simulation, we set the probability to successfully detect a resource (ε) constant for all individuals in that environment. This probability represents the abundance of a resource within an environment or landscape, and the true quality of that environment. Additionally, we varied the number of times an individual personally sampled the environment, the number of other individuals from which they acquire social information, and the relative weight they assign to each source of information. In each case, we examined how accurately an individual assessed environmental quality (ε) using private information alone, or a combination of both private and social information. We discuss the affect of integrating private and social information on the accuracy of an individual's assessment of environment quality

P1-177 AHMADYAR, S*; TRAN, T; RIVERA, AS; University of the Pacific; *arivera@pacific.edu*

Serotonin induces female swimming behavior in sexually dimorphic ostracod crustaceans

Male and female *Euphilomedes* ostracod crustaceans exhibit extreme dimorphism in their sensory systems and behavior. Here, we examine the role of serotonin in a sex-specific behavior. Male *Euphilomedes* spend about 90 minutes per night swimming in the water column, guided by their large compound eyes. Female *Euphilomedes*, on the other hand, lack compound eyes entirely and spend the majority of their time buried in the sand. They are only known to swim when disturbed. While the morphological difference between males and females is regulated at the developmental level, the locus of the behavioral difference is unknown. That is, it is not clear whether the swimming behavior arises from male-specific neuronal architecture or from male-specific activation of monomorphic circuits. Because serotonin is known to increase male-specific behaviors in other crustaceans we treated females with serotonin, which induced male-like swimming behavior. This suggests that both males and females have neuronal circuitry for spontaneous swimming behavior. Whether this is an example of females exhibiting male behavior, or represents a rare undescribed female behavior is unclear.

P2-127 AHMED, MA*; DEORA, T; BRUNTON, BW; DANIEL, TL; University of Washington, Seattle, WA; *danielt@uw.edu*

Multi-modal feedback in insect flight control

Animals rely on sensory feedback from multiple modalities to perform complex motor tasks such as pollination. We explored this relationship in *Manduca sexta*, crepuscular insects that fly in low light conditions, hovering over flowers as they pollinate and feed from them. They use both vision and mechanosensory input as they locate the nectary with their proboscis. As light levels decline, the lag between visual and mechanosensory information processing increases. Using behavioral analyses of feeding moths, we asked how reductions in light level influence their efficiency in locating the nectary. We combined 3D printing technology to generate artificial flowers, each equipped with sensors that detected the proboscis tip inside the nectary. We combined this approach with machine vision to track the motion of hovering moths under two light levels: 0.1 lux (moonlight) and 50 lux (dawn/dusk). In either light level we found that moths decrease the time to find the nectary over multiple visits to a flower. Across all visits, moths in higher light conditions took significantly longer to find the nectary (KS test p-value: 0.005 and a KL divergence of 1.61). In addition to taking longer, moths in higher light conditions hovered further from the flower during feeding (KS test p-value: 0.049). This shift in light level appears to significantly effect learning and motor control in these animals. These results could be explained by a shift in the weight of vision in higher light levels, even though it is slower than mechanosensory input.

28-7 AHMED, S*; SHEARER, B; O'BRIEN, H; Northeastern State University, Tahlequah, NYU School of Medicine, NY, OSU Center for Health Sciences, Tulsa; *haley.obrien@okstate.edu*

The Hemodynamics Of The Carotid Rete In The Brown Greater Galago, Otolemur crassicaudatus

Galagos, lorises, and tarsiers, have the unique ability to rotate their heads ~180°. In most other primates, such extended head rotation results in transient loss of consciousness from decreased cerebral arterial perfusion. Mechanisms for maintaining consciousness during head-turning in primates are unknown. Here, we hypothesize that an internal carotid arterial meshwork known as the carotid rete facilitates this behavior. Retia are uncommon among primates and have dramatically different hemodynamic properties than singular vessels. Modified from Ohm's law, vascular resistance is modeled after series and parallel electrical circuits. Contiguous arteries are conceptualized as vessels in series, and retia are modeled in parallel, which decreases resistance by providing numerous avenues for blood flow. We develop 2 hemodynamics models: 1) vascular resistance of the carotid rete in its standard anatomical orientation, and 2) the vascular resistance when the branches that form the carotid rete are reduced by 50%, stimulating head turning. We based these models on digital 3D renderings of the arterial pattern constructed from microCT scans of cadaveric galago specimens injected with radiopaque latex . We find that, because of the carotid rete's many interconnecting branches, the reciprocal resistance of this parallel circuit reduces resistance and maintains flow, even when retial branch lumen is decreased by half. Thus, we provide evidence that the carotid rete may help to continually supply blood to the brain through a mechanism of decreased resistance by providing multiple routes for blood to flow during the commonly observed behavior of extreme cervical rotation in galagos.

56-1 AICHELMAN, HE*; BOVE, CB; CASTILLO, KD; BOULTON, JM; KNOWLTON, AC; NIEVES, OC; RIES, JB; DAVIES, SW; Boston University, UNC Chapel Hill, UNC Chapel Hill, Boston University, Northeastern University, Boston University, UNC Chapel Hill, Northeastern University; *hannahaichelman@gmail.com*

Time Course Physiology of Caribbean Corals Reveals Divergent Responses to Global Change Stressors

Global change is threatening coral reefs, with rising temperatures leading to repeat bleaching events (dysbiosis of coral hosts and symbiotic algae) and increasing pCO_2 causing reductions in calcification. Global bleaching events reveal fine-scale patterns of coral survival; however, the traits that lead to success under stress remain elusive. We conducted a 95-day laboratory experiment to investigate the physiological responses of two Caribbean reef-building coral species (*Siderastrea siderea* and *Pseudodiploria strigosa*) from two distinct reef zones on the Belize Mesoamerican Barrier Reef System under ocean warming (28, 31°C), acidification (~400–2800 µatm), and the combination of the two. Calcification, total host protein and carbohydrate, Chlorophyll *a* pigment, and symbiont cell density were quantified every 30 days to characterize the acclimatory responses of each coral genotype and their symbionts. Holobiont physiology of the two species was differentially affected by these stressors, and changed over time. While *S. siderea* was more negatively affected by increased pCO_2, *P. strigosa* was more negatively impacted by elevated temperature, particularly after chronic exposure. Reef zone differences in calcification and total protein were also apparent in *P. strigosa* in response to experimental treatment. By tracking holobiont physiology through time, this experiment highlights that focusing on average trends over the experimental interval can obscure the complexity of corals' responses through time, and provides a framework for future studies to consider when investigating such long-term acclimatory responses.

P2-246 AICHELMAN, HE*; WUITCHIK, DM; ATHERTON, KF; KRIEFALL, NG; DAVIES, SW; Boston University; *hannahaichelman@gmail.com*

Do Facultative Coral Hosts Buffer Their Symbionts in Response to Thermal Extremes?

Increasing ocean temperatures resulting from climate change compromise the symbiotic relationship between coral hosts and their algal symbionts. Physiologically, coral hosts and their symbionts exhibit a wide array of stress responses; however, evidence suggests that host transcriptomes respond more strongly than the symbiont. This lack of transcriptional response by the alga raises the question: Are coral hosts regulating their symbiont's environment to buffer environmental stress? We capitalize on the facultative symbiosis between two coral hosts (*Oculina arbuscula* and *Astrangia poculata*) and their algal symbionts (*Breviolum psygmophilum*) and characterize the transcriptomic responses of both partners to thermal extremes. We hypothesized that symbiotic hosts would mount stronger responses to thermal extremes than their algal partners (i.e. host buffering) and that the response of their aposymbiotic counterparts would be more subdued (hosts without symbionts are free from buffering this stress). To test this hypothesis, symbiotic and aposymbiotic fragments of each species were exposed to three treatments: 1) control (18°C), 2) heat stress (32°C), and 3) cold stress (6°C) and prepared for genome-wide gene expression profiling. Orthologous genes shared across the host and symbiont were identified and differential expression analyses were performed to compare the magnitude of response of symbiotic hosts, aposymbiotic hosts, and algal symbionts. Gene ontology enrichment analysis was also performed to elucidate the relative functional pathways involved in the stress responses of hosts and symbionts. While analyses are ongoing, testing this hypothesis will give rise to valuable insights about the molecular mechanisms underlying symbiosis maintenance in corals and the potential for host buffering in this symbiosis.

6-1 AIELLO, BR*; SPONBERG, S; Georgia Institute of Technology; *baiello3@gatech.edu*

The visual perception of moving flowers during the flower tracking behavior in descending neurons in the hawkmoth, Manduca sexta

The visual identification of externally moving targets allows animals to locate and track predators, mates, and food sources. Insects that routinely track small targets have dedicated neurons in their brain and ventral nerve cord (VNC) that selectively respond to targets of various size. The moth flower tracking behavior, where a feeding moth tightly tracks the 3D motion of a swaying flower, relies on acquiring and acting upon both self-motion (wide field visual movement of the background) and the external motion of a flower. Emerging evidence suggests that some descending neurons in the moth VNC selectively respond to wide field or small target cues while others respond generally. It is unknown which class(es) of moth VNC neurons are responsible for encoding flower motion. To answer this question, we recorded the response of descending VNC neurons to wide field motion (WFM), small target, and flower stimuli using multielectrode arrays in tethered hawkmoths, *Manduca sexta*. We find that VNC neurons respond to moving flowers, and some neurons can have directional selectivity. Over 80% of the recorded neurons have a large overlap in response to the three classes of stimuli presented; neurons that are sensitive to flowers can also respond to either WFM, target, or all three types of stimuli. Not all cells are universally responsive and some show selectivity to flower stimuli, being silenced by or unresponsive to either wide field or small target stimuli. These results show that descending neurons of the moth VNC can have overlapping and unique selectivity to both target and flower stimuli, suggesting that the visual system of insects can be evolutionary tuned to the life history and ecologically relevant stimuli of a given species.

108-2 AKANYETI, O*; FETHERSTONHAUGH, S; Aberystwyth University; *ota1@aber.ac.uk*

A kinematic chain model to quantify undulatory locomotion in animals and robots

Undulatory locomotion is ubiquitous among soft-bodied animals and it inspires novel robot designs. However, manufacturing flexible robots is not straightforward due to technological constraints. Compared to their biological counterparts with high degrees of freedom, robots need to navigate around with a limited number of actuators. To bridge the gap between biology and engineering, we present a novel approach to identify the minimum number of segments required to describe the body movements of undulatory animals accurately. We use a kinematic chain model which consists of a series of linear segments with connected joints. We use empirical data and least square methods to automatically estimate the model parameters (i.e. number and position of joints) so that the difference between predicted and measured motion is minimized. We tested our approach to describe the midline kinematics of 10 fish species with varying body length (L), morphology and flexibility during steady swimming (up to 5 L s^{-1}). Our preliminary results indicate that the minimum number of segments that can describe the midline kinematics with 95% accuracy vary significantly between species (e.g. five segments for Northern barracuda, *Sphyraena borealis*, and ten segments for Clown knifefish, *Chitala ornata*). The position of the most anterior joint (connecting segment one and two) also varies between species (e.g. 0.5 L for barracuda and 0.2 L for knifefish). The goal of this research is to develop an analytical tool that describes animal movements with parsimonious kinematic models. These models can be used by biologists to quantify movement capability of animals, by roboticists to enhance the design of underactuated robots, and by software engineers to generate realistic animal movements for computer simulations.

P3-124 AKANYETI, O*; STRONG, J B; Aberystwyth University; *ota1@aber.ac.uk*

Achieving cohesive and mobile groups using simple sensory feedback

Previous research on swarm behaviour has shown that local interactions among neighbours can lead to stable movement patterns at the group level without a centralized control strategy. However, reverse-engineering the structure and dynamics of these interactions (either to understand the collective motion of animals or to achieve a desired collective behaviour in multi-robot systems) has been challenging. To begin to elucidate the relationship between local and global, we ask what is the minimum number of neighbours each member needs to take into account for a group to achieve a high performance? To address this question, we perform computer simulations in a three-dimensional environment with obstacles. Our agent interaction model expands on previous studies where each group member is programmed to choose between three simple behaviours: avoidance, alignment and attraction. A novel winner-takes-all approach is implemented for decision making with highest priority assigned to avoidance. The decision whether to align or attract is determined depending on the number of neighbours found in the near field, the probability of aligning increases with more neighbours. The performance of the group is evaluated using two metrics: cohesion calculated as the number of splits occurred within the group (fewer splits indicate higher cohesion) and mobility calculated as the coverage rate of the environment while avoiding obstacles (higher coverage indicates higher mobility). Our preliminary results suggest that independent of group size, agents can stay together and move around effectively by keeping only 6 neighbours in their near field. Next, we plan to conduct biological experiments to test whether a similar sensory feedback mechanism exists in fish schools and to develop new bio-inspired control strategies for multi-robot systems.

135-1 AKIN, DR*; GEHEBER, AD; Auburn University, University of Central Missouri; *dza0043@auburn.edu*

Morphological divergence of a stream fish in altered flow: teasing apart the influences of natural selection and plastic response on body shape

Cyprinella lutrensis is historically a stream dwelling minnow species (Family Cyprinidae) native to Missouri. Now, via damming, *C. lutrensis* occurs in both streams and reservoirs, including those of the Osage River drainage. The construction of Truman Dam (completed in 1979) has resulted in relatively high abundances of *C. lutrensis* within the reservoir and its surrounding tributaries. The widespread distribution of this species across the reservoir and connected streams provided an optimal study system for testing the effects of habitat alteration (through stream impoundment) on fish populations. Specifically, we were interested in the effects of flow alteration on *C. lutrensis* body shape. We hypothesized that populations in systems with no flow (i.e., reservoirs) would have reduced body shape streamlining. This was predicted due to the known importance of fish body form as it relates to locomotion in differing environment types. Here, we assumed that body streamlining would be beneficial for swimming in flowing environments. Analyses of morphology comparing *C. lutrensis* samples taken from Truman reservoir to samples taken from surrounding streams in the Osage River watershed showed significant differences in body shape between reservoir and stream populations, which indicated greater streamlining in stream populations. One possible mechanism of change (flow induced phenotypic plasticity) was tested in the lab using stream flow mesocosm units. This experiment also yielded significant results in support of the original hypothesis, and displays rapid phenotypic change dictated by environmental factors. Methods used, result implications, and future directions of study will be discussed.

P1-142 AKKIPEDDI, SMK*; XU, M; CHAN, KYK; Swarthmore College, Swarthmore, PA; *sakkipe1@swarthmore.edu*

Halogenated compound secreted by marine bacteria halts larval urchin development

Marine bacteria are ubiquitous and yet their ecological functions have not been fully characterized. The globally distributed *Pseudoalteromonas* genus, well known for their pervasive biofilms, produce a variety of potentially bioactive yet understudied halogenated organic products. One such secreted compound, 2,3,4,5-tetrabromopyrrole (TBP), has been found to be biocidal for several taxa of plankton while stimulating the settlement and metamorphosis of coral at nanomolar doses. Here, we tested whether the presence of TBP affects early development in sea urchins that are not in direct contact with a benthic microbial film. *Lytechinus variegatus* embryos were exposed to varying TBP concentrations for different durations of time over the first 48 hours post-fertilization. Concentrations as low as 500nM markedly reduced larval survivorship and retarded development. These deleterious effects became more pronounced as the concentration and duration of exposure to TBP were increased. Impairments in development when exposed to TBP appeared to be reversible, provided low exposure concentrations (< 500nM-1000nM) for limited exposure durations (< 1-4 hours). Immunofluorescence staining showed spindle defects in dividing embryos when exposed to TBP at high concentrations, which may contribute to mortality and impaired growth. Therefore, while TBP and other bacterial compounds like it may serve as settlement cues for corals, their cytotoxicity to single-cell algae and larval urchins could hint at the dangers of the benthos to developing embryos. If true, such compounds, along with the bacterial taxa that produce them, likely play underappreciated roles in the ecology, and potentially the evolution, of planktonic development in macroinvertebrates.

P2-237 ALAASAM, VJ*; KEEHN, JE; DURSO, AM; FRENCH, SS; FELDMAN, CR; University of Nevada, Reno, NV, Oregon Department of Fish and Wildlife, Central Point, OR, Utah State University, Logan UT, Utah State University, Logan UT; *valentina@nevada.unr.edu*

Gone with the wind: side-blotched lizards (Uta stansburiana) have fewer parasites and a reduction in reactive oxygen metabolites at wind farms.

Wind-generated power is one of the fastest growing alternative energies worldwide and will likely account for 20% of USA energy by 2030. However, surprisingly little is known about how the development of wind farms impacts surrounding ecosystems. Habitat fragmentation, noise pollution, and increased human activity associated with wind farms could increase physiological stress for terrestrial vertebrates and may impact susceptibility to infection. We captured 153 side-blotched lizards (Uta stansburiana) from three paired wind farm and undeveloped sites in the Mojave Desert. We quantified the external parasite load of each individual and collected blood samples to measure two proxies of oxidative stress: plasma antioxidant capacity (oxy) and concentrations of reactive oxygen metabolites (dROMs). Contrary to our expectations, individuals at wind farm sites had significantly fewer external parasites than at undeveloped sites. Oxidative stress, driven by decreases in dROMs, also differed between wind farm sites and undeveloped sites for k-strategist, yellow-throated females. Understanding the impacts of wind farms on local non-volant taxa is essential for developing strategies that will mitigate ecological costs of wind power.

P3-243 ALBA, JC*; ONTHANK, KL; Walla Walla University; *jomarie.alba@wallawalla.edu*

Predatory Behavior of Octopus rubescens in Response to Elevated Carbon Dioxide and Temperature

Increasing carbon dioxide levels in the atmosphere has resulted in global ocean warming and acidification. Little research has been conducted on how these ocean changes will impact predatory behavior of invertebrates such as cephalopods. Cephalopods have a large impact on marine food webs, owing to their abundance, high growth rates and flexible predatory behavior. Due to the ecological importance of cephalopods, changes in behavior could have far-reaching consequences in marine ecosystems. We measured the effects of two-week exposure to projected near-future carbon dioxide and temperature levels on the predatory behaviors of *Octopus rubescens* such as latency to attack prey, predator-prey orientation, striking distance, body pattern choice during attack sequence, and drill-hole localization. These data will help us to determine if elevated carbon-dioxide and temperature have an effect on the predatory behavior and strategies on *O. rubescens.*

136-7 ALBERTIN, CB*; PARNAIK, R; RAGSDALE, CW; Marine Biological Laboratory and University of Chicago, University of Chicago; *calbertin@mbl.edu*

Heterodox Ligands in an Ancient Signaling Center in Octopus Brain

Widely shared across metazoan neural development is a transcription factor network implicated in anterior-posterior brain patterning, including *OTX* anteriorly, the *HOX* genes posteriorly and an intercalated cassette of *GBX*, *PAX2/5/8* and *ENGRAILED*. In vertebrates, this cassette identifies the midbrain-hindbrain boundary, the site of a prominent signaling center known as the isthmic organizer (IO), which expresses the signaling ligands *FGF8* and *WNT1*. Outside of the vertebrates, soft-bodied cephalopods have the largest brains. We explored the role of these highly conserved developmental control genes with in situ hybridization experiments on *Octopus bimaculoides* embryos. We found that anterior *OTX*, posterior *HOX1* and an intercalated IO transcription factor cassette are readily demonstrated in octopus embryogenesis. Moreover, the IO cassette coincides with a morphological depression in the ectoderm (the "cleft"). The cleft in turn marks out the major structural transition in the prospective cephalopod brain, that between the subesophageal and supraesophageal masses. We found that the cleft, like the vertebrate midbrain-hindbrain boundary, is a major signaling center. It harbors most of the major developmental signaling molecules, including *HH*, *DPP* and multiple *WNT* genes. *FGF8* and *WNT1* are, however, absent. Our findings with this lophotrochozoan indicate that, even at the same stage of animal development, anterior-posterior signaling centers can show comprehensive transcription factor conservation in the face of marked signaling ligand lability.

96-4 ALEXANDER, SLM; BHAMLA, MS*; Georgia Institute of Technology; *saadb@chbe.gatech.edu*

Ultrafast and underdamped: Slingshot spiders design conical webs for ambush predation and self-survival

Numerous living systems employ biological springs and latches to mechanically amplify their power for ultrafast movements. The biomechanics of power-packed, ultrafast motion in both natural and robotic systems is an emergent topic of study, but is often one-sided, focusing solely on storage and amplification of power. How ultrafast organisms dissipate excess energy and prevent catastrophic self-destruction remains relatively unexplored. In this work, we focus on the dynamics of `Slingshot Spiders' to study both the energy storage and energy dissipation mechanisms involved in repeatable ultrafast motion. We bring high-speed cameras to the Amazon Rainforest and quantify the ultrafast hunting dynamics of the ``Slingshot Spider'' (SS) for the first time, since its first naturalist description almost a century ago. We discover that the SS exploits the stored elastic energy of their conical silk webs `springs' to achieve accelerations exceeding 1300 m/s2 (130 g-force) which, is the fastest full body motion achieved by an arachnid. The web release mechanism occurs in less than a millisecond, achieving accelerations faster than a flea jump. This need for speed underscores an ambush hunting strategy, where SS explosively hurls itself and its web to catch giant flying insects in mid-air, increasing its predation success compared to traditional insect-web-collision strategy. Finally, we explore the design space of SS's dynamics utilizing a damped oscillator model, uncovering the dual-functionality of the web structure: to both load elastic energy for powerful motion and to efficiently dissipate excess energy for self-survival. Our work highlights an underappreciated, yet crucial evolutionary trade-off in ultrafast systems that enables them to safely execute their extreme movements hundreds of times over their lifetime, without compromising on power output.

P3-5 ALMOUSELI, A*; MANZO, V; YACOO, KE; DAYFIELD, DJ; TORRES, VC; EVANS, KR; ROBERTS-KIRCHHOFF, ES; BELANGER, RM; University of Detroit Mercy; *almousab@udmercy.edu*

The effects and quantitation of atrazine in crayfish tissue post-exposure

The herbicide atrazine (ATR) is heavily applied in agricultural areas in the Midwestern United States where its concentration can reach over 300 ppb. Previous studies have shown that exposure ATR causes changes in cytochrome P450 expression and glutathione-S-transferase activity in the virile crayfish, Faxonius virilis. To correlate physiological effects of ATR exposure with accumulation in the hepatopancreas and muscle tissue, we employed the QuEChERS (Quick, Easy, Cheap, Effective, Rugged and Safe) method for pesticide extraction from crayfish tissue. QuEChERS was coupled with liquid chromatography-mass spectrometry for quantitation of ATR and its metabolites in muscle and hepatopancreas tissue of crayfish. The developed method also includes the use of ATR-d5, an isotopic internal standard, to improve the accuracy and precision of the pesticide quantitation. Figures of merit including the detection limit, the limit of quantitation, and the dynamic range were determined. Additionally, spike recovery tests were performed. Recently, the QuEChERS method was modified to increase the purity of extracted pesticides and metabolites. The validated method will be used to quantitate the accumulation of ATR and its metabolites in crayfish tissue for comparison with physiological changes observed in crayfish after ATR exposure.

79-2 ALONGE, MM*; DANIELS, DT; SCHOBEL, T; BENTLEY, GE; University of California, Berkeley; *mattina.alonge@berkeley.edu*

Flexible Expression of Sickness Behavior and Parental Care Across Stages of Avian Reproduction

Organisms are often challenged with balancing energy demand between competing physiological processes. For example, the demands of mounting immune responses can negatively impact reproductive success. Despite known costs of female reproduction, the mechanisms underlying parental behavior/physiology in immune-challenged female birds are unknown. Conceptually, reproductive life history trade-offs are not new, but no study has compared potential shifts in prioritization across stages of reproduction in female birds according to prior energetic investment. Breeding female zebra finches were injected with LPS or 0.9% saline on day 7 of incubation. Another cohort was injected similarly 7 days after hatching; a period of active provisioning. Nest attendance, flights, hops, and time at rest were recorded, and parental (and nestling) weights taken 0, 6, and 24 hrs post-injection. Blood was sampled at 0 and 6 hrs for CORT and PRL measurements. Our current data show that although LPS-treated incubating females significantly decreased activity (flights, hops), increased time spent at rest, and lost substantial mass this did not interfere with their parental behavior. Males increase time in the nest when their female mate is healthy. Analysis for nestling provisioning stage is underway. If trade-offs occur due to energy limitation, we predict females will maintain parental care during incubation but prioritize self-maintenance during increased energetic demands of nestling provisioning. Alternatively, predictions may be shaped by an investment perspective rather than purely energetic one, where individuals are likely to abandon a current reproduction when challenged in an earlier stage and likely to sacrifice self-maintenance at a later stage, given the amount of effort invested fitness.

89-5 ALTMAN, KA*; HALL, EM; ROLLINS-SMITH, LA; OHMER, MEB; RICHARDS-ZAWACKI, CL; University of Pittsburgh, PA, Vanderbilt University, Nashville, TN; *karie.altman@pitt.edu*

Effects of pond drying on northern leopard frog development, growth, immune function, and susceptibility to Batrachochytrium dendrobatidis

As the climate changes, warmer temperatures are expected to increase the rate at which ephemeral ponds dry, which will likely have consequences for amphibians. Reduced hydroperiods can influence larval growth and developmental rates and might also impact amphibian characteristics post-metamorphosis, such as immune function and disease susceptibility. We predicted that as ponds dry faster, (1) tadpoles would metamorphose quicker but at a smaller size, and (2) metamorphosed frogs would have reduced immune function and be more susceptible to disease. We tested these predictions by raising northern leopard frogs (*Lithobates pipiens*) in mesocosms assigned to one of four drying treatments: no-, slow-, medium-, and fast-drying. After frogs metamorphosed, we repeatedly exposed a subset of animals to *Batrachochytrium dendrobatidis* (Bd) and measured immune function in another subset of animals. Contrary to our first prediction, drying rate alone had no effect on development time or size at metamorphosis. In metamorphosed frogs, drying rate did not affect Bd load in our exposure experiment or T-cell response. However, T-cell response increased with larval period regardless of drying treatment, indicating that a longer larval period can be beneficial post-metamorphosis. Furthermore, frogs in the slow-drying treatment had a greater B-cell response than those in the medium-drying treatment, showing that some effects of reduced hydroperiod experienced in the larval period can persist post-metamorphosis. Taken together, our results show that the effects of pond drying rates on amphibians are not straightforward and require further study.

47-1 ALVARADO, SG*; KRUPAKAR, H; Queens College CUNY, GE Healthcare; *sebastian.alvarado@qc.cuny.edu*
Developing an automated pipeline for quantifying animal pigmentation using deep learning
Coloration is a salient trait across the animal kingdom that can allow an individual to become cryptic, conspicuous, or social. While some developmental patterns in pigmentation are static, others are dynamic to changes in their ambient environment. Despite a great deal of study in developmental pigmentation patterns, little is known about how environmental cues shape the developmental plasticity that allows an individual to change color. One approach to understanding these processes is through the lens of epigenetic modification and DNA methylation. DNA methylation of cytosine residues in gene promoters is a reversible modification that silences gene function in vertebrates. Since DNA methylation is involved in programming various cellular functions, it is likely that it facilitates molecular changes as pigment-bearing cells (chromatophores) change their composition during animal color changes and behavioral transitions. We used an African cichlid model system (Astatotilapia burtoni) with discrete reversible color morphs (blue and yellow) to dissect the underlying molecular processes that lend plasticity to animal coloration. Our findings suggest that epigenetic processes such as DNA methylation lend plasticity to coloration, which is an important hallmark driving selection. Furthermore, since genetic diversity does not account for the phenotypic diversity seen in Lake Tanganyika, we propose that DNA methylation may contribute to the processes that have led to the adaptive radiation of cichlids in East African Great Lakes.

P3-152 AMACKER, KY*; FARINA, SC; Howard Univeristy, Washington DC, Howard University, Washington DC; *kyra.amacker@howard.edu*
Asymmetrical Breathing in Flatfishes
Flatfishes are benthic fishes with laterally flattened bodies and two eyes on one side of the head. While their neurocranium is asymmetrical to accommodate their unique eye position, much of the rest of the cranial skeleton is symmetrical, including the opercular bones and branchiostegals that make up the gill chamber. Our study examines whether the kinematics and pressures generated by these chambers are also symmetrical. We performed a two-part experiment on Isopsetta isolepsis using surgically implanted sonomicrometry crystals on the eyed and blind side operculum, epaxial and urohyal to measure the positions of the bones during ventilation, and pressure transducers on the eyed and blind side operculum to track the pressures produced before and after burial. We found that flatfishes can perform both symmetrical and asymmetrical breathing, both in terms of kinematics and pressures, above and below the sediment. Asymmetry, when present, was very large in magnitude, with flatfishes "favoring" either the blind or eyed side, depending on how their head was positioned. We also found that Isopsetta have the ability to shift from asymmetrical movement during burial and symmetrical movement during ventilation and vice versa whether they were resting, swimming above, or buried beneath the sediment. Furthermore, from analyzing this behavior, we were able to conclude that the flatfish were using the urohyal as a shunt to pass water from the eyed to the blind side of the head to fluidize sand underneath the head during burial.

P1-38 AMMEN, SC*; DAVIS, JE; Radford University; *sammen@radford.edu*
From Killer Hornet Saliva to Mutated Super Flies: Investigating the Effect of Vespa Amino Acid Mixture (VAAM) on Energetics, Longevity, and Fitness
Vespa Amino Acid Mixture (VAAM) is a unique blend of amino acids found in the saliva of larval Asian giant hornets (*Vespa mandarinia*) that they pass to their parents through trophallaxis, apparently to upregulate their metabolic function and improve endurance. In a laboratory setting, VAAM increases ATP production in both yeast and house fly (*Musca domestica*) models, but subsequent tests have shown that the consequences at the organismal level vary wildly across trials. In *Drosophila*, VAAM tends to improve locomotion performance and endurance, albeit at the cost of accelerated mortality, presumably due to its deleterious impact on mitochondrial function. However, in some trials, organisms experience significantly extended lifespan in response to VAAM treatment. VAAM may also have potential to affect an organism across generations, as a single dose of VAAM was found to significantly increase locomotion performance in the 2nd generation offspring of treated fruit flies in several studies. However, these results are variable across trials and have proven difficult to replicate. In this poster I will discuss all the findings of VAAM across several studies and interpret them in the context of mitochondrial function, bioenergetics, and transgenerational epigenetics.

24-3 AMONETT, SD*; BALENGER, SL; University of Mississippi; *sdamonet@go.olemiss.edu*
Mother Knows Best: Immune-based Maternal Effects in Response to Mycoplasma gallisepticum Infection in Eastern Bluebirds (Sialia sialis)
Neonates lack adaptive immunity and are vulnerable to pathogens. In fact, adults carrying pathogens may transmit infections to their neonate offspring. In response to pathogens, mothers transfer passive immunity to offspring by transmitting antibodies via milk or yolk. Mothers previously or currently infected with a pathogen can transfer pathogen-specific antibodies to newborns, granting them immunological protection until they can synthesize their own. In birds, antibodies are deposited before eggshell formation within the mother's oviduct. It was recently discovered that wild eastern bluebirds (*Sialia sialis*) are common hosts of the avian pathogen *Mycoplasma gallisepticum* (MG). Adult bluebirds exposed to MG in the wild mount an adaptive immune response in the form of circulating antibodies. Serum samples collected in the breeding season of 2018 and 2019 showed that adult female bluebirds transmit MG-antibodies to their offspring, and these antibodies persist in young approximately 5 days post-hatch. PCR analysis of choanal cleft (throat) swabs from entire bluebird families indicate that both male and female adults may transmit MG infection horizontally, most likely through feeding behaviors. We will discuss the impact of vertical transmission of this pathogen and protective antibodies on the fitness of wild eastern bluebird nestlings.

40-6 AMPLO, HE*; FLAMMANG, BE; Rutgers Univeristy-Newark, New Jersey Institute of Technology; *hea7@njit.edu*
Frogfish Pectoral Fin Functional Morphology
Frogfish (Family Antennariidae) are highly derived benthic, teleost fishes capable of performing three modes of locomotion: jetting, swimming, and substrate-based locomotion. Previous literature has described how frogfish use their limb-like pectoral fins in order to "walk" underwater and describe the crutching versus alternating fin-fall gaits. Frogfish plant their distal pectoral fin into the substrate in order to walk, but have their fins outstretched while jetting and tucked against the body wall while swimming. Frogfish have a unique ball-in-socket shoulder joint morphology and fourteen different pectoral fin muscles, which may allow them to seamlessly transition between these three modes. While the presence of this extreme limb rotation has been described, the mechanism behind it is less clear. In this study, the pectoral fin and pectoral girdle of the Sargassum frogfish, *Histrio histrio*, and the shaggy frogfish, *Antennarius hispidus*, are described using microCT scanning, PTA staining, and gross dissection. The functional implications of forelimb rotation in walking will be compared to locomotor kinematics of other fishes and tetrapods.

138-6 ANDERSON, RC*; ZIADI, P; NIEDERHAUSER, J; Florida Atlantic University, Davie FL; *andersonr@fau.edu*
Why so many song types? Song sharing, song type matching, and the agonistic function of song type repertoires in Bachman's sparrow
Male Bachman's sparrows (*Peucaea aestivalis*) have repertoires of 33-55 primary song types as well as repertoires of "warble songs" and call types. How are these large vocal repertoires used during territorial disputes? We quantified responses to simulated territorial intrusions (STI) and found that more aggressive males sang fewer high-amplitude primary songs and more low-amplitude ‘‘whisper songs.'' On average males share 47% of their song types (range 28-81%) Song sharing is not higher among adjacent neighbors and does not decline significantly across a distance of 3.3 km. High song sharing suggests a role for song type matching during agonistic signaling. In a second STI experiment 16 of 22 (72%) males matched during playback of their own songs and 14 of 22 (64%) matched more than once but these rates do not exceed the chance matching rate. Markov-chain analysis of singing behavior (n=8) suggests that males deliver their songs in sequences with some song types grouped together in a predictable order. Playback of a bird's own song sequence did not increase the likelihood of song matching for most birds, but 4 of 21 birds matched at high rates when played their own sequence. Birds that matched playback were not more aggressive than those that did not match suggesting that song matching is not an immediate threat signal in this species.

S10-2 ANDERSON, PSL; University of Illinois, Urbana-Champaign; *andersps@illinois.edu*
Keep It Simple Stupid: Using simple models to explore how physical laws influence the evolution of biomechanical systems across clades
The field of comparative biomechanics strives to understand the diversity of the biological world through the lens of physics. To accomplish this, researchers apply a variety of modelling approaches to explore the evolution of form and function across phylogeny. These models range from basic lever mechanics, to physical models, to intricate computer simulations. While advances in technology have allowed for increasing model complexity there is still great insight to be gained through the use of relatively simple models with few parameters. Models are not literal representations of reality but simplifications of the events, scenarios or behaviors being studied. Any model, regardless of how complex, must make assumptions; simple models just make more assumptions than complex ones. While a complex model may account for more parameters simultaneously, simple models allow for individual parameters to be isolated and tested systematically, as seen in studies on vertebrate tooth form. More generalized models with fewer parameters means that a model can be applied across a wider range of organisms. As an example, physics models have been used to identify trade-offs common to power-amplified systems across a wide range of organisms. Simple models also make good starting points for comparative studies, allowing for complexity to be added as needed. To demonstrate these ideas, I perform a case study on body form in ants. Basic center of mass calculations are used to explore constraints and adaptation to proportions in ant body form across major ant clades. Results illustrate how simple, low-parameter models both highlight fundamental biomechanical trends, and aid in crystallizing specific questions and hypotheses for more complex models to address.

P3-87 ANDERSON, AP*; RENN, SCP; Reed College; *andersond@reed.edu*
A genus of gouramis, Sphaerichthys, as a novel system for investigating evolution of transitions of sex-roles in brood care and sexual selection.
The evolution of sex-role reversal or transitions in sex-specific brood care are subjects of interest to evolutionary biologists as the genomic and environmental mechanisms responsible have been demonstrated in a limited sex of taxa. I present the opportunity to investigate these questions in a subfamily of gourami fishes (Luciocephalinae) where, within one genus, female ornamentation has evolved and a switch in sex-specific brood care has occurred. The ancestral state of the taxon is that of monomorphism and male mouthbrooding. The species *Sphaerichtys vaillanti* has evolved a striking female banding pattern, a possible indicator of sex-role reversal, while *S. osphromenoides* has had a curious case of a transition to female mouthbrooding. I currently have begun genomic reconstruction on these fishes and outgroups to elucidate global patterns that might coincide with the evolution of these features. I have additionally begun husbandry and initial experiments to better describe behavior, gene expression, and hormonal regulation to fully link genetic underpinnings to phenotypic outcomes. Success in these endeavors could lead to *Sphaerichthys* serving as a model for the transitions of sex-roles in evolutionary biology.

72-7 ANDERSON, CV*; REITER, PA; ROBERTS, TJ; Univ. South Dakota, Vermillion, Brown University, Providence; *Christopher.V.Anders@usd.edu*

Examining the early stages of adaptive radiation in Anolis roquet from Martinique

Caribbean *Anolis* lizards have become a model system for the study of adaptive radiation and coevolution, whereby anoles have diversified to specialize in the use of different parts of their structural habitat. The resultant ecomorphs exhibit consistent morphology-to-habitat use relationships on each island, such that the same ecomorph on different islands look remarkably similar. They also exhibit similar morphology-to-performance relationships whereby their performance capabilities are closely related to their morphology and vary among ecotypes. Unlike other Caribbean islands, the island of Martinique is host to a single species, *Anolis roquet*. Across the island, however, *A. roquet* inhabits disparate environments. The lizards that occupy these differing habitats show noticeable variation in their physical characteristics, having previously been described as six different subspecies and as different ecotypes. We examined the morphology, sprint and bite performance, and muscle contractile physiology of two forms of *A. roquet* from a montane forest habitat and a xeric coastal habitat. We found significant differences in morphological dimensions, along with differences in some whole organism performance measurements between these two forms. Muscle contractile physiology, on the other hand, generally did not vary between these forms. Differences appear particularly prominent in head dimensions and bite force, possibly due to these forms specializating to different prey items or varying in their conspecific interactions. These results suggest that morphology and performance may specialize to novel environments and functional demands before muscle contractile physiology. Such patterns thus provide insight into the process of adaptive radiation and the effects of habitat variation on *Anolis* lizards in the absence of species level divergence.

74-5 ANDERSON, RA; Western Washington University; *Roger.Anderson@wwu.edu*

Using among-year climate conditions and climate indices to predict consequences for multiple trophic levels: plants, insects and lizards

In the northern extreme of the Great Basin desert scrub, climate variation is exemplified not only by the contrasts of La Nina and El Nino years, but also by comparing temperature and rainfall differences among consecutive years, across a fifteen-year span. As an ecosystem strongly limited by water resources, the among-year contrasts in temperature and rainfall in the desert scrub, along with aridity indices and evapotranspiration indices, can be used to predict contrasting outcomes among years in productivity at multiple trophic levels: 1) NDVI as a proxy of primary productivity, 2) abundances of arthropods (the primary and secondary consumers), 3) specific prey of lizards, 4) feeding rates by lizards (the secondary and tertiary consumers), 5) lizard body condition and 6) reproductive output of lizards, with special focus on the Long-nosed Leopard Lizard, *Gambelia wislizenii*, which eats vertebrates and arthropods. Trophic consequences of climate variation among years do correlate with indices, with the caveat that indices only approximate the dynamic timing and levels of precipitation and temperature.

P2-239 ANDERSON, HB*; HUTCHINSON, M; CORBIN, CE; HRANITZ, JM; Bloomsburg University of Pennsylvania, Pennsylvania Department of Agriculture, Harrisburg; *hba35279@huskies.bloomu.edu*

Avian Host Diversity Detected in Blood Meal Analysis of Two Species of Culex Mosquitoes Collected from Urban Habitats in Pennsylvania

West Nile virus (WNV) was first discovered in the United States in 1999, and is now the most common vector-borne pathogen in the country, transmitted primarily by *Culex pipiens* and *Culex restuans* mosquitoes. As vectors acquire WNV through blood meals of infected birds, an understanding of the avian reservoir populations of the virus is required to limit WNV spread to humans. Using mosquitoes collected by the Pennsylvania Department of Environmental Protection (PA DEP) from urban sites in all Pennsylvania counties between the years 2008-2013, this research aims to identify reservoir populations of WNV through blood meal analysis of *Cx. pipiens* and *Cx. restuans* samples. Preliminary results of this research reveal that both *Cx. pipiens* and *Cx. restuans* prey upon diverse hosts in urban habitats. Avian hosts detected in the sample include the House Sparrow (43.0%), American Robin (14.4%), Northern Cardinal (14.4%), Eastern Bluebird (7.1%), Red-winged Blackbird (7.1%), Green Heron (7.1%), and Northern Mockingbird (7.1%). This project is ongoing, and ultimately we will evaluate avian host-mosquito vector pairs for host distribution and host competencies to better understand factors influencing WNV disease transmission.

83-2 ANDREASEN, VA*; YAP, KN; YAMADA, K; WILLIAMS, A; ZIKELI, S; KAVAZIS, AN; HOOD, WR; Auburn University, AL; *vaa0008@auburn.edu*

The impact of maternal corticosterone on offspring morphology and mitochondrial physiology

The effects of maternal stress on offspring phenotype remain equivocal. An increase of circulating glucocorticoids in reproductive females may augment allocation of resources towards self-maintenance and away from offspring. Thus, elevated circulating glucocorticoids may negatively affect offspring development. However, maternal stress may induce preparative responses in offspring, such as higher tolerance to oxidative stress and more efficient mitochondria, which could positively impact survival. If early life experience is a good predictor of future environments, then increased mitochondrial performance may provide a benefit towards survival in poor conditions. To test this hypothesis, corticosterone (CORT) was administered orally to female mice from days 7 to 21 after parturition. Thus, offspring were indirectly exposed to CORT through the mother's milk and aspects of their mitochondrial physiology were investigated at two timepoints, 38 and 70 days of age. At both ages, we isolated mitochondria from liver and skeletal muscle to measure respiratory control ratio (RCR) and reactive oxygen species (ROS) production. Preliminary results show that skeletal muscle RCR was higher while ROS was lower in adult offspring (70 days old) exposed to maternal CORT. These effects suggest potential benefits to post-natal stress exposure which could assist in predator escape. Experimental pups had a lower body mass than control pups at both ages, though these differences were marginally insignificant. Data on oxidative damage, mitochondrial density and fecal CORT levels will also be presented.

P3-52 ANGELIS, E*; GREENWAY, G; MILLER, CW; University of Florida; *angelisemm@gmail.com*

How does weapon loss influence mating behavior in the coreid Narnia femorata?

Males of many species invest in elaborate and costly weapons in order to secure access to mates. The permanent loss of one of these sexually selected weapons is assumed to reduce male competitive ability and subsequent reproductive success. In the leaf-footed bug *Narnia femorata*, autotomy (loss of the weaponized hind limb) during development reduces competitive success. However, autotomy is also associated with the growth of larger testes via resource reallocation to primary reproductive tissue. Here we ask if autotomy also influences male mating behavior in this species. We then explore whether the developmental stage at which weapon loss occurs affects mating behavior. We assigned fourth instar juveniles, fifth instar juveniles, newly eclosed adults and two-week-old adults to either control (unmanipulated) or autotomized (induced left hind limb loss) treatments before pairing these focal males with a mating partner upon reproductive maturity. We observed and scored the occurrence and duration of a range of mating behaviors and found that autotomy did in fact impact mating duration; autotomized males mated for longer than control males, potentially compensating for their lost weapon by increasing time spent mating with females. This change in mating behavior may enable autotomized males to maximize their reproductive success when given a mating opportunity and provides insight into the complex interactions between behavior and morphology.

39-3 ANSELMO, CM*; BUTLER, JM; MARUSKA, KP; Louisiana State University, Baton Rouge; *cansel5@lsu.edu*

Can you feel me now?: The lateral line system mediates reproduction in an African cichlid

The mechanosensory lateral line system (LLS) of fishes is fundamental for detecting 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 showed that *Astatotilapia burtoni* males use mechanosensory information to mediate male-male territorial interactions. Many fishes also produce water movements during reproductive interactions, but little is known about the role of the lateral line system in reproduction in any of the ~30,000 fish species. To understand the importance of mechanoreception in reproductive contexts, we compared behavioral interactions and neural activation patterns between LLS-intact and LLS-ablated females exposed to intact males. Our data shows that males are less-likely to court LLS-ablated females, who are then less-likely to positively respond to those courtship attempts. Spawning also occurred less often in trials with LLS-ablated females, illustrating that lateral line information is important for reproductive success. To investigate neural processing of reproductively-relevant mechanosensory information, brains were collected after behavior trials and stained for the immediate-early gene *cfos* as an indicator for neural activation. LLS-ablated and LLS-intact females had different activation patterns in some sensory and socially-relevant brain regions. These results reveal that mechanosensory information is also processed in known socially-relevant regions. 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.

P1-258 ANTUNES, IK*; JOHNSON, EB; MERTZ, PS; MALISCH, JL; St. Mary's College of Maryland, University of Pittsburgh; *ikantunes@smcm.edu*

Development of an Enzyme Linked Immunosorbent Assay for Avian Corticosterone Binding Globulin

Corticosterone (CORT) is a frequently quantified hormone in the field of avian endocrinology. CORT is a metabolic hormone that fluctuates daily, seasonally and in response to acute challenges (stressors). Because of the hydrophobic nature of CORT, the majority of CORT is carried on hydrophilic corticosterone binding globulin (CBG). The need to measure CBG in comparative studies is debated and several different hypotheses have been proposed to explain the functional role of CBG. These hypotheses focus on either total hormone (CORT bound to CBG plus free CORT), free hormone (total CORT minus CORT bound to CBG) bound hormone (total CORT minus free CORT). We propose that increased inclusion of CBG in comparative studies will help elucidate the role of CBG in CORT physiology and help identify the functionally accurate hypothesis. However, a major impediment to the inclusion of CBG in comparative studies is the lack of a simple assay, such as an enzyme linked immunosorbent assay (ELISA) typically used to quantify CORT. Here we report on our progress generating an avian CBG ELISA using a novel CBG antibody against zebra finch (*Taeniopygia guttata*), and developing a standard for use in the ELISA for quantifying CBG. We report on the efficacy of using this assay with four typical avian models, White-crowned sparrows (*Zonotrichia leucophrys*), White-throated sparrows (*Zonotrichia albicollis*), Dark-eyed Juncos and Zebra Finch (*Junco hyemalis*). Routine quantification of CBG may lead to a better understanding of the role of CBG in CORT physiology for comparative studies.

75-5 ARIAS, AA*; BALL, AM; AZIZI, E; University of California, Irvine; *adriena@uci.edu*

Passive mechanical properties of crocodilian limb muscles correlate with in vivo function

The passive mechanical properties (i.e. passive stiffness) of muscle have been shown to influence the region of the force-length (F-L) curve over which it operates. Previous work in anurans has shown that muscles with distinct *in vivo* functions (i.e. energy production *vs.* dissipation) vary in passive mechanical properties, but it remains unclear whether this pattern is broadly held across terrestrial vertebrates or restricted to highly-specialized muscles. Here we use results of inverse dynamics analyses in juvenile alligators to deduce the *in vivo* functions of limb muscles during walking, and subsequently characterized the F-L properties of two different limb muscles *in situ*. Results from inverse dynamics suggest that elbow extensor muscles undergo a period of negative work (eccentric contraction) and ankle extensors muscles primarily produce positive (concentric contraction) or zero (isometric contraction) work during stance phase of walking. Based on these results and previously published anatomical data (Allen et al. 2010, 2014), triceps longus lateralis (TLL) and lateral gastrocnemius (LG) were chosen for muscle preparations. Our preliminary *in situ* results show that TLL passive force reaches 20% maximum isometric force (L_{20}) at shorter relative lengths when compared to LG. We also find that the slope of log-transformed TLL data is greater than that of LG (ANCOVA $p<0.05$), indicating an increase in stiffness of muscle that dissipates mechanical energy. These results suggest a causal link between a muscle's expected *in vivo* function and its passive stiffness, and this work in crocodilians expands the range of muscle passive stiffness literature to include reptiles and animals with semi-erect postures. Future work will determine the *in vivo* operating lengths of TLL and LG followed by *in situ* F-L characterizations to map where on their respective force-length curves these muscles operate at during walking.

P1-260.5 ARLINGHAUS, K; CHALLENER, R*; Bellarmine University, Louisville, KY; *rchallener@bellarmine.edu*

Impacts of Ultraviolet Light Exposure on the Activity of Antioxidant Enzymes in the Coelomocytes of the Sea Urchins Lytechinus variegatus and Arbacia punctulata

Many sea urchins play important ecological roles in their environments, and it is important to study the impacts of environmental stressors on their physiology. Ultraviolet radiation (UVR) exposure has significant negative impacts on marine organisms including an increase in reactive oxygen species (ROS). Oxidative damage by ROS at the cellular level can cause lipid peroxidation, DNA fragmentation, and even cell death which may result in inflammation or disease. To prevent this cellular damage, organisms generate enzymes, such as superoxide dismutase (SOD) and catalase, that breakdown ROS into harmless substances. Elevated SOD and catalase activities under UVB exposure have been detected for many aquatic organisms, yet it is unknown whether UVB exposure affects the activity of these antioxidant enzymes in many sea urchin species. *Lytechinus variegatus* is well known for its covering behavior in response to UVR exposure whereas *Arbacia punctulata* does not cover with any materials and remains fully exposed. Whether these behavioral differences result in differences in antioxidant enzyme activity in response to UVR exposure is not known. In this study, coelomocytes of *L. variegatus* and *A. punctulata* were exposed to UVB (302 nm) for two hours and catalase activity was measured using colorimetric assays. Results suggest UVB exposure significantly decreased catalase activity in the coelomocytes of both species (t-test, $p < 0.0001$, *L.variegatus*, $p = 0.0097$, *A. punctulata*). Whether these observed differences in antioxidant activity are associated with covering behavior is yet to be determined.

P2-104 ARMSTRONG, TBK*; DAVIS, E; DICKERSON, H; HEALY, JE; Austin College, Sherman, TX; *taqwaarmstrong@gmail.com*

Implication of Choice of Burrow Location in the Thirteen-Lined Ground Squirrel (Ictidomys tridecemlineatus)

Thirteen-lined ground squirrels (TLGS) range from Texas to Canada, but recently there are fewer colonies in the most southern portion of their range, possibly due to food shortages, habitat fragmentation, or climate change, including flooding of burrows due to winter precipitation while animals are in torpor. TLGS are antisocial burrowing rodents- lactating mothers share their burrow with juveniles until weaning, but during that time are territorial of their burrows and foraging areas. Little is known about the potential effects of climatic differences on burrowing behavior or life history characteristics. To fill this gap we live-trapped and examined life history characteristics (reproduction, behavior, hibernation pattern, and choice of burrow location) of TLGS across a latitudinal range from TX to MN. By measuring the relative abundance of preferred food in areas with and without burrows, I hypothesized that areas with burrows would have a higher food density within a 2m radius than areas without burrows. Alternatively, I hypothesized that more burrows would be located close to headstones than in the open, as headstones could be protective against predation. Neither hypothesis was supported by our data and suggests that food and protection alone cannot predict burrow location. Therefore, some other characteristic such as soil texture could explain burrow choice, supporting the potential explanation that contraction in species range is due to winter flooding events. Many southern populations were in areas with clay soil, which is susceptible to water retention and flash flooding events. This has implications for the survival of populations in other areas of the species range with similar soil types as the climate continues to change and these flooding events become more common.

P1-149 ARMSTRONG, R*; TORRES, T; WATSON, CM; SHIPLEY, MM; Midwestern State University; *raccewn1@gmail.com*

Characterization of Fatty Acid Profiles of the Butterfly Weed (Asclepias tuberosa) and its Specialist Predator, the Monarch Butterfly (Danaus plexippus).

Monarch butterfly larvae, *Danaus plexippus*, have a diet entirely composed of milkweed, (*Asclepias*) while the adults use nectar from a variety of sources. While the nectar eaten by the adults contains minimal lipids, the milkweed has a variety of lipids, and their constituent fatty acids help provide their nutritional needs. *Asclepias tuberosa* was selected to identify the fatty acids that the monarchs are ingesting. Milkweed leaves were sliced into small segments, dried, and then weighed. We hand collected monarch caterpillars and butterflies, and turned each into a slurry with a tissue tearor. Lipids from all samples were extracted via a mixture of chloroform, methanol, and water in a 4:2:1 ratio and then converted to fatty acid methyl esters (FAMEs) to be analyzed by gas chromatography. The most common fatty acid present in the milkweed was linolenic acid, or 18:3 (about 60% of all fatty acids). The caterpillars showed the most common to be palmitic acid, or 16:0, followed by 18:3. The adults showed oleic acid, or 18:1, as the most common fatty acid. This suggests that monarchs acquire the major starting lipid, 18:3, and turn it into different fatty acids for storage and utilization. Interestingly, different stages of the monarch's life have a different fatty acid profile, suggesting they utilize different lipids during different life stages. One unexpected result was that some monarchs showed as high as 50% 18:3 while other samples showed 0%.

P1-15 ARNAOUDOFF, LA*; SANGER, TC; Loyola University Chicago, Illinois; *larnaoudoff@luc.edu*

Three-Dimensional Embryological Atlas of Anolis sagrei based on micro-CT.

With the rapid rise of Evo-devo and the concurrent development of new imaging techniques, comparative studies of development have accelerated over the last decade. Squamates, lizards and snakes, lack a traditional experimental model species for developmental investigations, yet are important for understanding fundamental evolutionary questions because of their remarkable diversity. However, several squamate species have growing communities of biologists building new resources for comparative and experimental studies of lizard development. Creation of detailed embryological atlases for these species will help promote their advancement. In the past, scientists have had to rely on destructive methods to conduct detailed studies of internal anatomy. However, X-ray computed tomography, CT scanning, allows for sub-10 micron, non-destructive imaging of vertebrate embryos. This technique allows not only the ability to analyze the hard tissues, but also, with the help of chemical counterstains, the ability to differentiate among soft tissues. We are creating a detailed, 3D embryological atlas of the model lizard species, *Anolis sagrei*, using micro-CT scanning. For a subset of stages we are reconstructing the development of both hard and soft tissues, such as bone, muscle, and neural tissues. All reconstructions are being conducted in the free software package 3D Slicer. We are compiling 2D images that can be used for virtual histology and 3D models of each stage. This anatomical atlas will be essential resource for research on *Anolis* development and will help create a more comprehensive understanding of the embryonic development of *anoles*.

P3-233 ARREZ, SA*; ARANGO, K; FERRIGNO, A; GIDMARK, NJ; Knox College; *saarrez@knox.edu*

Impacts of a fin whale skeleton in teaching Art and Biology courses at an undergraduate-only college

Skeletal material is fundamental for teaching comparative anatomy to undergraduates, providing hands-on experience with variation in size, evolutionary history, and function. Size specifically is a difficult-to-grasp concept that is also pivotal in art classes. We acquired an incomplete 55-foot fin whale skeleton consisting of over 150 unorganized, fractured, and stained bones. A dozen students and two faculty spent the last year recording, identifying, cleaning, repairing, re-building and preserving bones prior to their articulation. We distilled a variety of previously-developed techniques to restore and preserve the skeleton. This project has provided ways to teach drawing methods conveying size, scale, volume, and mass from different perspectives. Our skeleton has also allowed for student-led independent research as part of the capstone requirement of Knox's Biology major. One student used measurements of changes in neural canal diameter as a proxy for the amount of information exiting the CNS at each spinal level. Differences in diameter of adjacent cervical and caudal vertebrae were the largest, suggesting that the greatest bandwidth of neural control is needed to drive mobility of the pectoral fins and tail. Another student-designed study investigated the long term effects of bacterial infection in vertebrae including degeneration of the vertebral centrum. To determine a possible causal pathogen, we are currently attempting to extract bacterial DNA with PCR. The restoration and articulation of the Knox College whale has been an incredible outlet for inter-departmental collaboration and development of undergraduate teaching and learning.

P2-202 ASENCIO, AM*; POWERS, JD; WILLIAMS, CD; MALINGEN, SA; DANIEL, TL; University of Washington, Seattle, WA, University of California, San Diego, CA, Allen Institute of Cell Science, Seattle, WA; *danielt@uw.edu*

Predicting complex modulus of active muscle from models of elastically coupled molecular motors

Muscle is active, regulated soft matter, hierarchically organized into a structure that has unique material properties, particularly regarding its instantaneous stiffness. Prior experimental work used dynamic testing to characterize the complex modulus of active muscle for fully activated isolated muscle fibers. This modulus measures the component of stress that is in phase with periodic length changes (elastic component) as well as the out-of-phase component (viscous component). The complex modulus for active muscle shows a highly non-monotonic behavior with increasing frequency of applied length change. Its Nyquist plot shows a cardioid shape as frequency increases. In contrast, both passive and rigor muscle shows very simple increases in stiffness with increasing frequencies, consistent with passive visco-elastic materials. We used a spatially explicit half sarcomere model to simulate muscle's dynamic force in response to applied sinusoidal length changes. In particular, we asked how well the model reproduces the material properties of skeletal muscle that have been previously measured. Our model is a stochastic simulation based upon a coupled elastic model of myosin motors, thick and thin filament mechanics, including titin mechanics and overall lattice spacing. We simulated force in response to applied sinusoidal length changes ranging from 4.3 to 100 Hz and found that our model reproduces the cardiod-like Nyquist plots seen in similar *in vitro* experiments. Using a computational model we show the emergence of muscle's unique macroscopic dynamics and material properties from microscopic principles.

P3-132 ASHLEY-ROSS, MA*; BRESSMAN, NR; Wake Forest University; *rossma@wfu.edu*

A twisted tail of intrigue: Does fish vertebral morphology constrain locomotor mode?

Diverse fish taxa of small body size move on land by means of coordinated tail-flips. In this behavior, the starting position is either lying on the fish's side or ventral surface, and the head and body are lifted over the tail as the body curls into a C shape. While the tail pushes against the substrate, continuation of the movement of the anterior portion of the body propels the fish into ballistic flight in the original direction of the tail. While representatives of multiple fish orders are capable of tail-flipping (e.g., Cypriniformes, Perciformes, Cyprinodontiformes, Blenniformes), not all tail-flippers are equally adroit. The most effective tail-flip jumpers (e.g., mangrove rivulus, *Kryptolebias marmoratus*, and the Pacific leaping blenny, *Alticus arnoldorum*) also demonstrate the ability to twist the tail about the long axis up to 90°, which allows the jump to begin from a prone position. How are these fish able to twist the tail to such an extent? We experimentally twisted the tails of less and more effective tail-flip jumpers, finding that in less skilled jumpers, the tail rotates only to a maximum of ~45°. We used CT scans of effective tail-flipping species that had been fixed in the tail-twisted position to examine where the ability to generate long-axis torsion resides. In *K. marmoratus*, tail twisting is distributed over most of the length of the vertebral column, with no obvious specializations of the vertebrae. This finding suggests that soft tissues may play a central role in determining vertebral flexibility.

116-2 ASSIS, BA*; AVERY, JD; TYLAN, C; EARLEY, RL; LANGKILDE, T; Penn State, University of Alabama; *bmd5458@psu.edu*

Honest Signaling, Sexual Conflict and Female Ornamentation: an Undesired Quality Signal?

Conspicuous sexual ornaments are uncommon in females of species with traditional sex roles, with such occurrences often attributed to genetic linkage of a trait selected for in males. In eastern fence lizards, males display colorful ornaments that are sexually selected, but any condition-dependent traits associated with ornament quality are unknown. Females may exhibit rudimentary ornamentation that carries reproductive costs, but it is unclear whether they display honest condition signaling as well. To investigate a potential adaptive role for female ornamentation in fence lizards, we used individuals from three populations to determine the relationship between ornament quality and typical condition-dependent traits in both sexes, while accounting for the effect of hormones normally associated with ornament development. In accordance with previous studies, we detected a strong relationship between testosterone levels during a specific developmental window and ornament quality at maturity. Ornament size and saturation were significantly correlated with body condition and immune response in males and therefore might signal individual quality, but these relationships were weaker or absent in females. It appears that ornament development in females is still sensitive, albeit more weakly, to androgen levels and condition-dependent traits. It is not known whether females employ this costly trait in intraspecific signaling, and thus its presence might indicate a scenario of intralocus sexual conflict. We speculate that females have largely reduced the energetic costs of ornaments by eliminating melanin deposition in these traits, while costs for iridophore production are not sufficiently high to drive females towards full sexual dimorphism.

S8-1 ASTLEY, H. C.; C, ; University of Akron; *hastley@uakron.edu*
Symposium Introduction - Long Limbless Locomotors Over Land: The mechanics and biology of elongate, limbless vertebrate locomotion
Elongate, limbless body plans are widespread in nature and frequently converged upon (with over two dozen independent convergences in Squamates alone, and many outside of Squamata). Despite their lack of legs, these animals move effectively through a wide range of microhabitats, and have a particular advantage in cluttered or confined environments. This has elicited interest from many disciplines interested in many aspects of their movements, from how and when limbless morphologies evolve to the biomechanics and control of limbless locomotion within and across taxa to its replication in elongate robots. Increasingly powerful tools and technology enable more detailed examinations of limbless biomechanics, and a combination of fossil discoveries and improved phylogenies have shed increasing light on the origins and evolution of limblessness, as well as the high frequency of convergence. Advances in actuators and control are increasing the capability of "snakebots" to solve real-world problems (e.g. search & rescue), while biological data has proven to be a potent inspiration for improvements in snakebot control. This symposium brings together prominent researchers on the topic from around the world, including biomechanists, physicists, and roboticists to foster collaboration and the exchange of ideas across disciplines and across taxa. The goal of this symposium is to identify major gaps in current knowledge and methods, promote links between biological and robotics researchers, and coordinate efforts to move the field as a whole forward. Support generously provided by the Company of Biologists and the Society for Experimental Biology.

S8-2 ASTLEY, H.C.; University of Akron; *hastley@uakron.edu*
Mechanics of Multi-articular Muscles Minimize Moments
The geometry of the musculoskeletal system, such as moment arms and linkages, determines the link between muscular functions and external mechanical results but as the geometry becomes more complex, this link becomes less clear. The musculoskeletal system of snakes is extremely complex, with several muscles which span numerous vertebrae, ranging from 10 to 45 vertebrae in the snake semispinalis-spinal (SSP) muscles (a dorsiflexor). Furthermore, this span correlates with habitat, with burrowing and aquatic species showing short spans while arboreal species show longer spans. Similar multi-articular spans are present in the prehensile tails of primates, the necks of birds, and our own digits. However, no previous analysis has adequately explained the mechanics of these multi-articular spans, either relative to mono-articular configurations or compared to greater or lesser spans. This talk uses well-established analysis techniques including the Method of Sections and the Minimum total potential energy principle to analyze the consequences of multiarticular muscle configurations. I show that multi-articular systems require a fundamentally metameric structure in which N joints require N muscles, as unconstrained internal degrees of freedom allow the system access lower potential energy states by sagging or buckling. For a cantilevered snake, increasing multi-articular span reduces both the force needed from any given muscle and the total muscular force needed across the entire muscular system. However, this improvement follows a hyperbolic distribution, with the greatest gains in transitions from mono-articular to spans of 2 or 3; all known snake SSP lengths fall into a region of much lower force with nearly linear slope and diminishing returns for extreme lengths. Continued work will examine dynamic locomotion and potential tradeoffs.

P1-183 ATTIPOE, AEL*; KAIMAKI, D-M; LABONTE, D; Imperial College London; *aea1718@ic.ac.uk*
Surface Tension of the Insect Pad Secretion
Many insects rely on the ability to cling to plants with a wide range of surface properties. Insects achieve this feat by using specialised adhesive pads located on their feet. The adhesive performance of these pads is usually attributed to capillary forces, as they are covered in a thin film of liquid. However, conclusive evidence in support of this hypothesis is scarce. Here, we determine the surface tension of the pad secretion of Indian stick insects (*Carausius morosus*), in an effort to provide information critical for a quantitative assessment of wet adhesion models. We overcome the limits posed by the minute quantity of the secretion by using Interference Reflection Microscopy (*IRM*) to image individual droplets deposited on transparent coverslips. *IRM* utilises destructive and constructive interference of monochromatic light, which results in fringe patterns that correspond to height contour lines of the imaged droplets. These fringe patterns can be converted into a height profile via a contrast detection algorithm, so reconstructing 3D profiles from 2D light microscopy images. Contact angles can then be extracted by fitting a spherical cap to the height profiles. On silane-coated glass coverslips ranging from hydrophilic to hydrophobic, the contact angles of the secretion varied from 6° to 15°, compared to 10° to 110° for water. These results are indicative of a liquid with low surface tension which wets even hydrophobic surfaces. Indeed, application of the *Owens-Wendt* theory suggested that the liquid's surface tension has a negligible polar component, consistent with previous results. A simple wet adhesion model based on the estimated surface tension fails to account for key features of the attachment performance of these insects, suggesting that capillary forces may not be its sole origin.

S11-5 AUDET, JN; Rockefeller University Field Research Center, Millbrook, NY; *jaudet@rockefeller.edu*
Comparative approaches for ecological and neurobiological correlates of innovation
In the wild, particularly in rapidly changing conditions, being capable of solving new problems can increase chances of survival. In the context of climate change, innovativeness is therefore undeniably a crucial trait. In the past few decades, birds appeared to be a taxa of choice to study innovation, thanks to the abundant literature of avian innovation reports. Innovation rate databases in birds have been successfully employed to assess relations between innovativeness and other traits such as invasion success, fitness and brain size. In order to assess more direct causes of variation in innovation, another approach consists in experimentally measuring innovativeness in captive wild animals using problem-solving tasks that mimic wild innovations. This method can allow for finer scale evaluation of ecological and neural correlates of innovation. In my talk, I will present results that were obtained using the latter approach, both at the inter-individual and inter-specific levels. I will show that such data can be used to 1) assess relations between problem-solving and a variety of cognitive and personality traits, 2) compare experimental behavioral data with other known traits of interest such as innovation rate or fitness, and, even more interestingly, 3) investigate neurobiological properties underlying variation in problem-solving and other cognitive traits. During my talk, I will present past data as well as ongoing projects utilizing the comparative approach at a neurobiological level, using state-of-the art molecular methods to answer our research questions.

P1-2 AUSTIFF, JK; Harvard University; *jkaustiff@g.harvard.edu*
Development of the Stomach of the Carnivorous Tadpoles of the Budgett's Frog, Lepidobatrachus laevis Compared to Filter Feeding Tadpoles
Typical frog tadpoles are filter feeders and lack a digestively active stomach. Only later, during metamorphosis, do they develop a functional stomach that allows the shift to feeding on larger prey as an adult. The tadpole of *Lepidobatrachus laevis*, however, is different: it develops an adult-like stomach during embryogenesis and is capable of feeding on larger prey as a tadpole. Consequently, *L. laevis* does not undergo a significant dietary shift at metamorphosis. Earlier studies of *L. laevis* lay the foundation for studying how this unusual tadpole stomach morphology develops. However, the complete course of stomach organogenesis has not been described and there is no detailed comparison to typical frog models. This study compares gut development in *L. laevis* to that in two other frogs, *Xenopus tropicalis* and *Bombina orientalis*, whose guts follow a more stereotypical (for anurans) developmental trajectory. Goals are to assess how similar the larval stomach of *L. laevis* is to a typical adult frog stomach; to determine if its embryonic development parallels stomach metamorphosis in *X, tropicalis* and *B. orientalis; and to document what degree of change it undergoes during metamorphosis. Histological staining is performed with hematoxylin and eosin to characterize general features, Alcian blue-periodic acid Schiff staining to reveal mucins, and Mallory's trichrome staining to trace development of connective tissues. Additionally, tissues are immunostained to show the onset and amount of pepsin production. This analysis will provide a greater understanding of the evolution of developmental modules, their role in the diversification of amphibian life histories, and how that diversification enables changes in diet and niche.*

P1-151 AUSTIN, A/A*; DAVIS, J; FOLTZ, S; Radford University; *admissions@radford.edu*
Frustrated Foragers: Can Displacement Behavior Communicate Food Quality and Accessibility Within and Between Species in the Wild?
The evolution and extent of inter and intraspecific social learning and social networks is a hot topic in studies of animal behavior. In this study, we examine how the feeding behaviors of individuals may transmit information both within and across species. Specifically, we used computer-automated bird feeders to observe the frustration and enthusiasm-related behaviors displayed by foraging feeder species when they were denied access to a preferred food source and correlated those with how individuals in the surrounding area might observe and use these behaviors as a means of assessing the food source for themselves. We also examine the prioritization, memory, and associative learning capability of these foragers in order to broaden our understanding of how species adapt and social learning evolves within a changing environment.

20-4 AWDE, DN*; LECHETA, MC; UNFRIED, LN; JACOBS, NA; POWERS, B; BORA, K; WATERS, JS; AXEN, HJ; FRIETZE, SE; LOCKWOOD, BL; CAHAN, SH; TEETS, NM; University of Kentucky, Lexington, University of Vermont, Burlington, Providence College, RI, Salve Regina University, Newport, RI; *davidawde@gmail.com*
Genetic mechanisms of basal thermal tolerance in Drosophila melanogaster
Shifts in daily and seasonal temperatures have a considerable effect on the performance, survival, fitness, and geographic distribution of all taxa. Thus, upper and lower thermal limits are important predictors of an organism's ability to cope with thermal variability and the effects of climate change. The ability to respond to thermal stress involves heritable genetic components and short-term shifts in gene expression; however the extent to which these two mechanisms overlap is unknown. For this study we used the *Drosophila* Genetic Reference Panel (DGRP) combined with RNA-seq in a single lab strain (Canton-S) to identify the overlap in genetic and transcriptional mechanisms underpinning critical thermal minima (CTmin) and maxima (CTmax). In the DGRP, there was greater phenotypic variation in CTmin, which ranged from 1.75 to 8.55°C, compared to CTmax, which ranged from 38.75 to 40.65°C. Upcoming analyses will determine the extent of overlap between genes identified via Genome Wide Association mapping (GWAS) using the DGRP and those identified via RNA-seq analyses with Canton-S flies exposed to their thermal limits. Together these results will characterize the relative contribution of genomic variation and short-term shifts in gene expression that underpin the thermal stress response in *Drosophila melanogaster*.

P3-9 AWKERMAN, JA*; LAVELLE, CM; HENDERSON, WM; HEMMER, BL; LILAVOIS, CR; HARRIS, P; ZIELINSKI, N; HOGLUND, MD; GLINSKI, DA; MACMILLAN, D; FORD, J; SEIM, RF; Gulf Ecology Division, US EPA, Gulf Breeze, FL , Exposure Methods and Management Div, US EPA, Athens, GA , Exposure Methods and Management Div, US EPA, Athens, GA , Research Cores Unit, US EPA, RTP, NC ; *awkerman.jill@epa.gov*
Cross-taxa Distinctions in Developmental Effects of Trifluralin Exposure between Representative Toxicological Species for Aquatic Risk Assessment
Standard ecological risk assessment practices often rely on larval and juvenile fish toxicity data as representative of the amphibian aquatic stage. This study compares developmental endpoints for zebrafish (*Danio rerio*) and the African clawed frog (*Xenopus laevis*), two standard test species, exposed to the herbicide trifluralin for 30 and 70 days, respectively. *D. rerio* were more sensitive in acute toxicity and demonstrated a reduction in growth measurements with increasing trifluralin exposure. Growth measurements in *X. laevis* at metamorphosis were not correlated with exposure; however, time to metamorphosis was delayed relative to trifluralin concentration. Species-specific gene expression patterns suggest that different biological pathways in *D. rerio* and *X. laevis* are perturbed by trifluralin exposure. Non-targeted hepatic metabolomics also identified a subset of metabolites that exhibited a non-monotonic response to trifluralin exposure in *X. laevis*. Linking differential cellular response with taxonomic distinctions in ecologically relevant endpoints will refine assumptions used in inter-species extrapolation of exposure effects and improve assessment of sublethal impacts on amphibian populations.

P1-69 AXEN, HJ*; TAFT, C; WILSON-WUESTEFELD, A; DEPELLIGRINI, F; CLIFFORD, M; Salve Regina University; *heather.axen@salve.edu*

Assessing Physiological Plasticity in the Face of Climate Change in Natural and Lab Reared Drosophila Species Collected Across Elevational Gradients

Temperature plays a large and crucial role in the distribution of species, affecting physiological processes, biophysical structures, metabolic activities and growth rates. Climate change models suggest temperature shifts will occur, altering regimes to which organisms have locally adapted. When relocation or behavior modification alone cannot mediate thermal stress, organisms may rely on epigenetically regulated physiological mechanisms. One physiological response activated by thermal stress is the production heat shock proteins (hsps); which protect cells by stabilizing and refolding stressed proteins or targeting them for degradation. Fruit flies in the genus Drosophila are distributed globally, occurring across a wide range of thermal conditions allowing for evaluation of the effects of evolutionary history on phenotypic plasticity. Thermally stable conditions in which variation between daily and annual high and low temperatures is relatively low may present relaxed selection on maintaining mechanisms of phenotypic plasticity, while populations adapted to variable thermal regimes, such as those in habitats that experience seasonality and strong shifts in minimum and maximum annual temperature may have an evolutionary advantage in the face of increasing variability due to climate change. To investigate the relationships between evolutionary potential and climate change, we evaluated minimum and maximum thermal limits in flies collected from populations across elevational gradients in California and Arizona. Following testing of thermal limits expression of genes associated with heat shock pathways were assessed using qPCR

P2-72 AXLID, EG*; MINICOZZI, MR; BUCK, CL; VON HIPPEL, FA; Northern Arizona University, Flagstaff, Minnesota State University, Mankato; *ega34@nau.edu*

Does Sodium Perchlorate Act as an Obesogen in Developing Zebrafish?

Sodium perchlorate ($NaClO_4$) is a compound used as an oxidizer in a range of military and industrial processes. It is highly water soluble and has contaminated waters across the United States. The compound is also an endocrine disrupter that inhibits thyroid hormone production. Here, we investigate the obesogenic effects of sodium perchlorate on developing zebrafish *(D. rerio)*. Accumulation of lipids in zebrafish tissues as a result of perchlorate exposure could suggest a similar relationship in humans and provide insight into possible causes of the ongoing obesity epidemic. To answer the questions of whether sodium perchlorate contributes to lipid accumulation, and where this accumulation occurs, we reared groups of zebrafish in four perchlorate treatments (10ppb, 10ppm, 30ppm and 100ppm) and a control (0ppm). The fish were euthanized at 133 days post fertilization with tricaine mesylate, embedded in paraffin, sectioned (with ventral, medial, and dorsal sections taken), and stained using Oil Red O. The lipid content in each fish as a whole, as well as in specific tissues, was quantified using Leica software. We predict that perchlorate exposed fish will have an increase in whole body lipid content as lipid accumulation is a common effect of thyroid hormone deficiency. We will also investigate the tissues that are most affected by perchlorate exposure.

P3-237 AYALA, A.N*; CHAMBERLAIN, C.; HOLBROOK, N.M; University of Texas at Austin, Summer Research Opportunities at Harvard, Harvard Department of Organismic and Evolutionary Biology; *aliayala5@gmail.com*

Temperate forests! How climate change affects growth and phenology

Plants are an organism commonly used to study climate change. Because they do not have the ability of locomotion, plants are forced to adapt or perish when unfavorable conditions occur. One of the responses plants have to climate change is by adjusting their phenology, the timing of life events. These life events include bud burst, leaf out, flowering, and fruiting. During climate change, warm temperatures can occur earlier in the year, "tricking" plants to unfurl their leaves earlier. With climate change, however, comes extreme weather events. The event we are most interested in are called late spring freezes- low temperature extremes that can occur after a plant has experienced leaf out and damage its exposed leaf tissue. Because climate change affects all organisms, we also expect to see herbivores moving towards cooler habitats, to our temperate forests. We chose to study temperate forests because they occur in a region that has a lot of seasonality. Growth, leaf investment, the phenology, and herbivore defense of the plant were measured in order to investigate the question. The methodology included making biweekly observations in a common garden, measuring diameter at breast height (DBH), height, leaf area, leaf wet weight, leaf dry weight, and leaf toughness using a clinometer. We hypothesize that we will find increased growth, less leaf investment, a shift forward in phenology, and increased herbivore defense. This study is a step towards understanding how climate change will affect temperate forests and the ecosystem services they provide.

102-5 AZZOLINI, J.A.*; DENARDO, D.F.; Arizona State University; *jlazzoli@asu.edu*

Effect of elevated glucose intake on physiological biomarkers

Ecotourism is a rapidly growing industry based on perceived economic and conservation value. For example, in the Bahamas tourists pay to visit islands where they can feed table grapes to endangered northern Bahamian rock iguanas (*Cyclura cychlura*). This interaction dramatically alters the iguanas' natural behavior and diet, and, thus, the physiological and ecological consequences of this activity is being thoroughly investigated. Previous studies have shown that reproductive females on tourist-visited islands have elevated oxidative stress, and some alterations in plasma-based innate immunity. Additionally, tourist-visited rock iguanas subjected to a glucose tolerance test display pre-diabetic physiology (i.e., increases peak blood glucose and delayed recovery to baseline values). As work with free-ranging individuals is challenged by the presence of numerous uncontrolled variables, we used green iguanas (*Iguana iguana*) as a proxy species to isolate the potential effects of increased glucose intake on oxidative stress and innate immunity. Green iguanas are readily available, and glucose-treated green iguanas that undergo a glucose tolerance test show a blood glucose profile similar to that of rock iguanas on tourist-visited islands. Iguanas were gavaged daily with either water or a glucose solution for four weeks. We collected blood samples prior to any gavaging, after two days of gavaging, and after four weeks of gavaging. This experimental design allowed us to examine both the acute and chronic effects of elevated glucose intake. Our results showed that oxidative stress (the balance between reactive oxygen species and antioxidants) remained consistent throughout the experiment. Therefore, it appears that increased glucose intake alone does not contribute to oxidative stress. The results of our immune assays (BKA, lysis, agglutination) are currently being analyzed, and will also be presented.

P2-88 BABB, MH*; LOHMANN, C; University of North Carolina at Chapel Hill; *mattbabb@live.unc.edu*

A Comparison of Stereotypic and Anticipatory Behavior in Cougars (Puma concolor) and Lions (Panthera leo) from Zoo to Sanctuary

A core pillar of animal behavior research is that environment can profoundly affect the behavioral phenotypes of animals. This principle can be studied especially well in research on animal well-being in the semi-controlled environments of zoological parks. Two reliable factors that have been used as real-time indicators of an animal's well-being are stereotypic and anticipatory behavior. Stereotypic behavior is a behavior that occurs repetitively with no purpose and is an indicator of animal distress when it is present in high rates. Anticipatory behavior is a behavior that occurs prior to receiving a reward. It has been accepted as an indicator of reward sensitivity and therefore monitoring its rate of occurrence can give insight into the animal's perception of its own well-being. Currently, much is known about these behaviors in felids inside of zoos, but there are very few studies that compare these behaviors between zoos and wildlife sanctuaries. Since behavior is a result of the environment that captive animals live in, examining the difference between a commercialized zoo and an animal-focused natural sanctuary could provide insight into what environments lead to captive felid mental distress. Cougars, *Puma concolor*, and Lions, *Panthera leo*, are popular felids that are found in zoos and sanctuaries across the United States and were chosen for this study because of availability. The purpose of this study was to compare the behaviors of the cougars and lions at the North Carolina Zoo in Asheboro, NC to the behaviors of cougars and lions at Carolina Tiger Rescue, a natural wildlife sanctuary in Pittsboro, NC. Through the use of video observations and GIS analysis, this study provides insights on the behavioral differences of felids in zoos compared to felids in a sanctuary setting.

15-5 BABIN, CH*; BELL, CD; University of New Orleans; *chbabin@uno.edu*

A global molecular phylogeny of chromosomal evolution in wild onions (Allium, Amaryllidaceae)

Polyploidy, the event of increasing nuclear chromosomes, is believed to be a significant driver of diversification among land plants. Mechanisms of chromosome number evolution include whole-genome duplication, half-genome increases (demi-polyploidy), gains or losses of single chromosomes that alter the DNA content of an organism (aneuploidy), or chromosome fission or fusion (ascending dysploidy or descending dysploidy, respectively). Considering the high variability in chromosome number transitions across multiple clades within angiosperms and the ancient genome duplication events responsible for their diversity, studies of non-model systems are necessary to close the gaps in our understanding of chromosomal evolution with respect to polyploid plants. *Allium* (Amaryllidaceae) is an ideal candidate for polyploid research because it is the largest genus in its family and includes numerous natural populations of diploid and polyploid species. Plants in this genus mainly occupy temperate climates in the Northern Hemisphere and include economically important ornamentals and cultivated crops such as leeks, garlic, chives, and onion varieties. Here, we present a global molecular phylogeny of *Allium* comprising 429 of approximately 800 species. We examined chromosomal evolution with chromEvol v. 2.0 (Glick and Mayrose, 2014) which uses likelihood-based methods for inferring the pattern of chromosome number change across a phylogeny. The ancestral base number was inferred to be $n = 8$, consistent with the most common haploid number of Old-World species. The best-fit model of chromosomal evolution indicated that chromosome transitions occurred through the constant gains and losses of single chromosomes as well as demi-polyploidization events, with the rate of chromosome gain events being approximately four to five times more likely to occur than half duplication and loss events.

140-2 BABONIS, LS*; RYAN, JF; MARTINDALE, MQ; Whitney Lab for Marine Bioscience, Univ of Florida, St. Augustine, FL , Whitney Lab for Marine Bioscience, Univ of Florida, St. Augustine, FL; *babonis@whitney.ufl.edu*

Things cells do

The concept of homology fuels many discussions (and frustrations) about the evolution of animal morphology. Little clarity comes out of these discussions due to a general lack of consensus about the general meaning of homology; however, we argue that a bigger problem lies in a lack of understanding about how the limited morphospace under which cells evolve can lead to erroneous conclusions that morphological similarity reflects meaningful homology. For example, the morphological similarity of the unicellular choanoflagellates to the choanocytes of sponges was the chief evidence used to place Choanoflagellata as the sister lineage to Animalia prior to the dawn of molecular phylogenetics. This placement was later reinforced by molecular phylogenies, artificially inflating the apparent value of morphological similarities. Given constraints on the biophysical capacity of membranes, cytoskeletal elements, and the surface area-to-volume ratio of the cell, we argue that eukaryotic cells really only do four things: grow/shrink, undergo membrane elaboration, adopt independent shapes, and gain/lose organelles. As such, cells with similar morphological features are expected to have arisen multiple times during the expansive diversification of animals. As a case study, we survey the evolutionary distribution of cells with apical cilia and microvilli across animals and summarize evidence for shared ancestry in a subset of these. We emphasize that cellular morphology alone is insufficient support for arguments of shared ancestry and propose a new standard for discussion of homology that requires evidence of embryological, genomic, and functional similarity as well.

9-1 BADGER, MA*; PERKES, AD; PFROMMER, BG; WANG, Y; MODH, A; DANIILIDIS, K; SCHMIDT, MF; University of Pennsylvania, Philadelphia, Pennsylvania; *mbadger@seas.upenn.edu*

From moments to months: Multi-timescale tracking and analysis of songbird social interactions in a smart aviary

Social networks are formed through the actions of individuals and the structure that emerges is central to processes occurring at several biological levels of organization. How individual actions modify social networks, however, remains an important and open question. In our study system, brown-headed cowbirds (*Molothrus ater*), females are known to influence male courtship behavior. The specific mechanisms behind this phenomenon have been difficult to discover, however, because interactions (e.g. body motions and vocalizations) between multiple pairs of individuals occur simultaneously and are difficult to classify without quantitative measurements. We used an array of eight cameras and 24 microphones followed by a computer vision pipeline to continuously record the position, posture, and vocalizations of cowbirds over the entire breeding season. With these data, we investigate how moment-to-moment interactions drive changes in the social network over months. Our data also provide a difficult setting containing multiple camera views, background motion, shadows, and changes in lighting, in which to test animal tracking, pose estimation, and re-identification algorithms.

P3-202 BAE, J*; BERTUCCI, EM; MOORE, JA; BOCK, SL; RAINWATER, TR; HALE, MD; PARROTT, BB; Augusta Univ., Univ. of Georgia, Benedict College, Tom Yawkey Wildlife Center, Univ. of Virginia; *JBAE@AUGUSTA.EDU*

"The effects of the developmental environment on telomere length in Alligator mississippiensis hatchlings"

The environment that developing embryos experience influences organismal fitness by affecting phenotypic trajectories and survival. The shortening of telomeres with chronological age is related to biological aging and functional declines. Telomere dynamics are also associated with lifespan, reproductive output, and individual quality; thus, telomere length may be informative of an organism's fitness overall. However, the question of how developmental environments influence aging trajectories is relatively unexplored. Here, we aimed to understand how environmentally relevant temperature fluctuations and exposure to the endocrine disrupting chemical, dichlorodiphenyldichloroethylene (DDE), affects telomere length in developing American alligators (*Alligator mississippiensis*). The incubation environment was manipulated to be either at a constant male-, female-, or intermediate-promoting temperature or following fluctuations observed in natural nests. Further, half of the embryos received an external dose of DDE just before gonadal differentiation. Neonatal alligators were hatched and growth was monitored for 10 days prior to taking a blood sample. The absolute average telomere length of red blood cells was quantified through the quantitative polymerase chain reaction using a single copy gene (sox9) to produce a ratio of telomere sequence abundance to single copy gene abundance (T/S ratio). We report our findings regarding how the developmental environment influences telomere length in hatchling alligators and predict how that might represent general quality and long-term health and survival. This study advances our understanding of long-term consequences of the developmental environment and insights for conservation for this species in a rapidly changing world.

P3-49 BAEZA, K*; RANCHOD, P; STEFFENSON, M; St. Edward's University; *kbaeza@stedwards.edu*

The Introduction of Commonly Used Pesticides and Their Effect on the Immunological Function of Honeybees

Colony collapse disorder (CCD) is a current phenomenon which is causing rapid declines in honeybee populations. While researchers have yet to find a direct cause of CCD, it is hypothesized that it may be the result of a combination of multiple factors such as global warming, parasitic *Varroa* mites, and the use of pesticides. The goal of this study was to identify the effect of four commonly used pesticides in agriculture (imidacloprid, glyphosate, thiamethoxam, and clothianidin) on the immune function of honeybees. For each pesticide, 150 honeybees were collected randomly from a set of hives in the Austin area and starved for four to six hours. A pesticide sugar water solution with biological relevant concentrations was then fed to each bee with a micropipette. Bees were then left for zero (control), two, or four hours after feeding before hemolymph was extracted. Hemolymph was added to buffer, lysed with glass beads, and placed at a -80oC to stop protein activity. Samples are currently undergoing several colorimetric assays utilizing a spectrophotometer to determine immunological protein activity including a RED 660 assay for overall protein concentrations, prophenoloxidase, catalase, and peroxidase. Anecdotally, bees subjected to the pesticide glyphosate appear to have higher mortality over time compared to the other pesticides tested. Bees that ingested glyphosate had significantly lower protein concentrations than all other pesticides tested. Prophenoloxidase activity appears highest when bees are exposed to clothianidin, while imidacloprid significantly decreases activity four hours after exposure. Results from this study will help determine what effects, if any, pesticides contribute to the onset of CCD.

P1-93 BAGGE, LE*; GOLDSTEIN, DH; LYONS, BA; WEHLING, MF; Air Force Research Lab, Eglin, FL and University of FL, Shalimar, FL, Air Force Research Lab, Eglin, FL; *laura.elizabeth.bagge@gmail.com*

Circularly Polarized Light Reflectance of and Wing Interference Patterns from Insects

Certain insect body and wing surfaces interact with light in unique ways; for example, many scarab beetles have body surfaces that reflect circularly polarized light and many small insects have wing membranes that produce distinct wing interference patterns (WIPs) that are likely to be highly polarized. Our study characterizes not only human-perceived appearances of insect surfaces, but also the polarization signatures and an insect's perception of these signatures in their natural environment. First, while it has been suggested that some beetles respond behaviorally to circularly polarized light, we still do not know whether any scarab beetles have the necessary optical structures to detect circular polarization. To address this, we are examining beetle species that that do and do not strongly reflect circularly polarized light from their cuticles (measured with a spectropolarimetric reflectometer) and measuring whether there are any quarter wave retarder optical structures in their eye morphologies via electron microscopy and micro-CT. Second, while the visibility of WIPs to the human eye depends strongly on the balance between reflections from the wing vs. the background, we do not know how WIPs may appear to an insect. We are characterizing a broad sampling of insects' WIPs (e.g. from Odonata, Hymenoptera, and Diptera) using multispectral (UV to near-IR) and polarimetric imaging techniques with a QSI640UV camera. Overall, we expect that our study of these insect surfaces will result in improved reflectance predictions and consideration of additional factors affecting an organism's ability to perceive the resulting spectral and polarimetric characteristics of light scattered from ultrastructural surface features.

112-3 BAIN, SR*; LOWER, SE; Bucknell University; *srb039@bucknell.edu*

Using Environmental Factors to Predict the Emergence Patterns of Firefly Species in Pennsylvania

How do environmental parameters affect the geographic distribution of organisms? Many organisms need to have specific conditions (temperature, sunlight, precipitation, etc.) in order to survive, develop, and eventually reproduce. The overall goal of this research project attempts to investigate environmental factors (air and soil temperature) influencing the species distributions of fireflies. Fireflies are a very widely admired organism but are vastly understudied; more information about their evolution, communication (in lighted and unlighted species), and physiology is being discovered about this organism everyday which makes it an interesting and current area of research. With that being said, there are many aspects of these organisms that still need to be researched which is where this study comes in. Flash patterns and DNA barcoding were used to identify which firefly species were present at three local field sites from May to August of 2019; abundances were also observed. That data, in addition to minimum and maximum air temperatures, were used to create a degree-day (mGDD) model. The degree-day model was adapted so it can be used as a predictive model of the various local firefly species found in years to come. Soil temperature was not put in this model because minimum and maximum values were not obtained daily. Many of the mGDD values for the different species found in this study matched up to previous findings; the ones that did not could have been because of geographic differences or speciation. Fireflies can be bio-indicators of environmental health; knowing more about how temperature affects when and where they emerge will begin to illustrate what could happen to firefly populations in relation to the continuation of climate change.

P1-229 BAKARI, KI*; LOMAX, JJ; FARINA, SC; Howard University, Brown University, University of Washington Friday Harbor Laboratories ; *imaniiio@yahoo.com*

Relating Occlusal Offset to Diet in Piranhas and Pacus

Serrasalmid fishes, such as carnivorous piranhas and their herbivorous pacu relatives, possess an extensive range of cranial morphologies that are believed to bear strong correlations to diet. Most notably, the morphology of their teeth ranges drastically across Serrasalmid species, from sharp piscivorous-like teeth which are well-equipped for consuming flesh, to incisiform teeth more closely associated with herbivory. However, tooth morphology is not the only contributor to the diversity of cranial forms found within the family. Across the taxon, Serrasalmid fishes display various degrees of occlusal offsets, wherein the teeth of the upper jaw or lower jaw will extend past their opposing counterpart. By creating and manipulating 3D-printed physical models to test bite performance, our study sought to answer the question of whether this degree of occlusal offset has any influence on biting ability with different types of prey. Eight representative species, five piranhas and three pacus, were chosen and evaluated for occlusal ability in order to determine the natural degree of occlusion for each species. We also tested whether specific degrees of occlusion can be attributed to certain diets, and how biting ability is affected when species are taken out of their natural occlusal positions. Our study found that underbites, which are generally associated with the piranha clade, performed better on the flesh-like experimental material than overbites, which are more typically associated with the pacu clade; in contrast, overbites outperformed underbites on the brittle material. This implies that Serrasalmid fishes have evolved to possess degrees of occlusion which best suit their dietary niches.

P3-74 BAKER, NJ*; GARCIA, L; Austin College; *nbaker16@austincollege.edu*

Transgenerational Effects of Predatory Stress in Pea Aphids

Predation stress affects the behaviors and distributions of many organisms, as well as their interactions with one another. Pea aphids (*Acyrthosiphon pisum*) are known to increase wing morph formation in generations following lethal predator stress to their colony, but behavioral responses to non-lethal stress, such as reduced reproduction and dropping off the plant, have received less attention. Here we seek to better understand pea aphid behaviors following non-lethal predator stress within and across generations. We exposed adult pea aphids to 2 hours of non-lethal predatory stress, induced by a lady beetle (*Hippodamia convergens*) with immobilized mouthparts. After exposure, *A. pisum* reproductive behavior was observed every 12 hours for 48 hours, and the number of offspring produced by stressed and control aphids were tracked. We found that within the first 24 hours, the amount of offspring produced by stressed *A. pisum* was significantly lower than the amount produced by control *A. pisum*. The amount of offspring produced over the second 24 hour period, however, was similar between both groups. The reproductive output between both groups over the total 48 hour time window showed no significant differences. These results indicate that stressed *A. pisum* avoid reproducing in an unsafe environment immediately after predation stress, but this stress response only lasts up to 24 hours. In additional ongoing experiments, we will use parasitoid wasps to induce non-lethal stress in *A. pisum* adults, and then investigate behavioral responses to non-lethal stress across subsequent generations. We expect that the offspring of *A. pisum* exposed to non-lethal stressors will exhibit more predator avoidance behaviors than control *A. pisum*. These experiments will contribute to our understanding of how reproductive and antipredator behaviors can be modified across generations of genetically identical organisms.

10-1 BAKER, CM*; BOYER, SL; GIRIBET, G; Harvard University, Cambridge, MA, Macalester College, St Paul, MN; *baker02@g.harvard.edu*

Phylogenomics and Biogeography of the Gondwanan Vicariant Harvestman Family Pettalidae (Arachnida, Opiliones)

We tested the hypothesis that Gondwanan vicariance contributed to the circum-Antarctic distribution of Pettalidae, a family of small, dispersal-limited arachnids whose phylogeny, based on morphological or Sanger sequence data, has until now been unresolved. We generated transcriptomic data for a phylogeny of sixteen pettalids, from nine genera. Data were analyzed using ML, Bayesian, and coalescence methods. The phylogenetic position of a biogeographically critical genus from Sri Lanka was further explored using quartet likelihood mapping and gene-wise changes in log likelihood scores. We also performed a dating analysis using fossil calibrations on a previously published Sanger-based phylogeny with near complete species sampling, and the backbone constrained to match our transcriptomic results. We then reconstructed the biogeographic history of the family under the DEC model, using the posterior distribution of our dating analysis to incorporate divergence time uncertainty, and looked for signatures of mass extinction in the family. We recover a mostly stable topology, with a clear division between a clade from landmasses of East Gondwana, and a grade from West Gondwana. Further interrogation of phylogenetic signal suggests a sister-group relationship between taxa from Sri Lanka and eastern Australia. Given the coincident timing and order of cladogenetic events with tectonic activity, Gondwanan vicariance can explain several diversification events in Pettalidae. Some divergences predate rifting, suggesting some level of ancient regionalization, though not trans-oceanic dispersal. Despite the fact that there likely has been widespread extinction in the family, especially across Antarctica and Australia, diversification analyses find a consistent rate of speciation throughout time.

P2-66 BAKER, JA*; HEINS, DC; KING, RW; FOSTER, SA; Clark University, Worcester, MA, USA, Tulane University, New Orleans, LA, USA; *jbaker@clarku.edu*

The search for the Holy Grail: an explanation for the relationship between offspring size and maternal size

To be a scientist is to live a life searching for the answers to questions about the world in which we live, and hoping to discover the deeper rules that guide life's patterns. Discovery of the deepest of these rules, followed by all of life, are in some sense the "Holy Grails" of science. Over the past 50 years, it has become apparent that in organisms ranging from plants to vertebrates, at the population level larger "mothers" produce larger offspring. This observation created a conundrum, for the earliest theory suggested that it should not be so. The fact that it is so widespread in life has prompted a very large number of theoretical, field, and laboratory studies attempting to find the deeper reason for its existence—to find this particular "Holy Grail" that defines how life must work despite the fact that it seems so counterintuitive. Unfortunately, it is becoming increasing clear that there may be no one "Holy Grail" explanation for this phenomenon. Rather, it appears that there may be at least four plausible underlying mechanisms that each produce this particular relationship between mother and offspring. We briefly describe each of these "mini Holy Grail" explanations, and explore how they differ. We end by offering an opinion as to our current understanding of this phenomenon.

103-4 BAKKEN, G.S*; SCHRAFT, H.A; ORDUNO-BAEZ, A; CLARK, R.W; San Diego State Univ.; *george.bakken@indstate.edu*
Temperature Dependences and Angular Resolution of the Pacific Rattlesnake Facial Pit.
The pitviper facial pit functions as a chamber-type "eye". Uniquely, rather than quantum detection, sensory endings detect temperature contrasts on the pit membrane produced by thermal radiation. A novel neural pathway transmits this thermal image to the optic tectum, where it is merged with the visual image. Computer models of image formation suggest an indistinct thermal image. Neural processing in the hindbrain sharpens the image, but further sharpening may occur and so the quality of the thermal image informing behavior is unknown. However, it is critical to ecological questions such as detecting prey and thermoregulatory targets against a cluttered thermal background. We are approaching this question by testing the response of Pacific rattlesnakes (*Crotalus oreganus*) to a target moving against a patterned background. Temperatures are chosen so that it can be detected only if the background is resolved. Selection of experimental conditions required knowledge of how, singly or in combination, body, neurosensory ending, target, and background temperatures affect response. Using a target moving against a uniform background in a preliminary factorial experiment (body x target x background temperatures), we found response increased with target - background contrast. There was no response to varying absolute target temperature with fixed 6 °C contrast. But, contrary to nearly all other physiological processes, response increased as body temperature decreased. This response is integral to the facial pit sensory system, as we found the response to a moving visual target was independent of body temperature. We will describe the apparatus and present preliminary results of the resolution experiment.

54-5 BALCHAN, NR*; MACKESSY, SP; University of Northern Colorado; *neil.balchan@unco.edu*
Venom Resistance in an Eastern Colorado Rodent Community
The Red Queen hypothesis describes the coevolutionary dynamic between predator and prey where both partners must evolve in tandem to remain competitive. In several cases, rodents have demonstrated resistance to the venoms of their snake predators. For example, the California Ground Squirrel (*Otospermophilus beecheyi*) exhibits high resistance to the venom of the Pacific Rattlesnake (*Crotalus oreganus*). Conversely, cases exist where a prey species apparently lacks physiological resistance to the venom of its predator - the Cape Ground Squirrel (*Xerus inauris*) lacks venom resistance to the predatory Puffadder (*Bitis arietans*) and Snouted Cobra (*Naja annulifera*). My research evaluates patterns of venom resistance in a Colorado grassland ecosystem, where the Desert Massasauga (*Sistrurus tergeminus edwardsii*) and Prairie Rattlesnake (*Crotalus viridis*) predate upon a suite of rodent species. Field sites are located in northern (one snake predator) and southern Colorado (two snake predators) to investigate patterns of resistance between and within locations at the geographic level. Median lethal dose assays are used to assess venom resistance of select rodent populations to specific rattlesnake venoms. Serum-based assays determine the protective effect that a rodent's serum exhibits against specific venom components. Preliminary results indicate a moderate protective effect of the serum of Deer Mice (*Peromyscus maniculatus*) and Meadow Voles (*Microtus pennsylvanicus*) against Prairie Rattlesnake venoms, but not Desert Massasauga venom. Studying patterns of venom resistance in a system with two predator and multiple prey species allows us to understand better the evolution of such defenses and to evaluate whether local adaptation exists.

117-3 BALEBAIL, S*; SISNEROS, J A; University of Washington; *sujayb@uw.edu*
Relationship of advertisement call parameters with phenotypic traits in "singing" male plainfin midshipman
The plainfin midshipman (*Porichthys notatus*) is a vocal species of teleost fish that uses social acoustic signals for communication. During late spring and early summer midshipman migrate from deep water to the rocky intertidal region to breed. Type I or "singing" male midshipman construct nests beneath rocks and produce low frequency, long duration advertisement calls or "hums" to attract mates for spawning. Females locate nests via phonotaxis, lay their eggs in a single nest, and then return to deeper waters. Type I males care for the offspring until they are old enough to leave the nest. Field studies have demonstrated that larger males contain a greater number of offspring in their nests and laboratory two-choice experiments showed that females prefer to lay eggs in the nests of males with larger body size. We tested the hypothesis that male hums convey not only location but also fitness information to potential mates. We recorded the hum of eight captive male midshipman overnight in a tank maintained at a temperature between 12.8 – 14.4 °C and measured various call features such as the fundamental frequency (f0) and second harmonic (f1) of the hum, average call duration, and calling effort. We then correlated these quantities with potential indicators of male fitness such body length, body size, Fulton's body condition, gonad mass, and gonadosomatic index. Call duration and calling effort did not correlate with any of the morphometric parameters, but the fundamental frequency (f0) and second harmonic (f1) of the hum correlated positively with Fulton's body condition, but not with other parameters. Our preliminary data suggest the hum harmonics may serve as a condition-dependent or "honest" acoustic signal that provides important information related to the quality of the sender.

101-1 BALENGER, SL*; SIKKINK, K; ZUK, M; BAILEY, NW; University of Mississippi, University of Minnesota, St Andrews University; *balenger@olemiss.edu*
Fitness consequences and immunogenetic strategies against a novel parasitoid in a field cricket
Among the parasites of insects, endoparasitoids impose a unique challenge to host defenses because they use the body of another insect for the development and maturation of their eggs and/or larvae. Tachinid flies are highly specialized acoustically-orienting parasitoids that release mobile larvae, which burrow into the host's body to feed. Larval feeding typically leads to host death. We investigated the possibility that coevolving *Teleogryllus oceanicus* field crickets employ post-infestation strategies to maximize survival when infested with the larvae of the parasitoid fly *Ormia ochracea*. Using crickets from the Hawaiian island of Kauai, where the parasitoid co-occurs, and crickets from the Cook Islands (Mangaia), where the parasitoid is absent, we evaluated fitness consequences of infestation by comparing feeding behavior, reproductive capacity, and survival of males experimentally infested with *O. ochracea* larvae. We also evaluated genetic mechanisms underlying host responses by comparing gene expression in crickets infested with fly larvae for different lengths of time against that of uninfested control crickets. We did find some evidence for population differences in fitness (spermatophore production) and survival (total survival time post-infestation), although in both cases significant population effects 1) were not associated with the slope of the response to different numbers of larvae and 2) only emerged from models containing body condition at one but not both time points evaluated. Patterns of gene expression similarly show some evidence of population differences in response to infestation, but we did not find evidence for consistent differences in genes associated with immunity or the stress response.

62-5 BALIGA, VB*; SZABO, I; ALTSHULER, DL; University of British Columbia, Vancouver, BC Canada; *vbaliga@zoology.ubc.ca*

Examining the evolution of range of motion helps resolve gaps between form and function in the avian wing

The vertebrate limb is a dynamic structure that often includes many endoskeletal elements yet has traditionally been analyzed via "static" measures of morphology such as length or mass. Can incorporating a structure's dynamic capabilities help explain apparent gaps between form and function? For example, studies have repeatedly found that across broad investigations of avian clades, the correspondence between wing shape and flight behaviors is coarse. The avian wing, however, is well-suited to trace the evolution of motion capability: by modulating wing shape via skeletal joints, birds generate and control forces to keep themselves aloft. We measured the three-dimensional movement capabilities of wings from cadavers of 61 bird species from 20 avian orders, spanning a wide range of body masses and flight behaviors. These cadaver measurements were coupled with high-speed video of *in vivo* wing usage in three focal species. Using a phylogenetic comparative framework, we found that various aspects of range of motion strongly associate with flight behavior and/or body mass. In contrast, wing shape bears little correspondence to either explanatory variable. The static morphological traits of the wing also exhibit high phylogenetic signal whereas range of motion traits show greater evolutionary lability. Collectively, these results suggest a new framework for understanding the evolution of the vertebrate skeleton: rather than static morphology, it may be emergent properties such as range of motion that are predominantly reshaped as behaviors and body size evolve.

34-8 BALLESTEROS, JA*; AHARON, S; GAINETT, G; ZERN, J; ZEHMS, PP; GAVISH-REGEV, E; SHARMA, PP; University of Wisconsin-Madison, The Hebrew University of Jerusalem; *ballesterosc@wisc.edu*

An Integrative Investigation Of Eye Loss In Levantine Arachnids

The unique adaptations of cave-dwelling organisms are one of the most fascinating examples of convergent evolution. The reduction or total loss of eyes is an example of the suite of adaptations exhibited by troglobitic animals. But in arachnids, the genetic mechanisms underpinning this iconic phenotype are virtually unexplored. The study system of this contribution consists of disjunct populations of two arachnid orders from Israel and Palestine. These display a wide phenotypic spectrum of eye size, ranging from the typical arrangement eyes to complete blindness. Here, we implemented RAD-Seq approach to characterize the evolutionary dynamics and species boundaries of the cave and surface populations. To identify retinal determination gene network (RDGN) members involved in the reduction/loss of eyes, we performed differential gene expression (DGE) analysis of embryos prior and subsequent to eye formation from blind and eye-bearing populations of a whip-spider (Amblypygi, *Charinus*). DGE analysis identified RDGN members that are highly expressed in the eye bearing and lowly expressed in the blind whip-spider (or vice versa); among those, we found eye patterning candidates whose expression has been well-characterized in spiders. As validation of the DGE, we interrogated the function of a high-ranking RDGN homolog in the spider *Parasteatoda tepidariorum* using RNAi. The resulting phenotypes from these assays show an array of phenotypes that mirror the reduction in eyes observed the cave adapted spiders of Israel. Together, the integration of these approaches is providing the first insights as to the developmental genetic basis of eye evolution in arachnids.

34-5 BALLOU, L*; ILIFFE, T; OLESEN, J; BRACKEN-GRISSOM, H; Texas AM University at Galveston, University of Copenhagen, Florida International University; *balloul@tamu.edu*

Molecular Phylogeny of Remipedia: Providing Preliminary Insights into the Evolution of Feeding across an Enigmatic Crustacean Group

Remipedes are a class of crustaceans that are found predominantly within submerged anchialine cave ecosystems. Due to the limited accessibility of these habitats, insight into the evolutionary history and feeding ecology of this group remains largely unknown. Three previous reports have developed interspecies phylogenies of Remipedia; however, the addition of recently discovered species and evidence of cryptic speciation warrants further investigation. The purpose of this research is to further elucidate the evolutionary relationships of species within Remipedia using morphological and molecular techniques. Three mitochondrial genes (CO1, 16S, Cytochrome B) and two nuclear genes (H3, 18S) have been amplified and sequenced from 150 remipede samples. Sequences will then be trimmed, aligned, and compared using GENEIOUS and IQTREE. In addition to molecular analyses, remipede mouthparts (mandibles, maxilla one and two, maxillipeds) were dissected and photographed using scanning electron microscopy. Remipedes exhibit highly distinctive mouthpart morphotypes at the family level which may suggest divergent feeding strategies across the Class. Mouthpart morphotypes will thus be traced across the molecular tree in order to identify potential patterns of feeding evolution.

P3-105 BALOUN, DE*; LANE, JE; MCADAM, AG; DANTZER, BJ; BOUTIN, S; University of Saskatchewan, Saskatoon, University of Guelph, University of Michigan, Ann Arbor, University of Alberta, Edmonton; *dylan.baloun@usask.ca*

Does the ability to dissipate endogenous heat to their environment constrain reproductive investment for wild endotherms?

Physiological processes used to obtain, extract, transform, and allocate resources from the environment (i.e., activity, digestion, metabolism, lactogenesis) create heat that is either used to maintain a high body temperature or must be dissipated to the environment to maintain homeostasis. The ‘heat dissipation limitation' hypothesis suggests that the ability to dissipate endogenous heat affects the capacity of endotherms to manipulate and allocate resources from their environment to their offspring. Female American red squirrels (*Tamiasciurus hudsonicus*) that delay reproduction (due to decreases in food abundance) are under selection to reduce investment in their offspring (realized as lower growth rates of offspring). Delays in reproduction by red squirrels coincide with the warmest parts of summer, which may exacerbate heat dissipation constraints and the ability to allocate resources to offspring. Hypothesis: reproductive output of female red squirrels is limited by their capacity to dissipate heat and by the lack of resources available in their environment. We predict that females that have their capacity to dissipate heat increased, will be able to transform resources to a fuller extent and increase investment in their offspring. We reduced the insulation of free-living red squirrels (by reducing dorsal fur cover using an electric razor) and followed them throughout reproduction to quantify metrics of reproductive output (i.e., litter mass and size, growth rates of individual offspring). This study is the first to combine a manipulation of the capacity to dissipate heat and to quantify reproductive output of a mammal in the wild.

P2-99 BARDJIS, C*; STEVENS, DR; GRAHAM, M; FOSTER, SA; BAKER, JA; Clark University; *cbardjis@clarku.edu*

The Role of Predation Threat in the Development of Antipredator Behavior

The impact of invasive species on native populations has become a growing concern in conservation. Not only can invasive species drive native population extinction events, but novel predatory species have been shown to alter the evolutionary trajectories of prey population behavior by introducing strong, novel selective pressures. Often, prey rely on suites of antipredator behaviors as a means of defense against predation threat. Thus, it is important to ask how the expression of antipredator behaviors evolves. Predatory Northern pike, *Esox lucius*, have invaded freshwater lakes in Southcentral Alaska. Native to these lakes are populations of threespine stickleback, *Gasterosteus aculeatus*, which serve as prey for pike. Previous research reveals that threespine stickleback antipredator behavior is likely a plastic trait. Our study investigates whether these antipredator behavioral patterns result from differing developmental environments, specifically developmental stress related to predation threats. Fish from both pike-invaded and pike-free populations were reared in lab either with or without simulated predation throughout development. These fish were compared with wild-caught fish from the same populations. Through these comparisons, we aim to assess whether or not the stress treatment imposed on lab-reared fish during development triggers plastic differences in phenotype analogous to those observed in wild populations. Our results in activity measures suggest interactions between population and developmental environment. This presentation in full unveils further insights into the role novel predation stress plays in acting as the mechanism underlying the plasticity of antipredator behavior phenotype expression.

10-6 BARDUA, C*; BON, M; FABRE, A-C; DAS, K; HERREL, A; STANLEY, EL; BLACKBURN, DC; GOSWAMI, A; NHM, London, MfN, Berlin, MNHN, Paris , FMNH, Florida; *carla.bardua.15@ucl.ac.uk*

Macroecology and Morphological Evolution of the Frog Skull

Anurans (frogs) are the most speciose lissamphibian clade, and they exhibit astonishing cranial diversity, creating a significant challenge for quantifying cranial morphology across the clade. Here we quantify anuran cranial morphology using high-density landmarks and semilandmarks for 173 anuran species sampling every extant anuran family. The complex morphology of the frog skull is represented by a total of 995 landmarks and semilandmarks across 15 cranial regions, making this the most comprehensive dataset of anuran cranial morphology to date, in terms of both taxonomic sampling and density of shape data. With these shape data we investigate ecological, developmental, phylogenetic and allometric influences on the morphology, evolutionary rate and disparity of each cranial region. Microhabitat use is a strong influence on morphology, evolutionary rate and disparity. Semi-fossorial, fossorial, and aquatic species are the most disparate and fastest-evolving, and this pattern is most evident for jaw suspensorium cranial regions. Fossorial and aquatic species occupy distinct regions of cranial morphospace, with fossorial species associated with dorsoventrally taller skulls. Developmental strategy, in contrast, exhibits either a non-significant, or a very weak, influence on morphology, evolutionary rate and disparity. However, ossification sequence timing significantly influences evolutionary rate and disparity across frogs, with later-ossifying bones significantly more disparate and faster-evolving than early-ossifying bones. Phylogeny and allometry are both significant influences on frog crania, and cranial modules are differentially influenced by phylogenetic, allometric, and ecological effects.

31-7 BARFIELD, SJ*; DAVIES, SW; MATZ, MV; University of Texas, Austin, Boston University, University of Texas, Austin ; *sbarfield@utexas.edu*

Co-recruitment of Relatives Leads to Emergence of Inbred Genetically Isolated Group within a Panmictic Population of a Broadcast-spawning Reef-Building Coral

Many broadly-dispersing marine taxa are species rich, show genetic heterogeneity on small spatial scales, and are locally adapted to various environmental conditions. How such genetic subdivisions can emerge despite apparent lack of barriers to genetic exchange continues to be the major paradox of evolution in the sea. One understudied process potentially contributing to genetic structuring in marine populations is variation in larval recruitment. Here, we report an unusual recruitment pattern in the broadcast-spawning coral species Acropora hyacinthus on Yap Island, Micronesia. Reduced representation genotyping of 281 individuals on this isolated reef system demonstrated island-wide panmixia but also a genetically divergent group of juveniles at one out of the four sites sampled, showing elevated inbreeding and familial relatedness, including two pairs of siblings. Notably, adult corals as well as the majority of juveniles at the same site belong to the panmictic gene pool, suggesting that representatives of the inbred lineage co-recruited from elsewhere and are at least partially reproductively isolated from the rest of the island population. Reproductive isolation is further supported by finding several distinct genomic regions of greatly reduced genetic diversity in the inbred lineage, encompassing genes involved in sperm-egg recognition and fertilization that may serve as reproductive barrier loci. We propose that co-recruitment of genetic relatives via cohesive dispersal, a process that was previously unrecognized in marine invertebrates with planktonic larval phase, can generate familial genetic structure on the background of general panmixia and might be important for the emergence of genetically distinct locally adapted ectomorphs and sympatric, cryptic species.

P2-134 BARKAN, CL; ZORNIK, E; LEININGER, EC*; Reed College, Portland, OR, New College of Florida, Sarasota, FL; *ezornik@reed.edu*

Identifying neuronal properties underlying the evolution of divergent vocal behaviors

To identify mechanisms underlying the divergent evolution of motor behaviors, we investigated a hindbrain circuit that controls vocal patterns in two frog species that diverged ~17 mya: Xenopus borealis and Xenopus laevis. Male advertisement calls differ: X. laevis calls consist of many rapid sound pulses with a ~1000 ms period, while X. borealis calls consist of a single sound pulse with a 200-500 ms period. Sound pulses in both species are activated by bilateral bursts of laryngeal nerve activity called compound action potentials (CAPs). To investigate premotor mechanisms of species-typical call production, we used electrophysiological recordings in fictively calling isolated brains that generate CAPs with species-typical temporal patterns. In X. borealis CAPs are long (~50 ms), while X. laevis CAPs are brief (~5 ms). Vocal premotor neuron activity matched species-typical CAP durations: X. borealis neurons produced long spike bursts during each CAP, while X. laevis neurons generated only 1-2 spikes during each CAP. We also investigated the neural basis of distinct call periods. Extracellular recordings in the premotor nucleus revealed a slow wave of activity that corresponds to each call period, and this wave persists when the premotor nucleus is isolated from other vocal areas. Further, both X. laevis and X. borealis premotor neurons intrinsically produce oscillations that may correspond to call periods. In sum, these findings reveal that distinct premotor circuit properties underlie the evolution of divergent vocal behaviors.

124-5 BARKHOUSE, JM*; NEWBREY, JL; NEWBREY, MG; Columbus State University; *barkhouse_jessica@columbusstate.edu*

Laying-Sequence Variation in the Yolk Carotenoids of Eastern Bluebirds

We are studying laying-sequence variation in yolk carotenoids and egg metrics of Eastern Bluebirds (*Sialia sialis*) breeding in Columbus, Georgia, USA. Carotenoids are fat-soluble yellow, orange, and red pigments that are synthesized by plants, algae, and photosynthetic bacteria. These pigments play important roles in immunostimulation, antioxidation, free radical scavenging, sexual signaling, color vision, and embryonic development in birds. We are using high performance liquid chromatography to identify and quantify the carotenoids in Eastern Bluebird egg yolks. Eastern Bluebirds are a particularly interesting study species because no prior research has investigated laying-sequence variation in the yolk carotenoids of the species. We found that the yolks contained β-carotene, β-cryptoxanthin, astaxanthin, lutein, and zeaxanthin, with lutein being the most highly concentrated carotenoid. Contrary to results reported for other Eastern Bluebird populations, we did not detect any significant differences in in the mass, length, or width of the eggs across the laying-sequence. Preliminary results show that total carotenoid concentrations decline across the laying sequence, suggesting that Eastern Bluebirds use a brood reduction strategy in carotenoid allocation.

48-6 BARNES, DK*; ALLEN, JD; William & Mary; *dbarnes@email.wm.edu*

Predator-induced plasticity across echinoderm life history stages

Marine invertebrates frequently exhibit complex life cycles, including major life history transitions that coincide with habitat changes. In many marine invertebrates, adults live on the bottom of the ocean (the benthos), and broadcast spawn their gametes into the water column, where fertilization occurs and they begin life drifting in the water column as planktonic embryos and larvae, eventually metamorphosing into juveniles and returning to the benthos at settlement. Morphological phenotypic plasticity in response to environmental cues, may be especially important for organisms with complex life histories. As echinoderm larvae approach settlement, waterborne cues from the benthos may provide information about the future juvenile habitat, permitting expression of phenotypes that may improve post-metamorphic survival and performance. Larvae are known to detect and respond to the composition of the benthos when selecting settlement sites, but little is known about how benthic predator cues received by larvae affect juvenile phenotypes. We tested whether cues from a predator in a future habitat (the benthos) can be perceived by echinoderm larvae in their current habitat (the plankton) and modify juvenile phenotypes as they settle to the benthos. Larvae of *Dendraster excentricus* and *Strongylocentrotus droebachiensis* were exposed to predatory crab cues once juvenile rudiment formation began. *S. droebachiensis* exposed to crab cues as larvae had significantly more juvenile spines at settlement than those not exposed to the cue; however, there was no significant difference in spine length, disk area, or age at settlement. In contrast, *D. excentricus* larvae exhibited earlier settlement when introduced to a crab cue. These results suggest that planktonic larvae are capable of responding to benthic cues, but those responses may vary among species.

P3-83 BARREIRA, SN*; BAXEVANIS, AD; NIH, Bethesda, MD; *sofia.barreira@nih.gov*

Exploring the Role of Ribosomal Biogenesis in the Context of Regeneration

The process of regeneration depends on proper cell growth throughout numerous cycles of cell division that, in turn, depend on the timely and flawless assembly of ribosomes. *Hydractinia*, a colonial marine hydroid from the phylum Cnidaria, is a proven model for the study of regeneration, as their stem cells are both pluripotent and have homologs to human genes associated with self-renewal and differentiation. We have determined the consensus sequence of rDNA repeats in *Hydractinia*, with four times as many rDNA repeats in its genome than seen in humans. While the coding sequences for each ribosomal component are similarly organized and roughly the same size, its intergenic spacer is 100 times shorter than in human. This suggests that *Hydractinia* rDNA array(s) may be under the control of a single promoter, enabling it to meet the high demand for ribosomes during regeneration. Protein domain structural analyses indicates that *Hydractinia* does not possess the canonical UBF protein, a transcription factor that binds to rDNA and required for the recruitment of the Pol I transcription machinery during ribosome biogenesis. The absence of UBF suggests that *Hydractinia* may employ a different mechanism for regulating transcription of rDNA genes than that used by higher eukaryotes, perhaps providing important insight as to the regenerative capacity of this organism. A comparison of de novo assembled transcriptomes across a wide taxonomic range indicates the canonical UBF protein is not present in non-bilaterians, suggesting the involvement of a novel protein or UBF precursor. This systematic characterization of rDNA repeats and transcription factors using comparative genomic approaches has already provided important clues as to the mechanisms underlying regeneration, providing a strong foundation for developing new clinical approaches to improve human health.

P3-44 BARSOTTI, AMG; MADELAIRE, CB*; WAGENER, C; TITON JR , B; GOMES, FR; MEASEY, J; University of São Paulo, Northern Arizona University, Stellenbosch University, Stellenbosch University; *cmadelaire@yahoo.com.br*

Challenges of the invasion front: water balance, stress and immunity in the Guttural toad

Species introduced by human activities may comprise many ecosystems, however, some species may become invasive and rapidly expand their population size, indicating that these species have an adaptive capacity to new environments. In South Africa, the bufonid species *Sclerophrys gutturalis* was introduced in a periurban area with colder and drier climatic characteristics from those in which native populations occur. Our goal was to understand the adjustments made by this species in its new environment in terms of stress physiology and immunity. We assessed corticosterone (CORT), neutrophil:lymphocyte ratio (N:L), bacterial killing ability (BKA) and hematocrit (Htc) basal and after standardize stressors (dehydration and movement restriction), as well as body condition index (BCI) and field hydration level, in males from the native (Durban) and invasive population (Cape Town). Individuals from the native population presented higher basal BCI and BKA and lower N:L ratio. After the experiment, the native population presented higher BKA than the invasive population. Individuals from both populations showed increased CORT after dehydration. The results show that the native population presents higher immunocompetence and BCI, indicating a better conditions when compared to the invasive population. Dehydration represented stress for both populations, increasing CORT levels. Thus, our results corroborate that the BCI and dehydration level can generate major impacts on the physiological processes for this species.

2-8 BARTS, N*; GREENWAY, R; HENPITA, C; ARNDT, S; SHAW, J; KELLEY, J; TOBLER, M; Kansas State University, Oklahoma State University, University of Cambridge, Oklahoma State University , Washington State University; *barts2@ksu.edu*

Repeated mitochondrial evolution underlies adaptation to extreme environments

Extreme environments are characterized by harsh physiochemical stressors that push organisms to their physiological limits. Despite the challenges presented by these habitats, life can be found thriving in nearly every example of extreme environment. The question remains whether or not organisms inhabiting similar extreme conditions evolve in similar ways. To test for these, we investigated the mechanisms that facilitate adaptation to hydrogen-sulfide (H2S), a potent respiratory toxicant that directly interferes with mitochondrial function, in evolutionary independent lineages of poecilids, with special emphasis on populations of *Poecilia mexicana*. Analysis of gene expression across sulfide-tolerant and -intolerant poecilids shows that H2S tolerance is potentially mediated by convergent modification and expression of genes involved in H2S toxicity and detoxification. The primary pathways associated with H2S tolerance were oxidative phosphorylation (OxPhos) and H2S detoxificatiom initiated by the sulfide:quinone oxidoreductase (SQR) pathway. We assessed function of OxPhos enzymes and SQR in response to H2S in three lineages of *P. mexicana* and show that sulfide-tolerant populations maintain higher OxPhos activity and have higher SQR activity compared to sulfide-intolerant fish. We also found evidence for increased regulation of internal H2S concentrations in sulfide-tolerant fish. Together, these pathways appear to be responsible for the maintenance of mitochondrial respiration rates in sulfide fish even when H2S is present. Our results indicate that convergent adaptations in mitochondrial processes facilitate the colonization of extreme H2S-rich habitats.

P1-72 BARTS, N*; NIEVES, N; TROJAHN, S; KELLEY, J; TOBLER, M; Kansas State University, Washington State University, Washington State University; *barts2@ksu.edu*

Exaptation as a possible mechanism facilitating invasion of extreme environments

Extreme environments push organisms to their physiological limits, and recent literature is rich in studies investigating the mechanisms of adaptation that allow organisms to thrive in these habitats. However, little is known about why only some species are capable of initially colonizing these extreme conditions. A potential explanation for this phenomenon is exaptation, where the function of a trait with a particular function is co-opted for a new function given new conditions. Here we tested whether exaptation may have facilitated the colonization of H2S-rich habitats. H2S is lethal to most organisms, and streams rich in H2S are characterized by low biodiversity due to limited physiological tolerance. In contrast, the ancestral freshwater environments are rich in biodiversity. In Mexico, no physical barriers prevent movement between H2S-rich and freshwater springs. Interestingly, only some species of fish that inhabit ancestral freshwater habitats have successfully colonized H2S-rich springs, and the mechanisms that facilitate these events are unknown. We used a comparative approach to investigate the transcriptional responses upon H2S exposure in ancestral populations of species with a derived sulfidic population and species that lack an H2S-tolerant phenotype. We predict that ancestral populations of successful invaders will possess a higher H2S tolerance and plastically modulate gene expression upon exposure to H2S in a way that resembles gene expression patterns in derived H2S-adapted species. In contrast, species that have not successfully colonized sulfide springs are predicted to have lower H2S tolerance and mal-adapted gene expression responses. We are investigating the gene expression response of H2S exposure to elucidate possible exaptations that exist in species with derived sulfidic populations

45-7 BASS, AH; BASS, And; Cornell University, UC Bodega Marine Laboratory; *ahb3@cornell.edu*

Behavioral Timing: The Essential Role of Neurohormonal Mechanisms

Field studies of animals behaving in their natural habitat provide an essential context for framing questions related to the evolution of daily and seasonal changes in social behavior. How the timing of such events on multiple timescales ranging from milliseconds to hours is determined by neurohormonal mechanisms remains largely unexplored. Studies of circulating hormones, like those led by Rosemary Knapp, are a cornerstone of all such investigations. How might we use such foundational information to identify the contribution of cellular and molecular mechanisms determining this form of adult plasticity? This and related questions will be addressed largely by focusing on recent evidence from studies of one particular group of aquatic vertebrates commonly known as toadfishes that exhibit alternative reproductive tactics and depend upon acoustic communication for their reproductive success. Research support from NSF IOS-1656664 and 1457108.

117-1 BASTIAANS, E*; JAVALY, N; O'LOUGHLIN, C; MCCORMICK, L; WEGRZYN, P; SUNY Oneonta, Portland State University; *elizabeth.bastiaans@oneonta.edu*

Can I Buy You a Drink? The Effect of Male Hydration Status on Male Mating Behavior and Female Life History in Bean Beetles

Individuals are expected to alter their reproductive tactics in response to variation in available resources. The bean beetle, *Callosobruchus maculatus*, is an ideal model for understanding how variation in resource availability affects reproductive behavior. Adults typically do not eat or drink after pupation, but they will consume water if given the opportunity. Also, male bean beetles have barbed intromittent organs that harm females during mating. Despite this cost, female bean beetles often mate multiply, even when males are prevented from harassing them. Previous work suggested that females may derive hydration benefits from male ejaculate transferred during mating, because females given access to water mated less frequently than females not given access to water. We asked whether water access would also affect male mating behavior or the reproductive success of females mated to well-hydrated vs. dehydrated males. We tested whether males given access to water transferred larger ejaculates, copulated for longer periods of time, or exhibited a stronger preference for virgin female mates than males not given access to water. We also tested whether females mated to these two categories of males differed in post-mating lifespan, fecundity, or egg viability. We found that males were more likely to copulate with virgin female beetles than with non-virgins, although they copulated with non-virgin females for longer. Hydration status did not affect the strength of males' preference for virgins. Females mated to hydrated males did not live longer than females mated to dehydrated males, but they exhibited slightly higher fecundity and higher egg viability.

S10-3 BATTISTA, NA; The College of New Jersey; *battistn@tcnj.edu*
Fluid-structure interaction for the people!
Hearts, jellyfish, seagrass, and general squishy things all have something in common - they all involve fluid-structure interactions (FSI). FSI applications are numerous and vital in many fields across science and engineering. While there exist robust methods for investigating FSI, many necessitate the use of complex computer simulations. The knowledge of how to carry out out such simulations creates a barrier that has made this traditionally under-utilized and inaccessible by researchers, particularly students. *IB2d* ("I beg to differ") is open source software that was specifically designed to make FSI accessible to the scientific community and student researchers. During this talk, I will highlight some standard approaches in FSI across a variety of applications, including biomechanics and biomimetic devices.

S5-2 BAUER, U; University of Bristol; *ulrike.bauer@bristol.ac.uk*
Functional Surfaces of Insect-trapping Pitcher Plants
Pitcher plants do not just solve physical problems – they *use* physics to solve one of the most existential problems in nature: finding food. Every single part of their pitfall traps is adapted to make the most of gravity. Anti-adhesive wax crystals line the inside of the trap. The collar-shaped trap rim is decorated with an elaborate pattern of microscopic ridges, grooves and steps, and turns into a deadly slide for insects when it is wetted by rain or dew. In some species, even the roof-like pitcher lid is modified into a rain-powered springboard that catapults insects into the fluid-filled trap below. The diversity and high level of perfection of their anti-adhesive surfaces means that pitcher plants have become a model for biomechanical research and an inspiration for the development of biomimetic functional surfaces. This talk summarizes the current state of research and gives an outlook on open questions and future directions.

72-6 BAUMGART, SL*; CLAESSENS, LPA; University of Chicago, Maastricht University; *slbaumgart@uchicago.edu*
Avian sternum disparity and ecomorphological implications
The avian sternum anchors the main muscles powering flight and is highly disparate in morphology. For instance, some birds feature long, narrow sternal plates with deep keels, others have almost square sternal plates and shallow keels, and some have very reduced or non-existent keels. Little work has focused on the relationship between the complex sternum shape and a bird's ecomorphology. Here, we use automated three-dimensional (3D) geometric morphometrics (auto3dgm in Matlab) on a sample of 124 isolated avian sterna to examine relationships between sternal form and function. The R package Geomorph was used to run a General Procrustes Analysis and a Principle Component (PC) Analysis to examine the sternal plate disparity across Aves. In our results, PC1 ranges between a square sternal plate and a shallow keel (e.g., owls, grebes) and a long, narrow sternal plate with a deep keel (e.g., turkeys and doves). PC2 ranges between a posteroventrally-inclined leading edge of the sternal keel (e.g., owls, turkeys) and an anteroventrally-inclined leading edge of the sternal keel (e.g., gannets, loons). PC3 ranges between an angled posterolateral margin (e.g., tropicbird, hornbill) and a rounded posterolateral margin (e.g., loons, kakapo). A 3D plot of these PCs shows that phylogeny seems to be the predominant factor driving most of the clustering in the analyses. Owls group together, pheasants and turkeys group together, and ducks and geese group together. However, convergence is also evident; for example, a cluster with doves, macaws, and terns exhibits very deep keels extending the full length of an anteroposteriorly elongate sternal plate. These observations suggest that certain sternum morphologies can be used for multiple behaviors and habitats and that sternal shape is not driven by phylogenetic relationships alone.

P1-214 BAXTER, D*; FARINA, SC; FATH, MA; TYTELL, ED; DONATELLI, CM; Tufts University, Howard University, University of Ottawa; *dana.baxter@tufts.edu*
Evolution of notochordal foramina in actinopterygian fishes
Most fish species have a hole that passes through the center of each vertebrae, called the "notochordal foramen." Since the notochord passes through the foramen, its size and shape likely affects the mechanical properties of the fish vertebral column. In this study, we quantified the size and shape of the notochordal foramen and the overall vertebrae in 72 actinopterygian species. We used micro-computed tomography scans from oVert (openVertebrate) scans downloaded from Morphosource.org to measure the anterior and posterior angles of the vertebral cones, the diameters of the vertebrae, and the canal diameters and centrum lengths at the vertebrae that were located at equidistant points along the body length of each fish. In order to determine these points, we measured the standard length of each fish and and quantified these parameters for vertebrae spaced every 10% along the body. Mapping the morphological parameters to a recent actinopterygian phylogeny using fishtree and phytools R packages, we found that the notochordal foramen shows a pattern of decreasing diameter throughout the evolutionary history of teleosts. A few groups do not follow this pattern, because they have a larger notochordal foramen diameter than the ancestral state. These patterns indicate that the existence of a large notochordal foramen is an important trait in the locomotor biomechanics of some species that have convergently evolved and persisted, despite a general trend of reduction across actinopterygians.

55-2 BEATTY, AE*; SCHWARTZ, TS; Auburn University; *aeb0084@auburn.edu*

We need to talk...about IGF2: A cross-species comparison of IGF1 and IGF2 expression in amniotes.

The Insulin and Insulin-like Signaling (IIS) network regulates cellular processes including growth, reproduction, and longevity. The top regulators of signaling in this network are the paralogous hormones IGF1 and IGF2. In mice and rats, IGF2 expression is turned off soon after birth, while IGF1 remains on throughout life. However, this is different from the expression patterns in humans and recent studies in reptiles that demonstrate IGF2 expression continues through adulthood. The lack of postnatal IGF2 expression in lab rodents has led to the hormone's physiological effects and regulation of the IIS network during adulthood to be ignored. To test the extent to which IGF2 is expressed postnatally in amniotes, we quantify the gene expression of the IGF1 and IGF2 hormones across amniote lineages using two approaches. First we use quantitative PCR on liver cDNA at three life stages (embryonic, juvenile, and adulthood) to compare the expression of IGF1 and IGF2 across the lab reared house mouse, wild derived house mouse, wild deer mouse, zebra finch, house sparrow, eastern fence lizard, and brown anole lizard. Second, we mine adult liver transcriptomes for all amniotes that are publicly available in NCBI and quantify relative expression of IGF1 and IGF2. In contrast to the biomedical models, we find that IGF2 is expressed ubiquitously across adult sauropsids and in many mammals, often at a higher level than IGF1. These data provide a fundamental understanding of IGF2 expression patterns in amniotes and in doing so has identified a spotlighting effect bias due to the acceptance of knowledge from laboratory rodents as being the default. Further, we identify species that can be used to study the function of IGF2 across lifespan.

P1-260 BEBUS, SE*; JONES, BC; ANDERSON, RC; Florida State University, Tallahassee, FL, Florida Atlantic University, Davie, FL; *sarabebus@gmail.com*

Brood-parasitized nestlings have higher baseline corticosterone concentrations

Intraspecific brood parasites lay their eggs in the nests of other species for host parents to care for and raise. Adults or newly hatched young of many brood parasite species evict host eggs and/or nestlings from the nest. However, non-evicting brood parasites, such as the brown headed cowbird (*Molothrus ater*), are often raised alongside host nestlings. Biologists have long been fascinated by the evolutionary arms race between brood parasites and their hosts and the effects of brood parasitism on fitness. We know that parasitism reduces short- and long-term survival of host chicks and adults, particularly in small host species. However, there remain gaps in our knowledge concerning the proximate mechanisms that mediate host response to brood parasitism. Glucocorticoids (including the main avian glucocorticoid, corticosterone [CORT]) are released by activation of the hypothalamic-pituitary-adrenal axis in response to stress and mediate a number of nestling behaviors and metabolic processes. We examined circulating levels of baseline and stress-induced CORT levels in hooded warbler (*Setophaga citrina*) nestlings from brown headed cowbird parasitized and non-parasitized nests. Nestlings from parasitized nests had higher concentrations of baseline CORT compared to nestlings from non-parasitized nests. Parasitism did not affect stress-induced CORT levels. Elevated baseline CORT during development can interfere with growth, however, we found no difference in mass or tarsus length between nestlings from parasitized and non-parasitized nests. Our findings suggest that presence of or competition with cowbird nestlings is a stressor to host chicks. Further study is needed to determine if parasitized induced changes in CORT have downstream behavioral effects.

41-4 BECKER, DJ*; SCHULTZ, EM; ATWELL, JW; HALL, RJ; KETTERSON, ED; Indiana University, Wittenberg University, University of Georgia; *danbeck@iu.edu*

Urban residency, host immunity, and infectious disease dynamics in a traditionally migratory songbird

Human-induced changes to climate and habitat (e.g., urbanization) can facilitate traditionally migratory animals becoming year-round residents. As migration can be energetically expensive, shifts to sedentary behavior may minimize energy demands from long-distance movements and their immunosuppressive effects. Residency in urban habitats could further minimize energetic demands owing to abundant food resources and allow sedentary animals to invest more in immunity. To examine how recent shifts to residency affects physiology in ways that may shape disease dynamics, we analyzed leukocyte profiles of two dark-eyed junco (Junco hyemalis) populations in southern California: the Laguna Mountain population, which breeds in high-elevation forests and migrates altitudinally, and the urban San Diego population, which was likely established by overwintering migrants in the 1980s and has become non-migratory. Over a two-year study of each population's breeding season in 2006 and 2007, we found no difference in the ratios of heterophils to lymphocytes between populations, suggesting similar baseline glucocorticoid levels. However, urban residents had higher total leukocytes than migrants, together suggesting minimal differences in energetic demands between populations. However, urban residency may confer immunological benefits through abundant anthropogenic resources. To explore the epidemiological consequences of such benefits, we outline a susceptible–infected–latent–infected modeling framework that couples migrant–resident interactions and their respective annual cycles. By varying the strength by which urban habitats modify host resistance and competence of residents, alongside migration-induced relapse, we show how these individual-level changes can scale up to shape population-level infection dynamics.

48-4 BEDGOOD, SA*; BRACKEN, MES; University of California Irvine; *sbedgood@uci.edu*

Making it Big and Losing Friends: Algal Symbiont Contributions are Shaped by Sea Anemone Life History

The stability of nutrient exchange in a mutualistic symbiosis is highly dependent on the availability of resources to both partners, and interactions between partners can shape niche partitioning among holobionts. Symbiotic sea anemones on California rocky shores obtain nitrogen and carbon from prey that they capture, but a large portion of their dietary carbon comes from contributions by symbiotic dinoflagellate algae in the family Symbiodiniaceae. We hypothesize that life history traits including allometry, surface-area-to-volume ratios, and reproductive strategies affect the potential for contributions from the algal symbionts. Our approach includes both observational and experimental studies of three congeneric sea anemone species. *Anthopleura xanthogrammica* is the largest species, *A. sola* is smaller, and *A. elegantissima* is the smallest, reproducing asexually to create large clonal mats. We designed an in situ experiment where the diets of sea anemones were manipulated by either adding or removing prey daily for three weeks. Tissue samples of sea anemone, algal symbiont, and common prey items were collected from the experiment and from an adjacent site for carbon and nitrogen stable isotope analysis. The $\delta^{15}N$ values suggest that the diets of sea anemone species are different even though the anemones are found in the same habitat. The $\delta^{13}C$ values are similar between *A. sola* and *A. xanthogrammica* but both are different from *A. elegantissima* values. We found that $\delta^{13}C$ values of *A. elegantissima* anemone tissue and associated algal symbionts closely match while *A. sola* and *A. xanthogrammica* anemone tissue and algal symbiont $\delta^{13}C$ do not match. This suggests that *A. elegantissima* relies mostly on algal symbiont contributions for its dietary carbon intake while *A. sola* and *A. xanthogrammica* receive a larger portion of their dietary carbon from heterotrophic feeding.

31-5 BEDWELL, H*; ABBOTT, E; BALOGH, A; KOLODZIEJ, G; HEJMADI, P; DIAZ, L; HUYNH, K; MA, J; MATZ, M; KENKEL, C; University of Texas at Austin, Austin, Texas, Atlantic Oceanographic and Meteorological Laboratories, NOAA, Miami, Florida, University of Southern California, Los Angeles, CA; *hbedwell@utexas.edu*

Hurricane-driven asexual reproduction in massive boulder corals in the Florida Keys

Despite being capable of both sexual and asexual reprouction, the major-reef builders in the Florida Keys have low to non-existent sexual recruitment rates. It is unknown how populations of these key species are being maintained. Focusing on the *Orbicella* genus, we hypothesize that coral populations are being maintained by storm-driven asexual reproduction: when a coral fragment breaks from the parent colony and grows into the reef to become its own individual colony, provided that is survives. While studies have been done on *Acropora* spp., no studies to date have investigated (1) whether hurricanes can cause boulder species to fragment, and (2) if so, whether such fragments can survive. To address these questions, we individually mapped and collected tissue samples from every coral and coral fragment along three 10-m transects at both an inshore and an offshore reef site in the Lower Florida Keys six weeks after Hurricane Irma made landfall. To identify species and assess clonality, DNA was extracted from 432 samples and genotyped using reduced representation 2b-RAD sequencing. The transects were resurveyed and resampled six and twelve months after the storm. The storm did result in substantial coral fragmentation: we identified storm-generated fragments of 8 different species, of which two boulder species, *Orbicella annularis* and *O. faveolata*, were the dominant fragmented species. We were able to genetically assign many of these fragments to parental colonies. Preliminary results show that hurricanes can fragment boulder corals, and poor water quality post-Hurricane Irma did not result in immediate fragment mortality.

P2-247 BEDWELL, H*; BAY, L; FULLER, Z; PRZEWORSKI, M; MATZ, M; University of Texas at Austin, Austin, Texas, Australian Institute of Marine Science, Columbia University, New York City, NY, Columbia University, New York City, NY; *hbedwell@utexas.edu*

Mitochondrial introgression and its role in coral thermal tolerance

Increasingly frequent thermal stress events are causing strong selection for higher thermal tolerance in corals. While most studies have focused on thermal tolerance associated with the coral's symbiotic algae, a recent study shows the larval thermal tolerance of *Acropora millepora* depends on maternal background, suggesting mitochondrial (mt) variation might also play an important role in coral thermal tolerance. To assess mt variation, 225 individuals were sampled throughout the mid-range of the Great Barrier Reef (GBR). DNA was extracted and individuals were genotyped using whole-genome resequencing. There are two mt haplotypes, and mt genome alignments of 12 acroporid species suggests one of the haplotypes is introgressed from another species. Both mt haplotypes are found at high frequencies in populations across the mid-GBR. However, it is unclear whether mt haplotype frequencies correspond with local thermal regimes, as samples do not span the entire 3°C thermal range of the GBR. To assess whether there are mitonuclear interactions associated with the haplotypes, larvae were obtained by crossing *A. millepora* adults with different mt haplotypes, thus crosses share the same nuclear background, but differ in their mitochondria. For each cross, ~2,000 larvae were reared at 28°C, as a control, and at 36°C, as a heat selection treatment. DNA samples were taken when only 25% of the larvae remained in the 36°C heat selection treatment. The survivors of the heat selection treatment and the unselected larval pools were sequenced, and bulk genotyped using 2b-RAD. If the two mt haplotypes result in different genomic loci responding to heat selection, this suggests mitonuclear interactions play a role in coral thermal tolerance.

85-3 BEERY, SM*; OLSON, RA; MONTUELLE, SJ; WILLIAMS, SH; Ohio University, Ohio University Heritage College of Osteopathic Medicine, Ohio University Heritage College of Osteopathic Medicine; *sb633118@ohio.edu*

Effect of food properties on molar occlusion during chewing in pigs

A fundamental component of mammalian feeding is mastication, involving occlusion of postcanine teeth to finely break down food into smaller particles. The dynamics of occlusion have primarily been inferred from surface features of the teeth, including occlusal topography and wear patterns. Recently, however, X-Ray Reconstruction of Moving Morphology (XROMM) provides the visualizing and measurement resolution necessary to characterize the dynamics of occlusion during chewing. Here, we use XROMM to investigate the effect of two food properties, stiffness and toughness, on molar occlusion during rhythmic chewing in pigs. Four pigs were fed size standardized pieces of apple (low toughness and low stiffness), carrot (high toughness and low stiffness), and almond (high toughness and high stiffness). We compared the duration of the occlusal period as well as the translations in the buccolingual, mesiodistal, and ventral-dorsal planes of individual cusps. Mixed effects modeling with repeated measures on individuals demonstrated that toughness and stiffness differentially impact occlusal dynamics. Increasing food toughness results in longer tooth-food-tooth or tooth-tooth contact during chewing, but there was no change associated with increased food stiffness. Translations of the first molar were observed in the mesiodistal plane across foods of different toughness while buccolingual displacements were different among foods of different stiffness. These results may reflect that low toughness foods require less tooth-food-tooth contact to facilitate bolus creation, whereas foods of different stiffness impact other measures of the gape cycle (i.e., translations).

21-4 BEHBAHANI, AH*; RAK, AK; SKUTT-KAKARIA, KJ; DICKINSON, MH; California Institute of Technology; *amirhb@caltech.edu*

Flies Remember Multiple Food Locations in the Absence of External Cues

The fruit fly, *Drosophila*, has an extensive repertoire of behaviors generated by a brain with only 100,000 neurons, which suggests remarkably low computational complexity. One essential behavior is foraging, which is complicated by the fact that food is variable in quality and patchy in distribution. One strategy that flies use to adapt to patchy and variable food environments is to execute a local search once they initially find food. During this local search, flies exhibit path integration; that is, they keep an internal memory of the location of the initial food patch. Path integration is arguably one of the most sophisticated tasks performed during locomotion and is thought to depend on the function of the Central Complex (CX), a set of unpaired nuclei in the core of the insect brain. Our lab recently showed that local search can be induced by an optogenetic stimulus in lieu of actual food. Using this paradigm, we can make flies perform local search in a constrained arena, such as a narrow circular channel. Using this fictive food within this simplified, one dimensional arena, we studied whether flies remember more than one food location. When we presented one or two fictive food sites, we found that fly's search behavior is biased toward food locations it previously encountered. We propose that when multiple foods are present, flies use the specific spacing of the food sites to update their search range to include all the food sites they have experienced. As the fly cannot see and must rely on an internal representation of distance, these experiments help provide compelling evidence of how spatial distributions may be encoded in the insect brain and future studies will be critical in determining whether the CX is involved in these functions.

P1-130 BENEDICT, C*; WOOD, P; GRISMER, L; OAKS, J; Auburn University, La Sierra University; *cab0109@auburn.edu*
Phylogenetic Placement of Burmese Tree Frogs in the genus Polypedates (Gravenhorst, 1829)
Amphibians of Southeast Asia have been shown to have high levels of cryptic diversity and the region offers a unique biogeographical area to study widespread divergent lineages. The Asian Rhacophoridae genus Polypedates has presented an ongoing and notorious systematic challenge. High levels of adaptation to local environments, phenotypic plasticity, and morphological diversity have led herpetologists to divide Polypedates into six distinct clades. Previous studies have few to no samples from Myanmar. We incorporate 60 Burmese samples to the dataset and focus specifically on the Sunda clade. We analyze the mitochondrial gene 16S rDNA and investigate the phylogenetic placement of previously unsampled Myanmar in the greater phylogeny of Polypedates.

22-4 BENSKY, MK*; BELL, AM; University of Illinois Urbana-Champaign; *bensky2@illinois.edu*
The evolution of cognition and behavior during a natural biological invasion
Species invasions provide an opportunity to study how traits evolve as organisms move into novel environments. The invasion process might act as a filter either via nonrandom dispersal and/or selection, thereby leading to phenotypic differences between the invading and source populations. Here we test the hypothesis that behavior and cognition facilitate the invasion process by comparing natural variation in behavior among genetically-differentiated populations of threespined stickleback that were reared in a common garden. Specifically, we compared sticklebacks from two populations from the ancestral source marine environment to sticklebacks from four freshwater lakes that differ in time since establishment. If increased neophilia and inhibitory control are beneficial for colonizing new environments, and thus evolve over the course of a biological invasion, then we predicted that derived freshwater populations would be more neophilic and exhibit higher levels of inhibitory control (i.e. more likely to abandon a behavior pattern that is no longer effective) compared to sticklebacks from the ancestral source population. We observed substantial variation in both traits among populations, and found support for our hypothesis: well-established freshwater populations were more neophilic and had higher inhibitory control than marine fish. Differences between very recently derived freshwater populations suggest that these differences can evolve rapidly, though nonrandom dispersal cannot be excluded as a potential explanation. These findings are consistent with the hypothesis that cognitive traits have played an important role in allowing stickleback to successfully colonize freshwater habitats, and that these traits have evolved during the invasion process.

56-8 BENSON, BE; AICHELMAN, HE; BAUMANN, JH; NIEVES, OC; STANIZZI, DA; CASTILLO, KD; DAVIES, SW*; Boston University, UNC CH, UNC CH; *daviessw@gmail.com*
Diel thermal variation supports growth and symbiosis in a reef-building coral
Rising sea surface temperatures pose the greatest threat to corals and lead to coral bleaching. Predictions about the likelihood of coral bleaching typically consider the duration and magnitude of elevated temperatures relative to a locally defined threshold. However, recent work suggests that heterogeneity in observed bleaching patterns may be better explained by the degree of diel thermal variation (DTV) experienced on a reef. Here, we sourced colonies of the reef-building coral *Siderastrea siderea* from six sites across the Bocas del Toro archipelago, which ranged in mean DTV (~2-4 °C). We conducted a 50-day common garden experiment to assess the influence of low, moderate, and high DTV (2, 3, and 4 °C, respectively) on growth and performance of *S. siderea* and then performed a two-week thermal challenge followed by a two-week recovery. Results suggest that corals sourced from higher DTV sites outperformed corals from less variable sites, regardless of treatment. In addition, experimental DTV had a positive influence on corals, with high DTV leading to increased growth and corals experiencing moderate DTV maintained higher symbiont densities after recovery. Analyses of baseline and post-recovery physiological traits as well as baseline algal and microbiome community compositions are ongoing. These analyses will shed light on how corals from higher DTV environments are able to maintain higher growth rates and how DTV modulates coral stress and ultimate recovery. Overall, our data support the hypothesis that DTV on the coral's native reef and in husbandry conditions plays a central role in growth and symbiosis of reef-building corals, highlighting the need to consider DTV when evaluating the resilience of corals to global change.

BERN-1 BENTLEY , GE; UC Berkeley; *gb7@berkeley.edu*
A Bird's Eye View of Reproductive Endocrinology
Puberty and reproduction are critical for the survival of all vertebrate species. Despite a long history of research, we still do not fully understand mechanisms underlying how puberty is initiated. Nor do we know why some wild animals will not breed in captivity even if sexual maturity has been reached. Some seasonally-breeding animals undergo transitions in reproduction that are akin to puberty and reverse puberty every year. Comparative studies have thus allowed us to delve mechanistically into questions of reproductive activation and inhibition. In this lecture, I will provide an overview of how studies on avian reproduction have informed us about the neuroendocrinological mechanisms underlying puberty, seasonal transitions in reproduction and associated behaviors, and reproductive inhibition. I will highlight questions that remain and avenues for future exploration.

P3-80 BENTLEY, V/L*; MYKLES, D/L; Department of Biology, Colorado State University, Fort Collins, CO; *Vanessa.Bentley@colostate.edu*

Investigating the function of Krüppel homolog 1 (Kr-h1) on molt regulation in Gecarcinus lateralis

The exoskeleton of arthropods must be shed for growth and development. In insects, the antagonistic signaling pathways between juvenile hormone (JH) and ecdysone regulate molting and metamorphosis. However, gene regulation of molting in crustaceans is not well understood. In insects, Krüppel homolog-1 (Kr-h1), a zinc finger transcription factor, is strongly induced by JH via the Met-SRC complex (methoprene tolerant-steroid receptor coactivator). When Kr-h1 directly binds to the promoter region of steroidogenic enzymes, methylation occurs thereby inhibiting ecdysone biosynthesis in the prothoracic gland (PG). As for crustaceans, Kr-h1 is involved in vitellogenesis in *Portunus tritubulus* and early development in *Daphnia pulex* while lacking JH responsiveness. As JH synthesis and ecdysteroidogenic genes are expressed in the crustacean molting gland (Y-organ), we hypothesize that Kr-h1 may act in the Y-organ analogous to that in the PG. In *G. lateralis* molting can be either induced by multiple leg autonomy (MLA) or eyestalk ablation (ESA), which removes the source of molt-inhibiting hormone (MIH). By using transcriptomic data of MLA and ESA *G. lateralis* individuals, Kr-h1 homologs were identified: two gene products were obtained from the MLA transcriptome and one gene product from the ESA transcriptome. The deduced proteins all had the seven zinc finger repeats that are characteristic of insect Kr-h1 who have eight repeats. Quanitative PCR will be used to quantify the effects of MLA and ESA on Kr-h1 mRNA levels in the Y-organ. Supported by NSF (IOS-1257732).

18-3 BENTZ, AB*; GEORGE, EM; WOLF, SE; RUSCH, DB; BUECHLEIN, A; ROSVALL, KA; Indiana University; *bentza@iu.edu*

Immediate and lasting neurogenomic responses to competition in a free-living songbird: an experimental manipulation of a dynamic social environment

Periods of social instability can elicit pronounced changes in behavior and adaptive re-allocation of resources to promote success in future competition. However, the molecular mechanisms underlying this phenotypic plasticity are unclear in the natural and dynamic social environments faced by free-living animals. Here, we experimentally generated intense social instability for a wild, cavity-nesting female songbird (tree swallows, *Tachycineta bicolor*). We reduced nest box availability after initial settlement, generating heightened competition; 24hr later, we returned boxes, causing aggressive interactions to subside. We collected females during the peak of competition and after it had ended, along with date-matched controls. We measured transcriptomic responses in two behaviorally relevant brain regions, the hypothalamus and ventromedial telencephalon. Gene set enrichment and network analyses suggest processes related to energy mobilization were upregulated during and after competition, while sensory perception and hormone processing were not upregulated until after competition had ended. Immune-related gene regulation was more complex, with lymphocyte processes downregulated during competition and antigen presentation upregulated after competition. Our data also hint at epigenetic mechanisms that may mediate the lasting effects of competition. By experimentally manipulating competition in the wild, these data collectively show how natural social instability causes shifts in gene expression that may facilitate the demands of competition at the expense of self-maintenance. Further, some of these effects persist after competition has ended, suggesting individuals may be "primed” for success in future social instability.

P3-99 BENTZ, EJ*; MASON, RT; Oregon State University; *bentze@science.oregonstate.edu*

Characterizing the Function of the Harderian Gland and its Interactions with the Vomeronasal Organ in the Red-sided Garter Snake

The Harderian gland is a large cephalic gland present in most groups of terrestrial vertebrates. Although this gland has been the focus of numerous studies for over 300 years, its physiological function has remained largely unresolved. In the red-sided garter snake (*Thamnophis sirtalis parietalis*), the Harderian gland appears to be an integral component of the vomeronasal chemosensory system both by facilitating the detection of non-volatile chemical signals and as a component of the extracellular immune system. The Harderian gland of *T. s. parietalis* secretes its contents solely into the lumen of the vomeronasal organ and exhibits sexually dimorphic seasonal structural changes coinciding with a mutually exclusive shift in behavior from spring mating to summer feeding. Using an integrated approach employing high throughout RNA-sequencing paired with protein mass-spectrometry, we examined the functional characteristics of the Harderian gland transcriptome as well as identified and functionally characterized the proteins present in vomeronasal secretions to describe a sexually dimorphic and seasonally variable role of this tissue. The Harderian gland showed high expression of genes associated with lipid-binding proteins those involved in the extracellular immune system. Proteins identified in the fluid of the vomeronasal organ showed an abundance of lipid-binding proteins and extracellular immune proteins. Antimicrobial properties of vomeronasal secretions were demonstrated via in-vitro bacterial killing assays. A protein of particular interest was identified as a lipid-binding protein of the lipocalin family and a likely candidate for a putative pheromone-binding protein facilitating the detection of female sexual attractiveness pheromone.

P3-172 BERGER, CA*; TARRANT, AM; Woods Hole Oceanographic Institution, MA; *cberger@whoi.edu*

Can the cnidarian circadian clock entrain to temperature cycles?

Circadian clocks allow organisms to anticipate and respond to periodic fluctuations in their environment. In order to synchronize to local conditions, clocks must integrate information from multiple cues such as light and temperature. *Nematostella vectensis*, the starlet sea anemone, exhibits circadian locomotory behavior and gene expression both in the field and in response to artificial light-dark cycles. Clocks are known to robustly entrain to daily temperature cycles in crustaceans and insects as well as ectothermic vertebrates, and this ability also exists in non-metazoan eukaryotes. However, thermal entrainment has not been well-studied in cnidarians or other non-arthropod invertebrates. We have designed a system to control temperature and conduct behavioral assays, allowing us to answer whether cnidarians, which belong to an evolutionarily early-branching group of animals, also exhibit robust thermal entrainment under constant light conditions. In insects and vertebrates, light and temperature activate overlapping yet distinct molecular pathways, but the photosensitive and thermosensitive elements of the cnidarian clock have not been identified. Gene expression analysis over daily temperature cycles will identify candidate genes whose expression differs between these two sensory modalities. Dissecting the behavioral effects and molecular components of different sensory pathways in an early-diverging metazoan will allow us to better understand the evolution of the metazoan clock.

S8-6 BERGMANN, P.J.*; MANN, S.D.W.; MORINAGA, G.; FREITAS, E.S.; SILER, C.D.; Clark University, Oklahoma State University, University of Oklahoma; *pbergmann@clarku.edu*

Convergent evolution of vertebral morphology and locomotion in snake-like lizards

Snake-like body forms have evolved convergently dozens of times in most major lineages of vertebrates. Despite studies of various clades with snake-like species, we still lack an understanding of their evolutionary dynamics and distribution on the vertebrate tree of life. We also do not know whether this convergence in body form coincides with convergence at other biological levels. Here, we present the first vertebrate-wide analysis of how many times snake-like forms have evolved, as well as rates of its evolution and reversion to a non-snake-like form. We then focus on five examples of snake-like form evolution in squamates and test if they are convergent in vertebral number and shape, as well as their surface locomotor performance and kinematics. We do this by comparing each snake-like species to closely related tetrapodal species and determining whether the direction of vertebral or locomotor change matched in each case. The five lineages examined are obscure, rare species that live in remote locations, providing a valuable glimpse into their biology. They are the skink lizards *Brachymeles lukbani, Lerista praepedita,* and *Isopachys anguinoides*, the basal squamate *Dibamus novaeguineae*, and the basal snake *Malayotyphlops cf. ruficaudus*. Our results support convergence among these species in the number of trunk and caudal vertebrae, and in vertebral aspect ratios, but not relative vertebrae length. We also find that the snake-like species are relatively slower than their limbed counterparts, with the exception of *Malayotyphlops*, and move with lower frequency and higher amplitude body undulations. This is among the first evidence of locomotor convergence across distantly related, snake-like species.

52-6 BERLOW, M*; PHILLIPS, JN; DERRYBERRY, EP; University of Tennessee, Knoxville, California Polytechnic State University; *mae.berlow@gmail.com*

Effects of Urbanization and Landscape on Wild Avian Gut Microbiomes

The rapid effects of human land development present relatively recent and stark changes in the environment. Recent work in birds and humans suggests that urbanization may affect the composition of animal gut microbiomes. Factors driving observed differences between urban and rural gut microbiomes are unknown, but may include diet, geography, and/or pollution. To better understand these effects, we investigated the relationship between urbanization and the gut bacterial community of white-crowned sparrow populations in the San Francisco Bay area. We addressed three questions: 1) Which aspects of a bird's environment influence their gut bacterial community? 2) Which host morphological characteristics best explain gut bacterial community? 3) Are these morphological characteristics mediating the relationship between host environment and gut bacterial community? We also assessed the effects of urbanization by examining the taxonomic composition of gut bacterial communities in birds across habitats. We find direct effects of environmental factors, including urban noise levels and territory land cover, as well as indirect effects through body size and condition, on alpha and beta diversity of gut microbial communities. Elucidating these effects provides a better understanding of how urbanization affects wild avian physiology.

P1-127 BERLOW, M*; KOHL, KD; DERRYBERRY, EP; University of Tennessee, Knoxville, University of Pittsburgh; *mae.berlow@gmail.com*

Can't Kill a Bird Twice: Evaluating Non-Lethal Sampling of Avian Gut Bacteria

Gut microbial communities play critical roles in the biological functions of their host, such as mediating nutrient absorption, digesting food components the host cannot, and offering protection against enteric pathogens. Extensive research on gut microbial communities has been conducted on mammals, including humans and rodents, but much less work has been done in birds. Furthermore, much of the research on host-microbe interactions make use of fecal samples and rectal swabs as a proxy for intestinal samples, which can be difficult to obtain directly. However, little is known regarding overlap between the microbial communities of the gut, feces, and swabs, which limits interpretability of results based on swabs and fecal samples. To address this gap in knowledge, we compared the microbiota from five sample types – proventriculus, small intestines, large intestines, cloacal swabs, and feces – across individual Zebra Finches (Taeniopygia guttata) housed in constant conditions with a standardized diet. We compared diversity and community composition through 16S rRNA sequencing. Our results show that microbial communities from both cloacal swabs and feces were distinct from proventriculus and small intestinal samples, but indistinguishable from large intestinal samples, indicating that these non-lethal samples may be useful proxies for large intestinal communities. Additionally, cloacal swabs were better than fecal samples in capturing individual variation, suggesting cloacal swabs may be particularly useful in experiments with a repeated measures design. Gaining insight into noninvasive sampling techniques for passerines has implications for studies of gut microbial diversity and abundance in wild bird populations. Further, reliable non-lethal sampling is necessary for experiments where repeated sampling is required.

P1-212 BERNING, D/J*; POWERS, A/K; GROSS, J/B; University of Cincinnati, Harvard Medical School; *berninde@gmail.com*

Convergent and Constructive Craniofacial Trait Evolution in Three Cave-Dwelling Populations of Astyanax Mexicanus

The Mexican tetra, *Astyanax mexicanus*, has evolved a number of regressive (pigmentation and eye loss) and constructive (enhanced lateral line and gustatory systems) phenotypes. Craniofacial anomalies, such as bone fragmentation and cranial bending, however escape simple classification. Prior work demonstrated that cavefish have more superficial neuromasts (SN) atop their fragmented facial bones, and this trait may facilitate certain cavefish behaviors facilitating food finding (e.g., vibration attraction). To understand how sensory and skeletal traits may interact with one another, we co-analyzed a number of phenotypes in surface fish and three cavefish populations, including: degree of fragmentation, third suborbital bone (SO3) size, severity of bend, eye orbit diameter, sixth suborbital bone (SO6) presence, and superficial neuromast (SN) and canal neuromast (CN) numbers. We found that fragmentation severity varied, with Pachón fish having the most elements followed by Tinaja and Chica. Fragmentation increased the surface area (SA) and volume (V) of the SO3. All cave populations had more SNs and higher SN density compared to the surface morph. CN number and placement was symmetric in surface fish, but varied greatly in all three cave populations. The presence of a ninth CN was perfectly associated with presence of the SO6 bone. Further, individuals lacking an SO6 had a smaller eye orbit. Compared to highly symmetric surface fish, Pachón and Tinaja cavefish exhibited a leftward dorso-cranial bend, while Chica cavefish exhibited moderate bends without a directional bias. This study represents the first comprehensive co-analysis of the sensory and skeletal systems in *Astyanax mexicanus*, and illustrates how craniofacial anomalies and sensory enhancement may interact to enable adaptation in the extreme cave environment.

109-1 BERTUCCI, EM*; PARROTT, BB; University of Georgia, Athens, GA; *emily.bertucci@uga.edu*
Characterization of the Age-Related DNA Methylome and Development of an Epigenetic Age Predictor in Medaka (Oryzias latipes)
Age specific patterning of DNA methylation ("epigenetic aging") is the single best marker of biological age as it is strongly correlated with chronological age, the onset of age-related disease, and all-cause mortality. Epigenetic age predictors use loci specific changes in the status of DNA methylation across the genome to predict chronological age with astonishing accuracy. Discrepancies between chronological and epigenetic or "biological" age can be used to explore the molecular underpinnings that determine different aging trajectories. Further, important life history characteristics such as the onset of reproductive maturity and senescence are associated with epigenetic age, suggesting that accelerated epigenetic aging may have implications on the timing of ecologically important life history events. We aimed to identify and describe the age-related DNA methylome and develop an epigenetic clock for a model fish species, medaka (*Oryzias latipes*), using reduced representation bisulfite sequencing of 2-, 6-, and 12-month old animals. Our findings suggest that a substantial portion of methylation changes correlate with chronological age, with a greater proportion of change occurring early in life relative to late. Using just 39 of these age-associated loci, we have developed a model that is highly predictive of chronological age (cor = 0.9495) and provides the ability to assess biological age acceleration in the response to environmental factors. Here, we present preliminary tests for age acceleration and provide a characterization of the age-related loci which demonstrates the genomic distribution and functional associations of the age-related methylome. Our results contribute towards ongoing research attempting to elucidate the functional role of DNA methylation in aging.

P2-52 BEYL, AR*; SMAERS, JB; GIGNAC, PM; WATANABE, A; WILBERG, EW; TURNER, AH; Stony Brook University, NY, Oklahoma State University Center for Health Sciences, Tulsa, New York Institute of Technology College of Osteopathic Medicine, Old Westbury; *alexander.beyl@stonybrook.edu*
Evolutionary Regime Shifts in Crocodylian Neuroanatomy
Paleoneurology bolsters our understanding of brain evolution through deep time. Archosauria, represented today by birds and crocodylians, has long been of interest to paleoneurologists. Croc-line archosaurs, despite low modern diversity, have potential for investigating brain evolution due to their numerous ecological transitions, extensive fossil record, and robust systematics. To analyze braincase endocast variation and probe for a connection between neuromorphology and ecology, we combined high-density 3D geometric morphometric data from crocodylian braincase endocasts with phylogenetic comparative methods to identify regime shifts in an OU framework. Our dataset contains 22 endocasts of 16 extant and six extinct species. Landmarks were sampled from four brain regions: cerebrum, optic lobe, cerebellum, and medulla. Each brain region was found to form a distinct module and were analyzed separately. Regime configuration hypotheses, including ecologically-based snout shape and habitat preference, were identified and tested for the whole brain and each brain region. For the cerebrum, optic lobe, and cerebellum, the best fitting regime hypotheses recovered a shift at crown-group Crocodylia or Neosuchia. For the whole brain and medulla, a shift was found in the crown, between crocodyloids and alligatoroids. This suggests the medulla is driving overall brain shape. Finally, ecological regime hypotheses varied in their fit for brain regions, suggesting regions vary in their response to ecology. Future work is needed to elucidate primary drivers of shifts within the crocodylian brain.

P1-64 BHAVE, RS*; REEDY, AM; WITTMAN, T; COX, RM; University of Virginia, Charlottesville; *rsb7bz@virginia.edu*
Copulatory transfer of fluorescent powder suggests sexual selection for larger males in a wild lizard population
Understanding pre-copulatory sexual selection in a wild population is often hindered by our ability to document copulations in real time. While studies often demonstrate that large males sire more offspring, higher mating success is inferred indirectly or often assumed, with few empirical tests demonstrating the same. In this study, we used fluorescent powders to assess mating rates for different size classes of males in a wild population of the sexually-dimorphic brown anole, *Anolis sagrei* . We captured nearly all males from a closed island population and powdered them around the cloacal region with one of four unique fluorescent colors, corresponding to non-overlapping size classes. We then, released these males on the island and captured adult females after a span of two days. We noted the presence as well as color of any powder on the cloaca and dorsum of the females, indicating copulation with males of that size class. We found that copulation rates were twice as high late in the breeding season (July, 52.86%) compared to earlier in the season (May, 25.54%). Overall, 2% of females were found to have mated multiple times, as inferred from multiple colors on the same individual. Across seasons, large males had significantly higher number of copulations (57.6%) compared to small males (42.3%). Additionally, females that mated were significantly larger than those that did not. Our study provides direct evidence for pre-copulatory sexual selection on larger body size in males. Future studies will focus on assessing if large males also sire more offspring.

S3-9 BHULLAR, B.-A.S.*; MANAFZADEH, A.R.; MIYAMAE, J.A.; HOFFMAN, E.A.; BRAINERD, E.L.; MUSINSKY, C.; CROMPTON, A.W.; Yale University, Brown U niversity, American Museum of Natural History, Brown University, Harvard University; *bhart-anjan.bhullar@yale.edu*
The origin of chewing in mammals required rolling of the jaw and involved broad continuity in molar form and function
Recently, we used a combination of 3D x-ray reconstruction of moving morphology (XROMM) and comparative analysis of fossil and extant anatomy to argue that the unique mammalian food processing system originally required independent rolling of unfused hemimandibles. Moreover, the original function of the therian tribosphenic molar was to grind food in a reverse mortar-and-pestle arrangement by which the talonid "mortar" moved transversely across the protocone "pestle." This transverse motion was enacted primarily by long-axis jaw rotation. Primitive therian mammals including opossums (Monodelphis domestica) retain the ancestral mode of chewing, including the mortar-and-pestle rotational grinding stroke. Here we consider the experimental and comparative data further and show that jaw roll is broadly conserved across mammals, and that the rotational grinding stroke can be inferred to have been present at the therian ancestor -- probably, in fact, well down the therian stem. Fusion of the jaw symphysis has occurred repeatedly in omnivorous and herbivorous therian clades and is associated with low-crowned teeth and grinding by transverse motion of the mandible. It is also associated with reduction of the angular process, which we argue serves to provide greater leverage for jaw-rolling musculature. Finally, we suggest that there is greater continuity in molar structure and function on the stem of Theria than has previously been appreciated.

59-4 BIERLICH, KC*; DALE, JD; FRIEDLAENDER, AS; GOLDBOGEN, JA; JOHNSTON, DJ; Duke University, University of California, Santa Cruz, Stanford University; *kcb43@duke.edu*

Dwarf minke whales along the Antarctic Peninsula: Evidence of climate migration or historic misidentification?

The global distribution of dwarf minke whales (*Balaenoptera acutorostra subspecies*) is poorly understood, but it appears they tend to occupy low latitude waters off the coasts of Brazil, South Africa, and Australia, and occasionally in the South Indian Ocean. In March 2019, we encountered dwarf minke whales (n = 5) along the South Shetland Islands (SSI), identified post-encounter through unoccupied aerial system (UAS) photogrammetry and resulting morphological and phenotypical comparison between Antarctic minke whales around the Western Antarctic Peninsula (WAP) (n = 40). The only published study documenting dwarf minke whales along the WAP and SSI includes 11 sightings from 2007-2010, suggesting they are rare and only recently encountered in this region. One possible explanation for the paucity of sightings in this region is a southward range expansion concurrent with regional warming and ecosystem forcing that has facilitated southward range expansions of other sub-Antarctic species. This hypothesis is supported by ongoing changes in the distribution and abundance of myctophid fishes, an important prey item of dwarf minke whales. Alternatively, they may have always been present along the WAP and SSI, but have been misidentified as Antarctic minke whales, as these two species are difficult to distinguish from one another, especially from boat-based surveys. UAS photogrammetry provides opportunity to view these animals in high-resolution to distinguish subtle differences in morphology and phenotype. This study quantifies phenotypic differences between dwarf and Antarctic minke whales, and compares them to other Southern Hemisphere populations, setting a foundation to effectively test these two competing hypotheses related to southward range expansions or historic misidentification.

26-3 BILAK, JD*; WHILES, MR; MILANOVICH, JR; BYSTRIANSKY, JS; WARNE, RW; Southern Illinois University, Carbondale, IL; Daniel P. Haerther Center for Conservation and Research, Shedd Aquarium, Chicago, IL.; *bilak@siu.edu*

Understanding the physiological mechanisms causing seasonal movement changes in common mudpuppies.

The common mudpuppy (Necturus maculosus) was once common in temperature lakes of North America, however, very little is known of their current population status or basic natural history, including seasonal movements. Intriguingly, these ectotherms appear to exhibit inverse seasonal activity patterns, increasing activity during the winter months. The physiological and ecological factors determining these patterns are poorly understood. While metabolic adaptations likely play a role, we suspect reproductive and foraging ecology are also central determinants of these seasonal activity patterns. In collaboration with the Shedd Aquarium veterinary staff, we implanted radio-telemetry transmitters in 27 mudpuppies between March and December 2017, at Wolf Lake in Chicago, IL. Mudpuppies were located every ~16 days from April 2017 – July 2018. Farthest movements were correlated with water temperature increases during March 2017 – December 2017, but not during December 2017 – July 2018. In addition to seasonal movements, we measured water-borne reproductive hormone metabolites and temperature dependent metabolism in captive animals. Increased encounters (captures and sightings) during colder temperatures may indicate mate searching or higher energy demands in preparation for ovulation and egg laying, as mudpuppies breed in late fall to early spring. Higher activity in the winter may be linked to increased catchability of fish or decreased seasonal predation. Temperature dependent metabolism suggests adaptations related to winter reproduction or foraging. Increasing our understanding of the mechanisms underlying seasonal movements and habitat selection of this distinctive salamander will facilitate conservation efforts in a changing climate.

P3-193 BILBREY, CM*; OLENSKI, M; DIRIENZO, N; DORNHAUS, A; University of Arizona, Tucson, 1995; *cbilbrey@email.arizona.edu*

Serotonin Reduces Aggression in Black Widow Spiders

Behavior varies amongst all individuals. Neurotransmitters are chemical messengers that can affect physiological functions such as heart rate, sleep, and mood. Serotonin is a type of neurotransmitter that, in humans, contributes to well-being and happiness. In *Latrodectus hesperus*, black widow spider, the levels of neurotransmitters have been shown to correlate with their behavior. To better understand if these chemical messengers are the cause of differences in behavior, manipulation of their levels are needed. How will serotonin injections affect aggressiveness in black widow spiders? 60 spiders were used in the experiment and randomly assigned to a treatment group. Treatment groups consisted of CO_2 administration, saline injection after CO_2 administration, and a serotonin and saline mixed injection after CO_2 administration. Each spider was placed onto their web and an aggression assay was performed after 2 hours, 24 hours, and 48 hours. Aggressiveness was measured by the number of times each spider attacked a vibrator placed on the web. The experiment was given twice. Results show that spiders injected with the serotonin/saline solution after CO_2 administration attacked significantly less than the other treatment groups. Higher levels of serotonin will decrease aggressive behavior.

89-3 BILLAH, MM*; RAHMAN, MS; University of Texas Rio Grande Valley; *mohammad.billah01@utrgv.edu*

Detection and Enumeration of Bacterial Pathogens in the American Oyster, Crassostrea virginica

American oyster (*Crassostrea virginica*) is a popular sea food for its delicacy and high nutritional value. Based on increasing concern about bacterial pathogen contamination in shellfish, our research objectives have been focused on detection, enumeration and comparison of two important microbial pathogens, *Escherichia coli* and *Salmonella* spp. proliferation in the American oyster in south Texas waters and controlled laboratory studies. Immunohistochemical analysis showed substantial bacterial pathogen's presence in gill and digestive glands in oysters collected from San Martin Lake (SML) compared to South Padre Island (SPI). Extrapallial fluid (EPF, an important body fluid) glucose levels, pH, and protein concentrations were significantly higher in oysters collected from SML compared to SPI. Laboratory studies showed increasing trend of bacterial pathogens with elevated temperatures (28 and 32°C) compared to control (24°C). EPF pH and protein concentrations were increased, however, EPF glucose levels were decreased with higher temperatures compared to control. Collectively, immunohistochemical analysis together with EPF pH, glucose levels, and protein concentrations results suggest that American oyster is prone to water-borne pathogen contamination in south Texas waters and increasing global temperature induces pathogen proliferation as well.

83-1 BILOTTA, F*; LEE, M; DANOS, N; University of San Diego; *ndanos@sandiego.edu*

Pregnancy-induced changes to muscle-tendon morphology and function

Live bearing is a defining feature of all eutherian mammals. In order to accommodate the fetus, the female body undergoes radical hormonal, morphological and mechanical changes. Yet, we know very little about the effects of pregnancy on skeletal muscle-tendon units and the whole organism. We used the gastrocnemius muscle of rats as a model system to examine the organ and whole animal level effects of pregnancy, by comparing animals that had never been pregnant, primiparous animals near the end of pregnancy, and postpartum animals. We found that muscle mass did not change significantly with pregnancy, even though pregnant animals were approximately 30% heavier than non-pregnant ones. However, in postpartum animals muscle mass was reduced by 22%. Muscle fiber size did not vary among conditions but postpartum animals were the only ones with muscle fibers larger than 0.20 mm^2. We predicted that muscle vascularization would increase with pregnancy due to the action of the hormone relaxin. Preliminary histological data support our prediction. Since relaxin is also an antifibrotic agent, we predicted that it would affect the mechanical properties of collagenous tissues associated with muscle. The stiffness of the proximal aponeurosis of the lateral gastrocnemius, as measured by the tangent slope at strain=0.13, did not vary by condition. Interestingly, there was high variation in all conditions. All females tended to have lower Achilles tendon stiffness than males, although this was not statistically significant. However, tendon stiffness had surprisingly low variability in the postpartum animals that was highly significant ($P< 0.001$). Ongoing videographic analysis in our laboratory is characterizing the gait of animals as they perform a demanding task (20% incline) to examine the effects of pregnancy on the whole body.

P2-158 BILYK, KT*; SFORMO, T; Western Kentucky University, Department of Wildlife Management, North Slope Borough and Institute of Arctic Biology, University of Alaska Fairbanks; *kevin.bilyk@wku.edu*

Heat Tolerance of North Slope Fishes

Arctic waters are home to a highly cold-adapted ichthyofauna. As these fishes have evolved for life in the cold, understanding their resilience to the expected rising water temperatures from global climate change is of increasing importance. Past work looking at heat tolerance has focused on only a few high-latitude northern species, and as a result it is unknown whether the diverse collection of nearshore, estuarine, and freshwater arctic and boreal fishes show a consistent reduction in heat tolerance. We began work to investigate the heat tolerance of this broader arctic ichthyofaunal by studying heat tolerance among key members of the fish fauna of Utqiaġvik (formally Barrow), Alaska. Situated on the Arctic coast, Utqiaġvik provides access to fishes that span the key ecological divisions of arctic waters. Organismal heat tolerance was measured for six species of local fishes using the critical thermal maximum methodology. This work aimed to put heat tolerance of these fishes into the context of previously studied polar, temperate, and tropical fishes, as well as the level of thermal variability seen in local waters. We found that these near shore fishes show high organismal heat tolerance, similar to what has been reported for a number of cold-temperate fishes. This high level of heat tolerance may reflect continued selective pressure on fishes inhabiting shallow coastal waters, as water temperatures rose above 11°C during our investigation. While generally heat tolerant, there was a notable split between species with lower tolerance such as least cisco and broad whitefish more commonly associated with freshwater habitats as compared to fourhorn sculpin and arctic flounder more commonly associated with brackish to marine habitats.

S11-11 BINGMAN, V P; Bowling Green State University, Ohio; *vbingma@bgsu.edu*

Avian Spatial Navigation and the Hippocampus: Can Diversity in Behavioral Mechanisms Guide Searches for a Genetics of Cognition?

Among the various forms of vertebrate cognition, spatial cognition and navigation appear universally dependent on the hippocampus of all tetrapods and possibly teleost fish as well. Co-occurring with this general uniformity are differences in the hippocampal-dependent representation of space among vertebrate groups that presumably reflect adaptive variation. Yet surprisingly, little is known about how variation in the organization and function of the hippocampus in different vertebrate groups can be explained by genetic variation. Here patterns of developmental gene expression may be informative. Independent of the hippocampus, there has been some success in identifying genetic correlates of the specialized migratory, but not navigational, behavior of birds and electroreception in elasmobranchs; findings that have some implication for understanding genetic influences on varying spatial abilities. Nonetheless, these examples are remote from cognition and one has to wonder if the search for genetic correlates of varying spatial cognitive abilities in animals can overcome experimental obstacles, not the least of which is obtaining the sufficiently large subject pools needed to detect the certain small effect sizes of single genes.

99-4 BIONDI, AA*; AMPLO, HE; CRAWFORD, CH; BEMIS, KE; FLAMMANG, BE; New Jersey Institute of Technology, Virginia Institute of Marine Science; *aab53@njit.edu*

Adventures in scaling and remodeled morphology: the case of the Ocean Sunfish

Mola mola (Ocean Sunfish; Tetraodontiformes: Molidae) are recognizable by their distinct morphological characteristics, including large lobate dorsal and anal fins which fuse to form a clavus in place of a non-existent caudal fin. Adult mola lack axial musculature, but by synchronous flapping of the dorsal and anal fins they are able to dive to depths of 600 meters and cruise at a speed of 3.2 km/h. Larval mola more closely resemble sister species of pufferfish, but early in ontogeny undergo rapid morphological changes. Previous work examined some of the skeletal changes in mola ontogeny using cleared and stained specimens, with particular focus on the formation of the clavus, however, no studies to date have looked at the myological changes that occur as a result of the body shape and skeletal transformations that take place. Using computed microtomography (microCT) scanning, we were able to produce high-resolution three-dimensional skeletons of three stages of mola fry and an adult mola for ontogenetic comparison. Phosphotungstic acid (PTA) staining and re-scanning of mola fry generated images of soft tissue morphology, allowing us to compare muscle volume, position, and fiber angle through ontogeny with measurements from dissections of adult mola. Herein we discuss the functional implications of drastic morphological modeling and changes in body size during ontogeny on the locomotor performance of *Mola mola*.

124-1 BIRCH, S*; PLACHETZKI, D; University of New Hampshire, Durham; *sjb1061@wildcats.unh.edu*

Investigating Sensory Integration and Settlement Responses to Sensory Stimuli in the Hydrozoan Ectopleura crocea

Community dynamics in benthic marine ecosystems are largely driven by larval settlement, which relies on larvae selecting suitable environments based on the integration of sensory cues. However, the sensory modalities that most affect larval settlement decisions are poorly understood in most systems. The benthic marine hydroid *Ectopleura crocea* has an indirect lifecycle that produces a motile larval stage called actinula. While researchers have previously investigated the biology of settlement in actinulae, no study has combined sensory behavior experiments with genomics studies. Here we examine the settlement response of actinula to different light and chemical environments in conjunction with a developmental transcriptome study investigating sensory gene expression. We hypothesize that larval settlement will be most influenced by the combination of biofilm-derived chemical cues and light cues, and that actinula will differentially express taste and chemoreceptors during stages where larvae are competent to settle. We test these hypotheses by combining RNA-seq on various stages of actinula development, from actinula through metamorphosis, with settlement experiments under different sensory conditions. Additionally, we use confocal microscopy at various developmental stages to explore the development of the neural network and its capabilities of sensory integration. Ultimately, our investigations of actinula larva at the molecular level will provide insights into the sensory modalities that influence the settlement decision.

35-2 BIRLENBACH, DM*; KELLER, JS; FOX, DL; University of Minnesota, University of New Mexico; *birle001@umn.edu*

Morphological Similarity in the Dentition of Competing and Non-Competing Rodents

One of the most fundamental species interactions is competition. However, in the fossil record competition cannot be observed or experimentally tested. Instead, paleoecological studies rely on morphological similarity to infer niche overlap. For mammals, similarity in dental morphology is used to argue for overlapping dietary niches and evidence of competition. Here, we test if competitor dentitions are more similar than those of non-competing species. To address this, we collected 535 shape descriptors and ratios of micro-CT scanned lower dentitions of 151 extant rodent species. We compared the differences in the scores of topographic variables used to infer diet, e.g. Dirichlet Normal Energy, Relief Index, and Orientation Patch Count, between 56 competitive species pairs drawn from the literature as well as between species not identified as competitors. We found that competitors are statistically closer in their morphology than non-competitors from the same dietary categories. A subset of the descriptors was then summarized using a principal component analysis. The distance was then determined between each species pair in a principal component morphospace that explained 90% of the variation and on average competitors exhibit significantly closer dental morphology than non-competitors. For 122 species, the morphospace distances were compared to Jaccard Indices (JI) calculated for the overlap in geographic ranges using NatureServe range maps for each species pairing to see if morphological similarity relates to geographic similarity. We found that morphological similarity and JI were poorly correlated suggesting geographic similarity is not well explained by morphological similarity. Our findings support the notion that competitors are more similar morphologically than non-competitors.

P1-179 BLACK, CR*; ARMBRUSTER, JW; Auburn University; *coriblack@auburn.edu*

Shape Variation of Armored Catfishes in a Phylogenomic and Ecological Context Using 3D Geometric Morphometric Techniques (Loricariidae)

Loricariidae is the most species-rich family in the order of Siluriformes, with nearly 1000 species in 100 genera. Commonly known as the suckermouth armored catfishes, the Neotropical family is known for their unique traits that include ossified dermal plates that cover the body, integumentary teeth known as odontodes on the plates and fin spines, and a ventral oral disk used in feeding and to adhere to objects in their habitats. Found throughout Costa Rica, Panama, and tropical to subtropical South America, loricariids can be found in all types of freshwater habitats, from rapid Andean rivers to quiet estuaries. The loss of three cranial biomechanical linkages has been correlated with an increase in morphological diversity resulting in an array of shapes that vary from dorsoventrally flattened to deep bodied. Comparisons of morphological and molecular phylogenetic trees indicate that there is rampant morphological convergence which is explored in this study through the analysis of body shape using 3D geometric morphometric analyses in a phylogenomic and ecological context. In the R package stereomorph, 33 landmarks that represent key anatomical features were rendered into three-dimensional space for 46 species across the family. Shape variation was summarized through a principal component analysis and the most recent genomic phylogeny was trimmed and overlaid onto the PCA. To test the correlation between ecological traits and shape, a phylogenetic ANOVA, Procrustes ANOVA, and SURFACE analysis were performed. Lastly, ecological ancestral states were inferred and mapped to the morphospace.

36-2 BLACKBURN, DC*; NIELSEN, SV; BAREJ, M; RöDEL, MO; University of Florida, Gainesville, Museum für Naturkunde, Berlin, Museum für Naturkunde, Berlin; *dblackburn@flmnh.ufl.edu*

Systematics and Biogeography of the African Slippery Frogs (genus Conraua), Including the World's Largest Living Frog

The African slippery frogs (genus *Conraua*) contain the largest extant species of frog, *C. goliath*, which can reach 32 cm in length and weigh more than >2.5 kg. The six described species have an unusual disjunct distribution across equatorial Africa, with two species (*C. alleni*, *C. derooi*) in western Africa, three (*C. crassipes*, *C. goliath*, *C. robusta*) in the Lower Guinean Atlantic Forests, and one (*C. beccarii*) in the highlands of Ethiopia and Eritrea. These species typically live in fast moving streams, and four are considered threatened, in part due to human consumption. The biology, evolution, and biogeography of these species remains poorly studied. Using a well-sampled multi-locus dataset, we generate a robust phylogenetic hypothesis for the recognized species that provides insights into the historical biogeography and evolution of body size in this genus. We also find evidence suggesting that populations within the two most widespread species (*C. alleni*, *C. crassipes*) likely represent distinct species requiring description.

P3-127 BLACKSHARE, TW*; FORD, MP; GARAYEV, K; MURPHY, DW; SANTHANAKRISHNAN, A; Oklahoma State University, University of South Florida, University of South Florida; *askrish@okstate.edu*

Metachronal, synchronous, and hybrid stroke patterns in aquatic paddling locomotion

Metachronal paddling is a form of locomotion common in pelagic crustaceans such as krill, in which a series of swimming appendages are stroked in an oscillatory pattern, each appendage with a phase lag compared to the neighboring appendage. In contrast, benthic crustaceans such as mantis shrimp spend most of their time on the seafloor, and perform a hybrid paddling stroke when startled that consists of a metachronal power stroke, followed by a nearly synchronous recovery stroke. We developed a dynamically scaled, self-propelling robotic paddling model, which was programmed to perform three types of idealized paddling strokes (uniformly metachronal, synchronous, hybrid with uniformly metachronal power stroke and synchronous recovery stroke), and a realistic stroke profile tracked from videos of freely swimming peacock mantis shrimp (*O. Scyllarus*). Using this robotic model, we evaluated the forward swimming performance of these different paddling strategies by measuring thrust, swimming speed, and acceleration generated by each stroke pattern. When stroke amplitude and appendage tip velocity during power stroke are unchanged between idealized stroke patterns, the uniformly metachronal pattern had the highest performance values in each evaluation category, followed by the hybrid pattern, with synchronous paddling showing the lowest values in each category. However, the use of hybrid kinematics allows for the possibility of increasing stroke amplitude, allowing the appendages to sweep longer arcs during power stroke. The effect of increasing stroke amplitude on forward swimming performance of these stroke patterns will be presented.

P3-101 BLEKE, CA*; FRENCH, SS; ROBERTS, SB; GESE, EM; Utah State University, Idaho Department of Fish and Game, USDA-National Wildlife Research Center; *bleke.cole@gmail.com*

Natural variations in fecal steroid hormones across pregnancy and population

We are investigating factors impacting pronghorn antelope (*Antilocapra americana*) population growth rates and fawn:doe ratios by conducting non-invasive fecal sampling from adult females. Fecal sampling was used to investigate reproductive physiology, physiological stress, diet, and nutrition, across habitat types, as they relate to subsequent fawn:doe ratios. We conducted validations for using fecal hormone metabolites to assess pregnancy rates, which has not previously been done for pronghorn. For validations, we collected fecals from two classes of female pronghorn, visibly pregnant and yearling, during late third trimester when pregnancy can be visually-diagnosed. Assay validations were performed to determine appropriate hormone concentrations, assay precision, and potential non-specific binding. From this work, we validated hormone concentrations that equate to pregnant versus nonpregnant individuals, calculated a pregnancy rate within each population and across the species in Idaho, and performed a hormone degradation study of female reproductive hormones to test the duration they remain viable in feces. Overall, this research will add to the growing body of literature utilizing non-invasive sampling techniques to monitor free-ranging wildlife populations. Specifically, we will elucidate factors that may be limiting pronghorn populations, provide insight on the physiological measures influencing pronghorn productivity, and provide parameters useful for population modelling

71-7 BLOOMSTON, NA*; PRATHER, JF; University of Wyoming; *nstill1@uwyo.edu*

Neural Circuits Underlying Decision Making

Decision making is a cognitive process in which an individual extracts information from sensory input and uses that to select one behavioral outcome from among many alternatives. To understand the neural basis of decision making, we turn to songbirds. Females evaluate the quality of male songs and use that information to select their mate. Females perform behavioral indicators of mate choice (copulation solicitation displays, CSD) in response to their mate's song played through a speaker, even if no male is physically present. Lesion studies have implicated the caudal nidopallium (NC) and caudal mesopallium (CM) in female song evaluation and mate preference, as altering activity in either site results in a change in female mate choice (Lawley and Prather, in preparation). Pathway tracing studies have revealed that the primary cortical recipient of output from CM is NC. CM also projects to dopaminergic pathways implicated in behavioral motivation, and to motor pathways through which activity may generate behavioral indicators of mate preference such as calls and CSD's (Dunning et al. 2018). Here, I expand on those studies to investigate projections through which NC may also influence activity of downstream targets. Preliminary results indicate that NC projects primarily to the same dopaminergic area as CM. These results indicate that these auditory cortical areas converge onto dopaminergic neurons implicated in motivation and reward, revealing a pathway that could play a key role in sensorimotor integration and decision making. These results will be discussed in light of additional experiments in which we are using optogenetics to understand how activity in individual pathways is related to specific aspects of song evaluation and mate choice.

15-2 BLUMSTEIN, MB*; RICHARDSON, AR; WESTON, D; ZHANG, J; WELLINGTON, M; HOPKINS, R; Harvard University, Cambridge, Northern Arizona University, Flagstaff, Oak Ridge National Laboratory, Oak Ridge, Oak Ridge National Laboratory, Oak Ridge; *blumstein@fas.harvard.edu*

A new perspective on ecological prediction reveals limits to climate adaptation in a temperate tree species

Forests absorb a large fraction of anthropogenic CO2 emissions, but their ability to continue to act as a sink under climate change depends on plant species undergoing rapid adaptation. Thus, considering the evolution of intraspecific trait variation is necessary for reliable, long-term species projections. We combine ecophysiology and predictive climate modeling with analyses of genomic variation to determine if sugar and starch storage, energy reserves for trees under extreme conditions, can evolve within populations of black cottonwood (*Populus trichocarpa*). Despite current patterns of local adaptation, and extensive range-wide heritable variation in storage, adaptive evolution in response to climate change will be limited by both a lack of heritable variation within northern populations and by a need for extreme genetic changes in southern populations. Our method has implications for species management interventions and highlights the power of using genomic tools in ecological prediction to determine the ability of a species to respond to future climates.

8-6 BO, TB*; TREVELLINE, BK; CABEZAS RUIZ, S; MORRISSEY, C; MARCHANT, TA; ENG, ML; LATTA, SC; KOHL, KD; Univ. of Pittsburgh, Univ. of Saskatchewan, Univ. of Saskatchewan, National Aviary; *botingbei@126.com*

Glucocorticoid Stress Hormones Affect the Gut Microbiota of Captive Birds

Stress exposure affects many aspects of host physiology, and increases in glucocorticoid stress hormones may affect the gut microbiota. Previous studies have shown connections between stress hormones and the gut microbiome, but have only used correlation in the wild or single treatments of stress hormones. Here, we tested whether the gut microbiome responds to the stress hormone corticosterone (CORT) in a dose-dependent manner. Twenty captive European Starlings were randomly divided into four groups (n = 5): Control group (Con, placebo), low-level CORT group (LC, 0.25mg), middle-level CORT group (MC, 1.5mg), high-level CORT group (HC, 7.5mg). Feces were collected before implantation, and 2, 7, 21, 27 days after implantation to understand the temporal changes associated with stress hormones. CORT implantation changed the composition and structure of gut microbiota in birds. We found that birds implanted with the low-level concentration of CORT had increased alpha diversity at the 2 and 7 day (ASV richness and Shannon index). Birds in HC groups exhibited the most distinct microbial communities compared to their starting point, though this effect disappeared within 21 days (unweighted and weighted UniFrac distances). At the phylum level, CORT treatment caused an increase in the abundance of Firmicutes and decrease in Cyanobacteria. These changes were temporary, as the abundances of bacteria partially recovered. Our findings clearly demonstrate a close link between glucocorticoid levels and gut microbiota in captive birds. Furthermore, we demonstrate that the gut microbiome responds to CORT in a dose-dependent manner, and so variation in environmental stress may have variable effects on the gut microbiome in natural populations.

7-2 BOCK, SL*; LOWERS, RH; RAINWATER, TR; HALE, MD; LERI, FM; PARROTT, BB; Univ. of Georgia, Kennedy Space Center, Clemson Univ., Univ. of Virginia; *samantha.bock@uga.edu*

Real-time responses to ecologically-relevant thermal fluctuations during temperature-dependent sex determination in the American alligator

An organism's ability to integrate transient environmental cues experienced during development into molecular and physiological responses forms the basis for adaptive shifts in phenotypic trajectories. During temperature-dependent sex determination (TSD), thermal cues during discrete periods of development coordinate molecular changes that ultimately establish sexual fates and contribute to patterns of inter- and intrasexual variation. How these mechanisms interface with the dynamic thermal environments in nature remains largely unknown. For example, ~70% of American alligator nests exhibit both male- and female-promoting temperatures during the thermosensitive period, often within the span of a daily thermal fluctuation. Here, we investigate how these opposing environmental cues are integrated into sexually dimorphic transcriptional programs across fine temporal scales. Alligator embryos were exposed to fluctuating temperatures based on empirically-derived nest thermal profiles and sampled over the course of a daily thermal fluctuation. Post-transcriptional alternative splicing of epigenetic modifier genes operating upstream in the sex-determining cascade respond rapidly to thermal fluctuations, whereas transcriptional changes of downstream effector genes occur on a delayed timescale. Together our findings reveal how the basic mechanisms of TSD operate in an ecologically relevant context and suggest a hierarchical model in which temperature-sensitive alternative splicing incrementally influences the epigenetic landscape to affect the transcriptional activity of key sex-determining genes.

69-7 BOERSMA, J*; JONES, JA; KARUBIAN, J; SCHWABL, H; Washington State University, Tulane University; *jordan.boersma@gmail.com*

Sex-specific causes and consequences of variable testosterone circulation in a tropical songbird

There is considerable debate about whether testosterone regulates traits similarly in male and female vertebrates. Meta-analyses of the relationship between male and female circulating testosterone have produced conflicting results, highlighting the need for empirical studies in species that exhibit variation in both male and female testosterone and the traits this hormone is known to mediate. The White-shouldered fairywren (Malurus alboscapulatus) demonstrates considerable subspecies-specific variation in testosterone circulation, behavior, and female ornamentation. Testosterone circulation in females appears to be linked to discreet female phenotypes: females from the subspecies with greater ornamentation and aggression circulated higher baseline testosterone, and unornamented females implanted with testosterone produced a major component of ornamental plumage and became more aggressive once the putative signal was acquired. Interestingly, males exhibited opposite patterns in baseline testosterone, as males from the unornamented female subspecies circulated the highest mean testosterone. Our findings challenge the idea that testosterone circulation is correlated and has similar function between sexes. We also present preliminary results from a long-term dataset quantifying variation in testosterone, social networks, and male sexual displays. We address how the social environment influences a suite of functionally linked traits and explore the causes and consequences of variable testosterone circulation between sexes.

P2-188 BOGACKI, EC*; RINGENWALD, BE; STARK, AY; Villanova University; *ebogacki@villanova.edu*

Stick and Run: Locomotor Behavior of Tokay Geckos on Wet and Dry Substrates

Tokay geckos (*Gekko gecko*) have been a focal point for adhesion research for the past several decades; studied intensively due to the remarkable capabilities of their adhesive toe pads. Although tokay geckos adhere strongly to many smooth, dry, synthetic surfaces, previous research has found that their sticking ability is greatly reduced when in contact with wet substrates that more closely mimic the wet, natural surfaces found in their environment. Adhesive performance on wet substrates varies, however, in the way that adhesion is maintained on wet hydrophobic substrates but not wet hydrophilic substrates. Interestingly, geckos show no significant difference in running speed across wet or dry hydrophobic and hydrophilic surfaces. Data even suggest sprint velocity increases on wet surfaces. To investigate the discrepancy between clinging and running performance on wet substrates, we quantified locomotor differences (i.e., number and length of stops and sprinting bursts, speed of sprinting bursts) of geckos running on wet hydrophobic and wet hydrophilic substrates. We predicted that stops on wet substrates are followed by faster burst speeds than stops made on dry substrates, and that geckos stop less frequently and for shorter periods of time on wet hydrophilic substrates than wet hydrophobic substrates. The results of this study will allow us to better understand how tokay geckos navigate their natural environment and perhaps alter their locomotor behavior based on substrate and adhesive conditions.

P3-23 BOGANTES, V.E*; WAITS, D.S; HALANYCH, K.M; Auburn University; *vikbogantes79@gmail.com*

Toxin diversity across the annelid tree of life

Annelida is a diverse phylum that includes earthworms, leeches, and many marine worms, and currently comprises approximately 20,000 species described with a variety of different lifestyles. Within annelids, some groups are known to produce toxins as a defense mechanism against predators and parasites or for prey capture. Although previous studies have focused only in a few groups because of pharmaceutical or insecticides uses (for example hematophagous leeches, and nereis toxin for insecticides), some recent studies in glycerids, amphinomids, and phyllodocids have shown that our understanding of toxin diversity and evolution in annelids is largely unknown. To study toxin diversity, 296 annelid transcriptomes from 91 families were analyzed (66 were retrieved from SRA) by sequence similarity using BLASTp against the SWISSPROT database. To identify putative toxin genes, BLAST reports were manually searched for hits to sequences previously identified by SWISSPROT as toxins or venoms. Preliminary analyses recovered 363 toxin-like genes for 288 out of the 296 transcriptomes, with most of the transcriptomes without toxin hits belonging to sipunculan species. The resulting hits were grouped into gene classes based on the SWISSPROT annotation of toxin genes with the most common including metalloproteinase M12, kunitz, peptidase S1, phospolypase B (PLB), and fibrinogen C terminal domain-like classes. PLB transcripts have been previously reported in amphinomid and glycerid annelid, but are best known from hymenopterans and snakes. Interestingly, homologs of PLB were present in 80% of the transcriptomes, thus our results suggest that genes associated with PLB are common among annelids. Additionally, homology searches using HMMER and Pfam databases are being conducted for cross validation of current results. Individual toxin families will be selected for phylogenetic analyses.

13-6 BOGGS, CL; University of South Carolina & Rocky Mountain Biological Lab; *cboggs@seoe.sc.edu*

Trans-generational Ecological Determinants of Egg Composition in the Butterfly Speyeria mormonia

Environmental conditions may affect offspring quality and quantity, which are important fitness components. Here I ask, what are the effects of variable environments on egg composition (offspring quality) in a holometabolous insect species? Using *Speyeria mormonia* (Lepidoptera: Nymphalidae), I focus on triglycerides, which as a group are important energy stores and cryoprotectants for overwintering larvae, which in this species do not feed before entering diapause. Using data from both the field and the lab, I show that triglycerides in eggs increase with the temperature under which the eggs were matured, as well as with larval rearing temperature for the mothers. Neither the larval nor adult food availability to the mother significantly affected the investment of triglycerides in her eggs. However, there was a non-linear trans-generational effect of adult food availability on investment: a female's investment was highest if her own mother experienced intermediate food availability. Any resulting selection pressures will be blunted by the fact that the population as a whole experiences the same conditions, which should lead to smaller effects on relative fitness than on absolute fitness. Nonetheless, which triglycerides are altered, their effects on absolute fitness, and the impacts on the butterfly's life history and population dynamics remain to be explored.

106-4 BOGGS, TE*; FRIEDMAN, JS; GROSS, JB; University of Cincinnati; *boggste@mail.uc.edu*

Parallel adaptation to hypoxia in the blind Mexican cavefish, Astyanax mexicanus.

Hypoxia is an important environmental pressure that likely drives novel adaptive solutions. To cope with this extreme condition, animals often evolve low-oxygen tolerance, or improve oxygen retrieval from their habitat. The blind Mexican cavefish, *Astyanax mexicanus*, inhabits an expansive cave network within the Sierra de El Abra region of northeastern Mexico. The caves in this system are geographically isolated from one another, and demonstrate variably low levels of dissolved oxygen within the subterranean pools. These cavefish, alongside extant ‘ancestral' surface morphs, enable powerful comparisons to determine how they thrive under hypoxic conditions. We evaluated hypoxia-tolerance in multiple, independent cave populations at the protein, cellular and genetic levels. We discovered that phylogenetically older populations display higher tolerance to hypoxia compared to phylogenetically younger (and hybrid) populations. These differences include alterations in hemoglobin concentration, as well as higher expression of a cohort of hemoglobin genes. This work provides insight to the genetic changes mediated hypoxia tolerance in blind cavefish, and showcases the diverse genetic and cellular strategies of adaptation among independent cavefish populations of the Sierra de El Abra.

29-5 BOLMIN, O*; ALLEYNE, M; WISSA, AA; University of Illinois at Urbana-Champaign; *obolmin2@illinois.edu*

How does Morphology Affect Jumping Kinematics of Click Beetles?

When unconstrained and from an inverted position, click beetles (Coleoptera:Elateridae) fold their body extremely rapidly to propel themselves into the air. This unique legless jumping mechanism is enabled by a thoracic hinge and is power amplified. The jump is divided into three stages: the pre-jump (energy storage), the take-off and the airborne stage (energy release). In this presentation, we answer the following questions: what are the dominant kinematic and the external morphological parameters driving the jump, how are they correlated and what is their respective contribution to the jump performance? The morphological measurements of 88 specimens from 13 genera, namely *Aeolus mellilus, Agriotes sp., Alaus myops, Alaus oculatus, Athous sp., Ampedus linteus, Ampedus nigricollis, Hemicrepidius sp., Lacon Marmoratus, Limonius sp., Melanactes sp., Melanotus sp., Parallelosthetus attenuatus*, of various sizes and shapes (body length varying from 2 to 35 mm) were taken. The take-off and airborne stages of the jumps of 54 specimens from 11 of these genera were recorded using high-speed video imaging. All videos were post-processed using ProAnalyst and Matlab software to derive kinematic jumping parameters of each specimen. From the morphological measurements, we show isometric scaling across species. Kinematic parameters such as the take-off velocity, acceleration and angle as well as morphological measurements such as the body length, mass, and elytra curvature for each specimen are used to compare the jump performance within and across species.

P3-238 BONFOEY, AM*; PADDA, SS; STAHLSCHMIDT, ZR; U Pacific; *a_bonfoey@u.pacific.edu*
Effects of Spatiotemporal Variation in Temperature and Water Availability on a Riparian Insect Community
Terrestrial life is constrained by temperature and water availability, which vary across space and time. Permanent water sources (e.g., rivers or lakes) buffer environmental temperatures and allow terrestrial animals to access water in the absence of sufficient precipitation. Yet, biologists lack a thorough understanding of the independent and interactive effects of spatiotemporal variation in temperature and water availability on riparian communities. Therefore, we explored these dynamics in an insect community in a hot-summer Mediterranean climate. At our study site in Stockton, CA, total precipitation varied between 0 and 235 mm for the driest and wettest seasons, respectively, and mean ground temperature varied between 7°C and 34°C for the coolest and warmest study periods, respectively. In each season, we used 61 pitfall trap arrays along 10 transects perpendicular to the Calaveras River. At each trap location, we measured ground temperature hourly, as well as estimates of insect biodiversity, abundance, and biomass. Our results will provide new insight into the complex role of spatiotemporal variation in temperature and water availability in community dynamics, which is important given the prediction for warmer, drier climates in many global regions.

57-7 BONIER, F*; COX, RM; Queen's University, University of Virginia; *bonierf@queensu.ca*
To each their own? Meta-analysis of evidence of optimality of endocrine phenotypes
Rosemary Knapp's research contributions emphasize the importance of considering individual life history stage and strategy when seeking to understand endocrine traits. This perspective has been central in clarifying the role of endocrine signals in regulating complex life history traits, and for understanding variation among individuals in responses to the same signals. In essence, this work placed the endocrine phenotype into an ecological and evolutionary context, and recognized that optimal endocrine phenotypes differ not only among the sexes, but also within sexes, among individuals with alternative reproductive tactics. Here, we extend this view to consider variation among individuals, rather than among morphs. If individuals express near-optimal endocrine phenotypes, well matched to their context, we predict that manipulations of these phenotypes (e.g., through hormone implants) should generally compromise fitness. We use a meta-analysis of hormone manipulation studies to test this prediction, and find some support for it, along with interesting sources of variation. Effects of hormone manipulations on fitness varied depending on the sex of individuals being manipulated, as well as on the metric used to estimate fitness. These findings reinforce the importance of understanding individual life history and environmental context when we seek to understand how selection has shaped, and is shaping, endocrine traits.

P2-226 BONNAN, MF; MOORE CRISP, L*; BARTON, A; DIZINNO, J; MULLER, K; SMITH, J; WALKER, J; Stockton University, Red Bank Veterinary Hospital; *leximoore@gmail.com*
Hands down: Understanding elbow kinematics of the central bearded dragon (Pogona vitticeps)
Despite decades of research on lizard locomotion, the mechanics of the elbow joint and its relationship to manus orientation remain understudied. Previous studies on monitor lizards have inferred from dissection and X-ray cine that manus pronation is dictated by long-axis rotation of both the radius and ulna relative to the humerus. To further explore the kinematics of the lizard elbow, we use XROMM (X-ray Reconstruction of Moving Morphology) to characterize elbow movements in the central bearded dragon, *Pogona vitticeps*. Our results show that during stance, the radius and ulna both rotate laterally on their long-axes relative to the humerus, especially during elbow flexion. Given that the radial and ulnar condyles of the humerus have different morphologies, the antebrachial bones follow different paths at the elbow, resulting in their distal ends moving in opposite directions. These movements of the radius and ulna maintain palmar contact of the manus with the ground during stance in what can be described as the squamate equivalent of pronation. At the end of stance, the long-axis rotations of the radius and ulna reverse, rotating medially relative to the humerus, allowing the manus to supinate.. We find it significant that manus pronation is maintained in part through movements of the radius and ulna (lateral long axis rotation) typically associated with supination in birds and (at least for the radius) in mammals. Our data suggest that more examples of elbow kinematics across reptiles and mammals are needed to enhance our understanding of the ancestral mechanism for amniote pronation and supination.

43-2 BONTRAGER, M; MUIR, CD*; MAHONY, C; GAMBLE, DE; GERMAIN, RM; HARGREAVES, AL; KLEYNHANS, EJ; THOMPSON, KA; ANGERT, AL; University of British Columbia and University of California, Davis, University of Hawai'i, University of British Columbia, University of British Columbia, McGill University; *cdmuir@hawaii.edu*
Climate anomalies are altering local adaptation
Adaptation to local climate is ubiquitous, but global climate change may be generating mismatch between the conditions that populations experience and the optima to which they have evolved. This mismatch is likely to decrease individual fitness and disrupt local adaptation. We investigate these effects with a synthesis of data from 149 published transplant studies, and find that fitness declines when populations experience temperatures that deviate from their historic averages, but is not sensitive to precipitation variation. Deviations in temperature affect the magnitude of local adaptation detected in transplant experiments. The negative effects of climate anomalies on fitness and local adaptation may be an early warning sign that populations are at risk in the absence of rapid adaptation or gene flow

S6-2 BOONMAN, ARJAN*; EITAN, OFRI; YOVEL , YOSSI; University of Tel Aviv; *arjan.boonman@gmx.net*

The acoustics of flapping flight in birds and bats; a preliminary analysis

Most studies on the acoustics of bird flight focus on gliding- and not on flapping flight. Here we present preliminary acoustic data on the sound of wing-flapping in a number of bat- and bird species. We did not record the acoustics of the wing-beat rate itself but of the acoustic impulses created by each individual flap of the wing. In this context we show that during take-off, when barn owls must flap strongly to create sufficient lift, the sounds of wing-flaps are clearly audible. We also present a case of specialized 'wing-claps' used by fruit bats in the Old World. The exact mechanism of creating each clap is still unknown, but we proved these claps to be used in a form of rudimentary echolocation to detect large structures.

38-4 BORTONI, A*; MORRIS, AT; YOUNG, IR; BREUER, KS; SWARTZ, SM; Brown University, Providence, USA; *alberto_bortoni@brown.edu*

Synchronous Muscle Recruitment for Stable Flight Control in Egyptian Fruit Bats

Bats demonstrate a remarkable capacity to recover flight stability after perturbations from the environment. This ability is likely supported by the precisely-timed recruitment of wing muscles, which modulate the production of aerodynamic forces. However, we know little about neuromuscular control mechanisms in bat flight. Studies of limb movement in response to perturbations during terrestrial locomotion show a proximo-distal control gradient in which performance of muscles that control proximal joints is insensitive to perturbations, in contrast to activity of muscles controlling more distal joints. We hypothesized that when flight is asymmetrically perturbed, the activity of left and right pectoralis major muscles would remain synchronized. To test this, we recorded electrical activity of the pectoralis muscles using wireless dataloggers (Vesper Pipistrelle, 4.1g) from five *Rousettus aegyptiacus* trained to fly along a corridor (1.5 x 6.0 x 2.0m). Bats passed through a window that divided the corridor's length in half en route to a landing pad; in perturbed flights, a jet of air was delivered to one wing (2.5X body weight) as bats flew through the window. We tracked the 3D position of 15 markers on each individual using six high-speed cameras. We compared the timing of muscle recruitment with kinematics for all flights. Results show symmetrical recruitment in all flight trials, demonstrating that recovery of stable flight after perturbation does not alter the recruitment symmetry of the pectoralis in *Rousettus aegyptiacus*. This supports the idea that proximo-distal limb muscle activation gradients are a fundamental characteristic of vertebrate neuromechanical control.

P3-166 BORTONI, A; MORRIS, AT*; YOUNG, IR; BREUER, KS; SWARTZ, SM; Brown University, Providence, RI; *alexander_morris1@brown.edu*

How Bats Don't Crash and Burn: Bilateral Muscle Recruitment for Recovery Maneuvers in Egyptian Fruit Bats

Bats show outstanding flight agility and control. Yet, they often fly through windy conditions and in close proximity, so they collide often. They minimize the impact of these collisions through their ability to quickly recover stable flight. Here, we investigate the motor control of the pectoralis major muscle during recovery maneuvers of *Rousettus aegyptiacus*. Previous studies perturbing terrestrial vertebrates reveal a graded pattern of muscle activation during the recovery response, involving load-sensitive recruitment of distal muscles and load-insensitive recruitment of proximal muscles. We hypothesized that the right and left pectoralis in bats would maintain synchronous activation throughout a flight perturbation. To test this, we trained five bats to fly through a corridor with six high-speed video cameras, while collecting electrical activity of bilateral pectoralis recruitment from electromyogram electrodes attached to a wireless data logger (Vesper Pipistrelle, 4.1g). Bats flew through a window in a divider bisecting the corridor. On test trials, an air jet 2.5x their body weight struck one wing at this moment. We analyzed spatial position using camera recordings of 15 marks on each bat, and compared this set with the timing of the electromyogram data. All trials showed symmetrical recruitment in the pectoralis major muscles. We conclude that proximal muscle recruitment in our model bat species is not altered by a significant perturbation during flight. Similarly to the limb control model in terrestrial vertebrates, bats maintain proximal muscle control that is independent from the force of a perturbation.

68-6 BOVE, CB*; DAVIES, SW; RIES, JB; UMBANHOWAR, J; MCCOPPIN, J; FARQUHAR, E; CASTILLO, KD; UNC-Chapel Hill, Chapel Hill, NC, UNC-Chapel Hill, Chapel Hill, NC and Boston University, Boston, MA, Northeastern University, Boston, MA; *colleenbove@gmail.com*

Physiological and transcriptomic responses of coral hosts and algal symbionts of four Caribbean corals under global change

The continued rise in ocean $p\mathrm{CO}_2$ and temperature is of concern for marine organisms, especially highly susceptible reef-building corals that rely on a relationship with symbiotic algae, which governs the success of the coral holobiont. Diverse physiological responses of coral holobionts, at individual and species levels, will determine the future success of coral reefs. We investigated the independent and combined effects of acidification (2803300 µatm) and warming (28, 31 °C) on the physiological responses of coral hosts and algal symbionts of 4 Caribbean coral species (*Siderastrea siderea, Pseudodiploria strigosa, Porites astreoides, Undaria tenuifolia*) from inshore and offshore reefs on the Belize Mesoamerican Barrier Reef System. To illuminate molecular underpinnings of these responses, gene expression of *S. siderea* were explored. Warming more negatively altered host physiology of *S. siderea*, while symbiont physiology responded to warming and acidification. Preliminary gene expression showed transcriptome resilience across stressors, however, natal reef drove gene expression profiles. Warming reduced *P. strigosa* host and symbiont physiology, although inshore symbionts were less affected. Host physiology and chlorophyll a of *P. astreoides* were reduced under acidification, while chlorophyll a increased with warming. Determination of *U. tenuifolia* physiology was difficult due to high mortality. These results highlight diverse physiological responses of coral holobionts under global change and understanding this variation is critical to predicting the future of Caribbean reefs as global change continues.

74-8 BOVO, RP*; SIMON, MN; PROVETE, DB; NAVAS, CA; ANDRADE, DV; University of Sao Paulo and University of California Santa Cruz, University of Sao Paulo, Federal University of Mato Grosso do Sul, Sao Paulo State University; *rpbovo@gmail.com*

Intraspecific Variation in Thermal Tolerance and Water Balance of Amphibians Across Subtropical Elevational Gradients

Most empirical studies have used interspecific comparisons to assess vulnerability to environmental/climate change. However, intraspecific variation is the source of evolution and population or species differences in variation can result in different responses to such changes. In this study, we test how altitudinal gradients affect variation of thermal and hydric traits - both strongly associated with the evolutionary history - in amphibians. We compared mean thermal and hydric traits across different altitudes within-species in five anuran species. We sampled specimens from two mountain ranges at the Brazil's Atlantic Rainforest, from sea level to 1600 m, and measured thermal tolerance (critical thermal maximum, CTmax, and minimum, CTmin) and water balance (rates of evaporative water loss, EWL, and water uptake, WU). We hypothesized that populations from highlands would show lower CTmin, CTmax, EWL and higher WU, as well as higher thermal tolerance range (i.e., thermal fundamental niche, TFN) and warming tolerance (WT, i.e. the difference between CTMax and the maximum temperature of the environment). Effect of altitude was stronger in thermal traits compared to hydric ones. For most species, we confirmed our expectations for CTmin, CTmax, WT and TFN, however EWL or WU showed no difference along the elevational gradient. Taken together, our results indicate that species respond in different degrees to environmental/climate change and, therefore, assessment of vulnerability can be biased depending on which population is measured. This has implications on predictability of climate change impact on species, and deserves further consideration.

93-4 BOWERS, ME; KAJIURA, SM*; Florida Atlantic University; *kajiura@fau.edu*

There and back again; a blacktip's tale

The commonality that all migratory species share is some motivational factor that drives their movement. Sharks follow narrow ranges of environmental parameters when migrating over large distances. Blacktip sharks, *Carcharhinus limbatus*, migrate south from their summer mating grounds in Georgia and the Carolinas when water temperatures drop below 21°C. They overwinter off the coast of southeastern Florida in dense aggregations when sea surface temperatures are below 25°C. Upon the vernal equinox, they head north again to Georgia and the Carolinas. Only rare strays are reported to travel north of Cape Hatteras, NC, a boundary that was described over seventy years ago. Since that time, sea surface temperatures have increased 0.85°C. However, some areas like the Gulf of Maine are warming at a disproportionate rate. Many marine species have shifted their distribution poleward as oceans have warmed globally. This research assesses whether the migratory pattern of the blacktip shark has shifted in response to warming oceans. Fifty-one male blacktip sharks were tracked using acoustic telemetry. Hot spot analysis suggests poleward shifts have occurred in the migratory pattern of this population. If poleward migratory shifts continue, the seasonal influx of blacktip sharks into higher latitudes may cause trophic cascades that affect ecologically and economically important species. The blacktip shark may have already reached its maximum latitude if the Gulf of Maine is too warm to accommodate the thermal preference of these migrators. This may lead to greater densities of blacktip sharks in New York waters.

38-5 BOYNTON, AM*; CARRIER, DR; University of Utah; *alicia.boynton@utah.edu*

Function of cervical muscles during human running

Core musculature functions to stabilize the pelvis and trunk against moments imposed by activity of extrinsic limb muscles. Conventionally, the human core is thought to include the axial muscles located between the pelvis and the diaphragm. We suspect, however, that the core includes all of the axial muscles of the trunk and neck. During running, the muscles of the human neck must function to control the posture of the head, but they may also play a role in stabilizing the trunk against the moments imposed on the pelvis by the extrinsic leg muscles. To test if neck muscles play a role in controlling the posture of the head we monitored changes in their activity when subjects ran with 4.5 kg added to their heads, roughly doubling head mass. If activity of neck muscles is required to control head posture, we would expect muscle activity to increase substantially when head mass is doubled. To test whether cervical muscles play a role in core stabilization we increased the fore-aft and vertical forces of running with elastic tethers attached to the subjects via a waist harness. If neck muscles do play a role in core stability, we predict that higher locomotor forces will be associated with elevated cervical muscle activity. We found that when subjects ran at constant speed (2.7 m/s) doubling the mass of the head had little or no effect on the activity of the muscles we monitored. In contrast, alterations of forces imposed on runners in the fore-aft direction resulted in significant changes in cervical muscle activity. These results suggest that superficial cervical muscles act as part of the human core to stabilize the trunk against moments imposed at the pelvis by extrinsic leg muscles during running. The observation that neck muscles provide stability for the legs of humans has implications to the locomotor function of the tetrapod neck, prevention of spinal injury, and treatment of chronic cervical and back pain.

129-7 BRACKEN-GRISSOM, H.D*; DELEO, D.M; PORTER, M.L; IWANICKI, T.; SICKLES, J.; FRANK, T.M; Florida International University , University of Hawai'i at Mānoa, University of Hawai'i at Mānoa, Nova Southeastern University; *hbracken@fiu.edu*

Evidence for Extraocular Photosensitivity in the Bioluminescent Organs of Deep-sea Shrimp

Extraocular photoreception has not been previously described in deep-sea invertebrates. Here, we investigate photosensitivity in the bioluminescent light organs (photophores) of deep-sea shrimp, an autogenic system in which the organism possesses the substrates and enzymes to produce light. Through the integration of transcriptomics, in situ hybridization and immunohistochemistry we find evidence for the expression of opsins and phototransduction genes known to play a role in light detection in most animals. Subsequent shipboard light exposure experiments showed ultrastructural changes in photophores similar to those seen in crustacean eyes providing further evidence that these photophores are photosensitive. In many deep-sea species, it has long been documented that photophores emit light to aid in counterillumination – a dynamic form of camouflage that requires adjusting the organ's light intensity to "hide" their silhouettes from predators below. However, it remains a mystery as to how animals fine-tune their photophore luminescence to match the intensity of downwelling light. Photophore photosensitivity allows us to reconsider the organ's role in counterillumination - not only in light emission but also light detection and regulation.

P1-124 BRADY, K*; KOVACS, J; VOISIN, D; WELCH, J; Spelman College; *kaibrady16@gmail.com*
Characterizing the gut microbiome of honeybees
On nearly every surface and inside almost every organism, there are millions of tiny microbes that are invisible to the naked eye. Some of these microbes, known as symbionts, live in symbiosis or within other organisms. These tiny microbes include bacteria, fungi, and viruses. Honeybees (Apis mellifera), like most insects, host symbionts in their guts. Previous research has identified and characterized nine bacterial species clusters that dominate the gut microbiome of honeybees. While the microbes in their hives and honey have not been as well characterized, we know that honeybees come into contact with a variety of microbes while foraging. The microbes that are present may depend on the season and region the hives that the honeybees are located in, as well as the gut microbial composition of workers in the hive. We used DNA metabarcoding to assess whether there are regional and/or temporal differences in the symbiotic environment of the guts of worker bees and the symbionts in stored honey. We will also address the following questions: What microbial symbionts are present in honey and how does the season impact that? How are these microbes related to the ones present in the guts of honeybees?

70-7 BRADY, PC*; GARCIA, M; HERNANDEZ, T; AALUND, M; GRUEV, V; CUMMINGS, ME; University of Texas at Austin, University of Illinois at Urbana Champaign; *scorpionjeger@hotmail.com*
Measurement of cephalopod polarization patterns with color video-polarimetry and computer vision techniques.
Cephalopods have long been known to visually sense polarized light, yet quantifying polarized patterns from these animals has been lacking due to technical difficulties of polarization imaging underwater. We use a custom-built high definition color polarization camera with vertically stacked color photodetectors that has been engineered to be diver operated under water. We use a modified the computer vision tool, perspective from n points (PnP), to fit a virtual 3D model to the 2D image. Using this 3D model, we model the polarization reflections in virtual space and compare with the measured animal. Reef squid, Sepioteuthis lessoniana and Sepioteuthis sepioidea, show specific patterns of the degree of polarization that are dependent on the solar and viewing angle. Specific angle of polarization patterns were found that are not correlated with the solar position. These polarization patterns may contribute to the unique and intricate schooling patterns found in these squid. We quantify these schooling patterns using a goPro-VLAM tracking technique that is able to measure the body positions of animals in addition to being able to map their environment. The Broadclub Cuttlefish, Sepia latimanus show rapid changes in polarization states in response to the movement of the videographer.

P2-109 BRADY, PC*; GARCIA, M; HERNANDEZ, T; AALUND, M; ELLERD, R; GRUEV, V; CUMMINGS, ME; The University of Texas at Austin, University of Illinois at Urbana Champaign, Texas A&M University; *scorpionjeger@hotmail.com*
A comparison of two distinct pelagic camouflage strategies in teleosts
Creole wrasse and Bar jack are evolutionarily distinct, yet they have converged to school together in a particular pelagic environment above coral shelves in the Caribbean. In this environment, each fish uses a different reflection method to match the water column color with high fidelity. The creole wrasse has a blue coloration that matches the blue color of the water column where they forage above the coral. This species has a high polarization reflection that may aid the creole wrasse with camouflage from the polarization sensing copepods they hunt. The bar jack has broadband silvery skin that reflects the color of the water column. It can also be found in and among sea grass where the color of the water column is much greener. Bar jack have a high degree of depolarization and their polarization reflection is more complicated. We use a custom-built high definition color polarization camera with vertically stacked color photodetectors that has been engineered to be diver operated under water. We use a modified the computer vision tool, perspective from n points (PnP), to fit a virtual 3D model to the 2D image. Using this 3D model, we model the polarization reflections in virtual space and compare with the measured animal. We find that the creole wrasse performs similar to the bar jack in weber contrast with few exceptions but performs much better in the polarization channel. There are distinct differences in body positioning patterns between the two fish.

P1-79 BRANDT, E E*; ROSENTHAL, M F; ELIAS, D O; University of Western Ontario, University of California, Berkeley; *eebrandt@berkeley.edu*
Temperature Effects on Multimodal Sexual Signals in an Ectotherm: a Network Analytical Approach
Temperature is an important factor influencing all aspects of animals' lives, from physiology to behavior and ecology. One understudied research avenue is understanding how temperature affects sexual behavior. In a previous study, we discovered that desert-dwelling jumping spiders (*Habronattus clypeatus*) have temperature-dependent multimodal sexual signals. Aspects of male visual and vibratory signals change dramatically with ambient temperature. Females also show different patterns of sexual receptivity at different temperatures. In the present study, we performed mating trials at two different temperatures with *H. clypeatus* to explore the details of female mate choice. We specifically used a network analytical approach to understand (1) how aspects of sexual displays are correlated with one another and (b) how these networks change with changing temperatures. We performed courtship trials at room temperature (~25 C) and at a temperature shown previously to result in higher mating rates (~50 C). We then measured a number of aspects of male and female sexual behavior, and assessed changes in the correlation network structure of courtship, specifically network modularity and edge density. Network structure is predicted to change if different components of courtship respond differently to changes in temperature, which previous research suggests may be the case. Changes in a courtship display's correlation network can affect both how selection courtship acts, and the information that the display is able to contain. With these methods, we are able to give a more nuanced view of how multicomponent displays are comprised and change with changing environmental conditions.

63-7 BRASS, KE*; HERNDON, N; GARDNER, S; GRINDSTAFF, J; CAMPBELL, P; Oklahoma State University, University of California, Riverside, and Oklahoma State University, University of California, Riverside, and Oklahoma State University; *kbrass@okstate.edu*

Epigenetic effects of paternal perception of predation risk on offspring phenotypes

In stable environments, parents able to transmit information such as predation risk should have offspring that are pre-adapted to the environment they will encounter as adults. While intergenerational epigenetic transmission of paternal experience has been demonstrated in mammals, whether paternal perception of predation risk can alter offspring phenotypes has not been investigated. We exposed male mice to a predator odor (2-4-5-trimethylthiazoline, TMT) and measured offspring behavioral phenotypes throughout development as well as adult neural gene expression and stress reactivity. We predicted that offspring of males exposed to TMT would exhibit decreased activity and increased anxiety-like behaviors relative to controls because these behaviors are analogous to anti-predator behaviors in the wild. Unexpectedly, we found that offspring of TMT-exposed males tend to be more active and exhibit fewer anxiety-like behaviors relative to controls. In the prefrontal cortex, we found evidence of increased relative expression of the mineralocorticoid receptor (Nr3c2) in experimental offspring. Additionally, offspring of TMT-exposed males exhibited decreased baseline plasma CORT relative to controls. These results suggest that fathers exposed to predation threat produce offspring that are bolder and, potentially, more likely to flee than freeze when predators are present. Importantly, this study provides evidence that ecologically relevant paternal experience can influence offspring phenotypes.

P1-14 BREEN, CM*; FUNK, EC; MCCUNE, AR; Cornell University; *cb736@cornell.edu*

Role of Bmps in Evolution of Gas Bladder in Ray-Finned Fishes

Studying the gene networks that dictate morphogenesis during development can provide important insight into evolutionary origins of morphological novelties. The gas bladder, an air-filled sac that affords buoyancy control, is a major morphological innovation within the vertebrate clade. It is unique to ray-finned fishes; all other bony vertebrates have ventral lungs. These structures are homologous, but the key difference to understanding the evolutionary transition from lungs to the gas bladder is that lungs bud ventrally from the foregut endoderm during development while the gas bladder buds dorsally. We investigated the genetic basis of this dorsoventral inversion by examining the expression patterns of *Bmp4*, ventrally expressed during lung budding in mouse, and *Bmp16*, a paralog expressed during gas bladder budding in zebrafish, in three species: bichir, which retains ventral lungs; bowfin, which diverged soon after gas bladder evolution; and zebrafish, which diverged more recently. *Bmp4* is expressed in the lung buds in bichir, as it is in mouse, but is not expressed in the gas bladder in bowfin or zebrafish. *Bmp16* is expressed in the gas bladder bud and associated foregut endoderm in bowfin. *Bmp16* was lost in numerous bony vertebrate lineages, including mammals, but it is not known whether it is retained in bichir. If *Bmp16* is retained in the genome and expressed during lung budding in bichir, it is possible that *Bmp*s 4 and 16 both functioned in lung development in the bony vertebrate ancestor, *Bmp4* taking over the functionality of *Bmp16* in lineages in which the latter was lost. In contrast, if *Bmp16* is retained in bichir but not expressed during lung development, it is more likely that *Bmp16* only became involved in air-filled organ development when the gas bladder evolved.

P2-11 BREEN, CJ*; CAHILL, AE; Albion College; *cjb20@albion.edu*

Survivability and Reproduction in Daphnia, Copepods, and Ostracods Under Changing Salinities

Michigans's inland salt marshes are a very rare habitat in North America, and little is known about the invertebrates that live there. To gain a better understanding of the adaptations necessary to live in these habitats, we conducted two experiments. The first experiment tested a single invertebrate in two different waters, the invertebrates that were tested on were ostracods taken from the salt marsh, copepods taken from the Kalamazoo River near the Albion College campus, and *Daphnia pulex* that were ordered from Carolina Biological. We tested for local adaptation in the invertebrates by testing each species in freshwater from the Kalamazoo River and from the salt marsh and measuring population growth (survival and reproduction) for two weeks. We found that only the copepods had a significant difference in performance between the two environments tested. This was strange because they did better in the water from the salt marsh, which isn't their natural habitat. The *Daphnia* and ostracods did not have a significant difference in survivability between the two environments. We then conducted a second experiment where each replicate contained two species of invertebrate. Both salt marsh water and freshwater were tested in this experiment. The purpose of this experiment was to test if competitiveness/fitness in these two environments gave an advantage to one of the two invertebrates being tested. In the second experiment the only invertebrate that significantly outperformed the other was the ostracod, which outcompeted the *Daphnia* in both environments. It was also found that there was no significant difference between the copepods and ostracods, and the copepods and *Daphnia*. Knowing that copepods survive and reproduce better in the salt marsh raises more questions as to why they haven't been found there. Copepods don't outcompete ostracods, which are naturally found in the salt marsh.

74-6 BREITENBACH, AT*; PAITZ, RT; BOWDEN, RM; Illinois State University, Normal; *atbreit@ilstu.edu*

Let's Do the Time-lag Again: Ecologically Relevant Incubation Temperatures Delay the Response of Sex-determining Genes in a Turtle with TSD

Even though most organisms are exposed to variable bouts of warm temperatures, we know relatively little about how the timing and continuity of heat exposure influences biological processes. If heat waves increase in frequency and duration as predicted by climate change models, it is important to understand how these bouts of warmer temperatures could affect thermally sensitive species, including reptiles with temperature-dependent sex determination. We hypothesized that 1) the continuity of exposure to warm temperatures would affect resulting sex ratios in *Trachemys scripta* hatchlings, and 2) the duration of exposure to warm temperatures would affect the expression of two genes in the sex-determination cascade, *aromatase* and *Dmrt1*. To test the first hypothesis, eggs were initially exposed to daily fluctuations of 25±3°C (which produce all males) and then two 7-day heat wave days of 29.5±3°C separated by varying amounts of days at 25±3°C (sex ratio data to be collected October 2019). To test the second hypothesis, we exposed eggs to a 9-day heat wave (same thermal parameters), and sampled embryonic gonads on the last day of the heat wave as well on days 1, 3, 5, and 7 after the end of the heat wave. Surprisingly, neither *Dmrt1* nor *aromatase* increased in expression following the heat wave. Expression of both genes slightly decreased after the last heat wave day, and then gradually increased back to initial levels. These data suggest that the response of some sex-determining genes to fluctuating temperatures may be slower than has been defined by constant temperature studies and underscore the importance of accounting for natural variation in temperature when studying such phenomena in the laboratory.

113-2 BRESSMAN, NR*; HILL, JE; ASHLEY-ROSS, MA; Wake Forest University, Winston Salem, NC, Tropical Aquaculture Laboratory, University of Florida, Ruskin, FL; *noahbressman@gmail.com*

Why (and how) did the catfish cross the road? Chemoreceptive terrestrial orientation and amphibious natural history of the invasive walking catfish (Clarias batrachus)

Walking catfish (*Clarias batrachus*) are an invasive species in Florida, renowned for their air-breathing and terrestrial locomotor capabilities. However, it is unknown how they orient in a terrestrial environment. Furthermore, while anecdotal life history information is widespread for this species in its nonnative range, little of this information exists in the literature. The goals of this study were to identify sensory modalities that walking catfish use to orient on land, and to describe the natural history of this species in its nonnative range. Fish (n = 100) were collected from around Ruskin, FL, and housed in a greenhouse, where experiments took place. Individual catfish were placed in the center of a terrestrial arena and were exposed to four treatments: deionized water- and alanine solution-wetted bench liner in direct contact with the fish, and pools of filtered and pond water out of direct view or contact. Additionally, 88 people from Florida wildlife-related Facebook groups who have personal observations of walking catfish on land were interviewed for information regarding their terrestrial natural history. This data was combined with observations from 38 YouTube videos of walking catfish in Florida. Walking catfish exhibited significantly positive chemotaxis toward alanine, suggesting chemoreception is important to their terrestrial orientation. Walking catfish emerge most frequently during or just after heavy summer rains, particularly from storm drains in urban areas, where they may feed on terrestrial invertebrates. By better understanding the full life history of walking catfish, we can improve management of this invasive species.

P3-55 BREWER, VN*; LANE, SJ; SEWALL, KB; MABRY, KE; New Mexico State University, Las Cruces, Virginia Polytechnic Institute and State University, Blacksburg; *vbrewer@nmsu.edu*

Effects of Urbanization on Extra-pair Paternity in the Song Sparrow

Urbanization can affect the behavior of free-living animals. We examined the effects of low-density urbanization on extra-pair mating in urban and rural populations of song sparrows (*Melospiza melodia*) in Montgomery County, VA. We genotyped 70 song sparrow nestlings from 27 nests, along with their social parents and all other captured adults at 15 microsatellite loci. We assigned genetic paternity using the program CERVUS, successfully assigning 38 of 70 nestlings (54%) to a father. Only one nestling was assigned to a male that was not the social father, confirming extra-pair paternity. However, 22 additional nestlings were tested against a genotyped social father, but not assigned to a genetic father, leaving the possibility of extra-pair siring by an unsampled male. The lack of successful assignment of nestlings to sampled social fathers suggests that up to 34% of nestlings may be the result of extra-pair mating, in line with other studies of extra-pair paternity in song sparrows. Preliminary results suggest that there are higher rates of extra-pair offspring and nests in rural areas, as compared to urban areas. However, due to a limited sample size of rural nests (N=3), we cannot yet draw definitive conclusions about the effects of urbanization on extra-pair mating. Future plans include increased sampling of rural nests, and the use of single nucleotide polymorphisms (SNPs) to increase power to detect extra-pair mating.

S3-4 BRINK, KS*; CHUONG, CM; WU, P; RICHMAN, J; University of British Columbia, University of Southern California; *kirstin.brink@gmail.com*

Effects of Premature Tooth Extraction on Tooth Replacement Rates in Iguana iguana

Reptiles with continuous tooth replacement, or polyphyodonty, replace their teeth in predictable, well-timed waves in alternating tooth positions around the mouth. This process is thought to occur irrespective of tooth wear or breakage. However, premature extraction of functional teeth in alligators stimulates dental epithelial cell proliferation, potentially leading to faster tooth replacement. Therefore, without a long-term study, it is unknown if these early changes in cell proliferation lead to more rapid tooth replacement or if timing is in fact intrinsically controlled. Furthermore, it is unknown if this proliferation is unique to crocodilians or is characteristic of all reptiles. In this study, we aimed to determine if tooth extraction affects tooth replacement timing long-term in juvenile green iguanas. We analysed an historical collection of x-rays collected for up to 7 months after functional tooth extraction. We also performed new extraction experiments for molecular characterization of dental tissues. Results show that premature tooth extraction has no effect on tooth replacement timing, and teeth are replaced on average every 20 weeks at each position. Cell proliferation is not detected until 12 weeks after extraction in the successional lamina, matching the expected development time of a tooth in iguanas. The differences observed in molecular activity in the successional lamina between alligators and iguanas could be due to the morphology of the dental lamina and maintenance of potential stem cells, tooth attachment type, or feeding ecology. Ongoing longitudinal studies in the alligator and leopard gecko will further elucidate the mechanisms of continuous tooth replacement in polyphyodont reptiles.

17-3 BRISCOE, AD*; MACIAS-MUñOZ , A; RANGEL-OLGUIN, AG; BRISCOE, Adr; University of California, Irvine; *abriscoe@uci.edu*

Evolution of Phototransduction Genes in Lepidoptera

Vision is underpinned by phototransduction, a signaling cascade that converts light energy into an electrical signal. Among insects, phototransduction is best understood in *Drosophila melanogaster*. Comparison of *D. melanogaster* against three insect species found several phototransduction gene gains and losses, however, lepidopterans were not examined. Diurnal butterflies and nocturnal moths occupy different light environments and have distinct eye morphologies, which might impact the expression of their phototransduction genes. Here we investigated: 1) how phototransduction genes vary in gene gain or loss between *D. melanogaster* and Lepidoptera, and 2) variations in phototransduction genes between moths and butterflies. To test our prediction of phototransduction differences due to distinct visual ecologies, we used insect reference genomes, phylogenetics, and moth and butterfly head RNA-Seq and transcriptome data. As expected, most phototransduction genes were conserved between *D. melanogaster* and Lepidoptera, with some exceptions. Notably, we found two lepidopteran opsins lacking a *D. melanogaster* ortholog. Using antibodies, we found that one of these opsins, a candidate retinochrome, which we refer to as unclassified opsin (UnRh), is expressed in the crystalline cone cells and the pigment cells of the butterfly, *Heliconius melpomene*. Our results also show that butterflies express similar amounts of *trp* and *trpl* channel mRNAs, whereas moths express 50X less *trp*, a potential adaptation to darkness. Our findings suggest that while many single-copy *D. melanogaster* phototransduction genes are conserved in lepidopterans, phototransduction gene expression differences exist between moths and butterflies that may be linked to their visual light environment.

P3-20 BRISENO, JL*; TASSIA, MG; WAITS, DS; HALANYCH, KM; University of California, Santa Cruz and Auburn University, Auburn University; *jlbrisen@ucsc.edu*

TIR Domain-Containing Protein SARM1 Diversity in Deuterostomes and Lophotrochozoans

Innate immunity pathways are shared among all animals to detect conserved surface molecular motifs used by pathogenic microbes. In animals, the Toll-like receptor (TLR) pathway is defined by Toll/interleukin receptor (TIR) domains to bind these pathogens. The TLR pathway has several highly conserved TIR domain-containing proteins that have been well characterized in model organisms. In this study, we analyze one such TIR domain-containing protein, SARM1, in Deuterostomia and Lophotrochozoa. In jawed vertebrates, SARM1 inhibits the MYD88-independent TCAM1-dependent pathway via a negative regulator loop. In other lineages, SARM1 function is unknown. Although a TCAM1 homolog is absent in many invertebrate lineages, SARM1 is present and has been hypothesized to play a role in neuron physiology, innate immunity, or both. Our results confirm the hypothesis that SARM1 is indeed a conserved protein. SARM1 is characterized by two N-terminal sterile alpha motif (SAM) domains and a single C-terminal TIR domain. SARM1 is present in all sampled taxa, but has variability in total length, domain placement, and domain characterization. These findings emphasize the importance of sampling across all taxonomic groups to reveal evolutionary patterns, novel function, and protein composition. Given that SARM1 is conserved across a broad range of Metazoa, future work is needed to understand how this protein is functionally utilized in invertebrate taxa.

P2-143.5 BRITTAIN, CB*; SMITH, T; STILL, SE; MENON, A; CRISTOL, DA; WADA, H; Auburn University, Auburn, William & Mary, Williamsburg; *cnw0012@auburn.edu*

Effects of Dietary Methylmercury on Songbird Hippocampal Neuroanatomy

Methylmercury is a widespread neurotoxic stressor in both aquatic and terrestrial environments, yet many terrestrial species have been overlooked in studying its effects. Using the zebra finch (*Taeniopygia guttata*) as a model songbird, we previously showed that birds exposed to sublethal levels of dietary methylmercury throughout their lifespans displayed impaired spatial learning; however, in this study mercury did not affect our measure of spatial memory nor were differences in hippocampus volume observed. The hippocampus is a region of the brain related to spatial cognition, so this difference in learning could be due to effects of mercury on neural processes in the hippocampus rather than simply volume. We hypothesized that methylmercury would hinder neural processes such as migration of young neurons to the hippocampus, survival of immature neurons to this region, and integration of immature neurons into existing neural networks within the hippocampus. To test this hypothesis, we extracted brains from zebra finches that had been exposed to methylmercury throughout their lives and whose spatial cognition had been tested. We predict that mercury-exposed birds will display decreased density of immature and mature neurons in the hippocampi, quantifying these measures utilizing immunohistochemical staining.

P1-264 BROGREN, D*; BURLEY, A; HOLIHAN, M; GRAVES, S; CHRYSLER, J; POPPS, K; SCOTT, J; Saginaw Valley State University, University Center, MI; *jascott1@svsu.edu*

High fat diets induce early signs of non-alcoholic fatty liver disease (NAFLD) independent of carbohydrate content

Diets high in fat have been shown induce non-alcoholic fatty liver disease (NAFLD), which is characterized by steatosis, inflammation, and metabolic changes in the liver. To investigate the metabolic and physiological effects of dietary fats and carbohydrates, adult mice were placed on low-fat (62% carb, 7% fat, 20% protein), Western (36% carb, 36% fat, 20% protein) and ketogenic diets (5% carb, 71% fat, 20% protein) for 8 weeks. Changes in physiology were analyzed by measuring changes in body composition, histology, and hepatic gene expression. At 8 weeks, there was a significant increase in body, ependymal fat pad, and liver weights in both Western and ketogenic mice, relative to mice fed the low-fat diet. The increased liver weight corresponded with observable increase in lipid accumulation (steatosis) in liver sections. Furthermore, an increase in left ventricle thickness was observed with both diets high in fat Analysis of the expression of 84 hepatic genes associated with NAFLD indicated that exposure to Western and ketogenic diets resulted in altered expression of genes associated with insulin resistance, lipid accumulation, hepatocyte injury, and an increase in blood cholesterol. However, the ketogenic diet mice also induced expression of anti-inflammatory genes. Thus, the results suggest that an increase in dietary fat, independent of carbohydrates, can lead to early signs of NAFLD; however, a ketogenic diet may induce anti-inflammatory mechanisms that could delay disease progression.

3-1 BROWN, CE*; DEBAN, SM; DUDLEY, R; SATHE, EA; University of South Florida, Tampa, FL, University of California, Berkeley, CA, University of California, Berkeley, CA; *cbrown43@mail.usf.edu*

Directed Aerial Descent in Arboreal Salamanders

Many arboreal animals, from insects to vertebrates, use directed aerial descent (DAD) to avoid predation, locate mates or resources, and minimize deleterious impacts of a jump or fall. Such behaviors may have been an important precursor to the evolution of flight in vertebrates, and thus merits closer inspection even outside the context of the arboreal-cursorial debate. Here, we show that arboreal salamanders in the genus *Aneides*, some of which inhabit the crowns of the world's tallest trees, use DAD during jumps despite having no apparent specialized aerodynamic control surfaces such as skin flaps. High-speed cameras were used (at 500 fps) to image arboreal salamanders from dorsal and lateral perspectives as they jumped from both raised platforms onto a landing pad, and into a vertical wind tunnel that simulated an extended descent. One non-arboreal plethodontid, *Ensatina eschscholtzii*, was studied in the vertical wind tunnel for direct comparison. *E. eschscholtzii* cannot jump, and its aerial performance varies greatly. Kinematic analysis revealed that all filmed salamanders were capable of mid-air stabilization, parachuting, and landing in a prone posture during jumps or falls. *Aneides vagrans* may also be capable of controlled maneuvers during extended descents as simulated in the vertical wind tunnel. Mid-air stabilization, parachuting, and maneuvers appear to be controlled by deliberate movements of the limbs, feet, and tail of these arboreal salamanders. This new example of DAD, the first to document the mechanics of aerial behavior in any salamander, suggests that the oft-cited long limbs and active tail of *Aneides* may serve in functions supplemental to climbing, and also is relevant to aerial hypotheses for the origin of flight in vertebrates.

117-2 BROWN, T A*; TSURUSAKI, N; BURNS, M; UMBC, Baltimore, MD, Tottori University, Tottori, JPN; *tbrown8@umbc.edu*

Genotyping-By-Sequencing via 3RAD Capture to Determine Reproductive Mode in a Facultative Parthenogen

Alternative reproductive systems, wherein individuals do not exclusively reproduce sexually, may provide unique insight regarding sexual conflict. *Leiobunum manubriatum* and *L. globosum* are facultatively parthenogenetic Japanese harvestman which vary in sex ratio across their geographic distribution. Males of both species possess morphology which suggest coercion may be common during mating events. In previous efforts, we used genotyping-by-sequencing and a SNP array panel to determine the reproductive mode of females. We found that despite the availability of males, females in populations with high male frequency reproduced primarily through parthenogenesis. Additionally, females from populations with few males were not significantly more fecund than females in equal sex ratio populations. These results also identified that a more accurate, cost-effective method to rapidly genotype thousands of samples was necessary. 3RAD Capture combines the low input DNA requirements and decreased PCR error rate of 3-enzyme RADseq with the high coverage of bait capture sequencing. First, specialized capture baits were designed from previous RAD sequencing of *L. manubriatum*. These baits target loci suitable for genotyping, maximizing usable reads from minimal template DNA. Samples were digested using three enzymes, and custom oligonucleotides were ligated to cut ends. Following this preparation, the library is hybridized with bait probes which are targeted with streptavidin beads. The captured DNA can then be isolated and sequenced with high efficacy. Rapid and accurate genotyping facilitates sire assignment of thousands of egg specimens, providing insight on the factors which maintain sex in these facultative parthenogens.

140-3 BRUECKNER, A*; PARKER, J; California Institute of Technology, Pasadena, CA; *bruckner@caltech.edu*

Single Cell Assembly of a Chemical Key Innovation in a Rove Beetle

Evolutionary novelty can arise from the emergence of new cell types with new biological functions. How new cell types are constructed molecularly during evolution is poorly understood. Here, we deconstruct the assembly of novel cell types comprising an evolutionary key innovation in animals using single cell sequencing. A chemical defense gland in rove beetles (Staphylinidae) is the putative catalyst behind the global radiation of this clade into >16,000 species. We show how defense gland function was pieced together from ancestral molecular source material to create two, clade-specific secretory cell types, each capable of synthesizing and secreting distinct compound classes. Production of noxious benzoquinones by one cell type evolved from duplication of a tyrosine-oxidizing laccase enzyme, with an ancestral role in cuticle tanning. Production of a short-chain alkane by the second cell type evolved from recruitment of a partially duplicated cuticular hydrocarbon pathway lacking elongase-mediated chain extension. The alkane-producing cells form an epithelial reservoir into which both cell types secrete, the alkane dissolving the benzoquinones to create a bioactive defensive secretion. These results exemplify how cell types with new properties are constructed through molecular evolution, and can synergize to create emergent organ functions.

P1-250 BRYANT, A.R*; GABOR, C.R; SWARTZ, L.K; LOWE, W.H; WAGNER, R.; Texas State University, Division of Biological Sciences, University of Montana, Division of Biological Sciences, University of Montana, Ohio University; *arb326@txstate.edu*

Steam Salamander Larvae Downregulate Corticosterone in the Presence of Fish Predators

In amphibians, exposure to stressors early in life can have continuing negative impacts later in life. These negative consequences, including decreased body mass at time of metamorphosis as well as increased susceptibility to disease, have been demonstrated in several species of salamanders and may have broader implications for conservation. We sampled Northern stream salamander larvae, *Gyrinophilus porphyriticus*, from two streams that each had native fish predators in the lower reaches and none in the upper reaches. We measured baseline and stress response (to agitation) corticosterone release rates of larvae using a non-invasive water-borne hormone assay. We hypothesized that larvae from stream reaches with fish predators would have different baseline and stress response corticosterone levels than larvae from reaches without fish predators. We found that corticosterone was downregulated in larvae from reaches with fish predators. We also found that corticosterone was downregulated in the stress-induced samples from both treatments. These results indicate that the decrease in corticosterone is related to the presence of a predator but populations exposed to a predator are not chronically stressed. While mass and snout-vent length (SVL) did not vary across reaches, down regulation of corticosterone could have long term consequences on mass and SVL after metamorphosis for individuals from reaches containing predators.

126-6 BUCHINGER, TJ*; FISSETTE, SD; BRANT, CO; LI, K; JOHNSON, NS; LI, W; Michigan State University, East Lansing, MI, US Geological Survey's Hammond Bay Biological Station, Millersburg, MI; *buching6@msu.edu*

A Pheromone Antagonist Liberates Female Sea Lamprey From a Sensory Trap

The sensory trap hypothesis predicts males use signals that mimic nonsexual cues to gain access to mates. In theory, deceptive signaling might lead to honest communication if females evolve to discriminate the mimic from the model and react appropriately to each per the context. We investigated if and how female sea lamprey (*Petromyzon marinus*) discern a nonsexual chemical cue from a male pheromone that mimics it. Sea lamprey migrate into streams following chemical cues released by larvae residing in nursery habitats near spawning grounds. Sexually mature males signal to females using a sex pheromone that partially mimics the larval cue; the major component of the male pheromone 3-keto petromyzonol sulfate (3kPZS) is also released by larvae and influences the nonsexual migratory behavior of sea lamprey and other species that do not use it as a sex pheromone. We postulated females discriminate between the larval cue and the male pheromone using petromyzonol sulfate (PZS), a behavioral antagonist of 3kPZS. Chemical analysis confirmed that both larvae and males release 3kPZS but revealed proportionally more PZS in larval odor than male odor. In a natural stream, 100% of females chose the nest baited with a mixture of 3kPZS and PZS typical of males over that of larvae when each was applied at the same concentration of 3kPZS. Our results indicate females use a behavioral antagonist to avoid orienting towards larval odor while tracking the male pheromone that mimics it, and offer rare evidence females can adapt to use mimetic male signals for honest communication.

41-7 BUCKLEY, KM; Auburn University; *kbuckley@auburn.edu*
Immune Responses in Sea Urchin Larvae Highlight Fundamental Aspects of Animal Immunity
Wide-ranging aspects of organismal biology are influenced by the microbial world. By orchestrating these relationships – through protecting against pathogens and promoting a beneficial microbiota – the immune system operates at the forefront of evolutionary biology. Immune response is a system-wide phenomenon that integrates mechanisms for microbial detection and clearance with physiological pathways that maintain host homeostasis. The larval stage of the purple sea urchin (*Strongylocentrotus purpuratus*) provides an experimentally tractable, morphologically simple system in which to study immunity from a system-wide perspective. In response to marine bacterium *Vibrio diazotrophicus* in the seawater, larvae elicit a synchronous, non-lethal inflammatory response. The cellular response consists of changes in gut morphology, immune cell recruitment, and changes in cell motility. Analysis of gene activity reveals that the most acutely upregulated gene in the early phase of response are two groups of IL17 paralogs, which are expressed exclusively in gut epithelial cells. Perturbation of IL17 receptor signaling results in reduced levels of tnfaip3 (an IL17 feedback inhibitor), nfkbiz (an IL17 target gene in vertebrates), transcription factors cebpα and cebpγ and soul1 (SOUL domains are evolutionarily widespread and involved in immune responses). These results indicate that the highly regulated IL17 expression in the gut epithelium and signaling through IL17R1 form a central axis of larval gut-associated immunity. Transcriptional regulation is also apparent within a battery of genes with homologs throughout non-vertebrate bilaterian organisms. As invertebrate deuterostomes, sea urchin larvae share an important genetic heritage with the vertebrates but provide an experimentally tractable system. These findings define fundamental aspects of immune control and are relevant for understanding gut immunity in a wide range of animals.

93-6 BUO, C*; TAYLOR, E; BARTLES, J; CHRISTMAN, K; DAYAL, P; LONDRAVILLE, RL; University of Akron; *cb46@zips.uakron.edu*
Spatial mapping and visual cues influence navigation in Entomacrodus striatus
We collected *Entomacrodus striatus*, an amphibious rockskipper, from a rock jetty in Moorea, French Polynesia, and tested their jumping abilities using a flow table. Amphibious fish routinely navigate between terrestrial and aquatic habitats using either spatial mapping or visual cues to determine where to safely jump. We recorded jumping direction during three sets of trials: eleven rounds of training, three rounds of visual cue disruption testing, and two rounds of spatial memory disruption testing. During the first round of training, the fish were able to jump to safety in a novel environment, regardless of starting orientation ($p < 0.001$). *E. striatus* were able to learn the terrain after repeated conditioning and continued to jump in the same direction after we moved rocks to the opposite side of the table ($p = 0.033$). To test memory disruption, we injected the fish with NOS inhibitor L-NAME and found fish jumps became randomly distributed ($p = 0.452$). In this study, we show blackspotted rockskippers successfully navigate through a combination of both visual cues and spatial mapping while on land.

2-7 BURFORD, B*; WILD, L; SCHWARZ, R; KOSMA, M; CHENOWETH, E; SREENIVASAN, A; GILLY, W; HEINTZ, R; FIELD, J; HOVING, HJ; STRALEY, J; DENNY, M; Stanford University, University of Alaska Fairbanks, GEOMAR, University of Alaska Southeast, Alaska Fisheries Science Center, Southwest Fisheries Science Center, GEOMAR; *bburford@stanford.edu*
Poleward proliferation of an inshore squid
Ongoing shifts in temperature and oxygen availability are thought to alter the abundance and distribution of metabolically-viable habitats for marine ectotherms. Motile species with larger bodies and longer lifespans can compensate by migrating long distances to inhabit more suitable waters. These "climate refugees" then interact with and potentially affect their new ecosystems. However, smaller-bodied species with short lifespans are thought to remain within ecosystems, where they exhibit recurrent boom-bust dynamics. California market squid (*Doryteuthis opalescens*) is a small, abundant, and ecologically-important marine ectotherm that primarily inhabits the California Current (CC) in the northeast Pacific Ocean. With a typical lifespan of 6 months, population fluctuations in the CC that correlate with changes in oceanographic conditions have largely been attributed to boom-bust dynamics, and little attention has been given to the species' latitudinal migratory potential. However, beginning in 2015, *D. opalescens* appeared in unprecedented abundance in the Gulf of Alaska (GOA), an ecosystem 3,000 km northwest of the central CC. We relate this multi-generational poleward migration to ecophysiology, life history, and trophic ecology, and examine the event's historical, geographic, and environmental context. Our data suggest that the causes and consequences of climate-related migrations in small, short-lived marine ectotherms have important implications both for the life history of the migrants and the ecology of the communities and ecosystems into which they migrate.

71-3 BURKHARD, TT*; PHELPS, SM; University of Texas at Austin; *tburk@utexas.edu*
Evidence for heritable variation in the songs of Alston's singing mouse
Advertisement vocalizations can attract mates, deter rivals, aid in species recognition, and drive reproductive isolation. Because adaptation relies on heritable variation, examining the heritability (h^2) of acoustic variation is critical to understanding the evolution of vocalizations and the species that make them. Alston's singing mouse (*Scotinomys teguina*) is a small and diurnal species that lives in cloud forests of Central America. We used a combination of breeding studies and genomics-based methods to test for heritable variation in song structure among these mice both in the lab and field. We first took advantage of geographic variation in song effort to experimentally examine whether heritable variation contributes to intraspecific differences in song. We caught animals from Costa Rica and Panama, populations that naturally differ in song length. We reared animals from each of these sites in captivity, and crossed them to produce F_1 and F_2 animals, recording songs from each of these three generations. Population differences in song elaboration were maintained in lab-reared animals, suggesting a heritable basis to population differences, with F_1 and F_2 animals exhibiting intermediate song lengths. Next, we estimated the heritability of song within a Costa Rican population. We recorded songs and collected DNA from wild-caught mice. We used RAD-seq to generate SNPs from each individual and to calculate a genomewide relatedness matrix (GRM). Finally, we fit generalized linear mixed models to calculate h^2 of song. Our preliminary results estimate h^2 to be between 0.2 - 0.4 for different aspects of song. Together our data support the hypothesis that there is heritable variation in song structure both within and among populations of singing mice.

S11-1 BURMEISTER, SS*; LIU, Y; University of North Carolina, University of Texas Southwestern Medical Center; *sburmeister@unc.edu*

Hippocampal transcriptomes are associated with cognitive ability in two species of frog

The complexity of an animal's interaction with its physical and/or social environment is associated with behavioral flexibility and cognitive complexity. While this relationship has been studied extensively in birds and mammals, we know comparatively little about cognitive ecology in amphibians. We examined differences in cognitive ability in two species of frog with divergent natural histories. Poison frogs are diurnal, territorial, and utilize spatially distributed resources during parental care. Túngara frogs are nocturnal and use ephemeral puddles to breed in a lek-type mating system. Using standardized laboratory tasks, we find that green-and-black poison frogs (*Dendrobates auratus*) prefer to use spatial cues while túngara frogs (*Physalaemus pustulosus*) prefer local cues. Further, green-and-black poison frogs display greater behavioral flexibility than túngara frogs in a reversal learning task. Finally, green-and-black poison frogs are capable of using true spatial memory to solve a modified Morris water maze. Spatial memory and behavioral flexibility are associated with hippocampal function in mammals. Thus, we used RNAseq to examine species differences in the medial pallium, the amphibian homolog of the hippocampus. We found that genes related to learning and memory, neurogenesis, and synaptic plasticity were upregulated in green-and-black poison frogs, while genes related to apoptosis were upregulated in túngara frogs. While there are many reasons that these two species may differ in medial pallium gene expression, such differences provide an opportunity to identify candidate genes that enable greater behavioral flexibility and cognitive complexity in green-and-black in poison frogs.

S11-10 BURMEISTER, SS; University of North Carolina; *sburmeister@unc.edu*

Integrative Comparative Cognition

A long-standing question in biology is *what are the mechanisms that shape the evolution of cognition?* One effective way to address this question is to study cognitive abilities in a broad spectrum of animals. While comparative psychologists have traditionally focused on a narrow range of organisms, today they may work with lizards, birds, or bees. This broader range of study species has greatly enriched our understanding of the diversity of cognitive processes among animals. Yet, this diversity has highlighted the fundamental challenge of comparing cognitive processes across animals. An analysis of the neural and molecular mechanisms of cognition may be necessary to solve this problem. For example, if similar cognitive abilities are mediated by different neurobiological mechanisms, this may support the conclusion that they are not, after all, comparable. Further, a mechanistic approach can inform how the evolution of cognitive abilities have been constrained at the neural, molecular, or genetic levels. Recent advances in next-generation sequencing enables one to study neurogenomic mechanisms of comparative cognition in a broader range of species providing a potentially powerful tool to create an integrative perspective of comparative cognition.

S7-1 BURNETT, KG*; DURICA, DS; MYKLES, DL; STILLMAN, JH; College of Charleston, The University of Oklahoma, Colorado State University, San Francisco State University; *burnettk@cofc.edu*

SICB Wide Symposium: Building Bridges from Genome to Phenome: Molecules, Methods and Models

Understanding the mechanistic basis by which genes give rise to both stability and variation in phenotypes is one of the Grand Challenges articulated by NSF. Accordingly, scientists in many disciplines are using a wide variety of organisms and experimental approaches to generate complex datasets at different levels of biological organization, all aiming to elucidate aspects of the genome-to-phenome framework. The goals of the Building Bridges Symposium, including invited speakers and related oral and poster complementary sessions are to build connections among ongoing research efforts, as well as to identify critical gaps and future needs to accelerate and facilitate this critical area of research. The Symposium is organized by members of NSF's Animal Genome-to-Phenome Research Coordination Network (AG2P RCN) to encourage networking across disciplines, gender, ethnicity, and professional ranks. Participant discussions at a concluding workshop will serve as the basis for a white paper identifying major gaps, key barriers and leading edges in the field of genome-to-phenome research.(NSF IOS 1927470)

30-3 BURNETT, NP*; BADGER, MA; COMBES, SA; University of California, Davis; *burnettnp@gmail.com*

Wind and canopy height affect honey bee flight performance in cluttered environments

Bees flying in natural habitats often encounter unpredictable wind conditions and cluttered vegetation – features that may adversely affect flight performance. Despite many studies examining how bee flight is affected by wind or by obstacle arrangement, we know little about the strategies that bees adopt when traversing spatially variable environments with both obstacles and wind. We examined the flight performance and behavior of honey bees (*Apis mellifera*) flying through a chamber with an array of vertical obstacles that did not extend to the ceiling, allowing bees to fly through the obstacles and/or above the obstacle "canopy." We varied the height of the array between trials (obstacles occupied 5% to 65% of the vertical space in the chamber) and tested bees flying upwind, downwind, and in still air. As obstacles grew taller in any wind condition, bees flew more slowly and took more time to traverse the array but did not change peak performance (maximum speed and acceleration). In each wind condition, bees adjusted the lateral component of their flight paths to stay farther from tall obstacles than from short obstacles. Finally, bees in wind did not adjust the vertical extent of their paths in response to array height, whereas bees in still air increased the total vertical space traversed – they extended the upper extent of flights (flew higher) but maintained the lower extent of flights as array height increased. Our results show that simple variation in obstacle features like height can interact with wind to alter bee flight performance and behavior. Thus, bees foraging in natural environments, and the pollination services they provide, may be affected more than previously thought by the interaction between wind and the configuration of surrounding vegetation.

P2-89 BURNS, MP*; SALTZ, JB; Rice University; *mpb5@rice.edu*
Understanding the sources of variation that contribute to differences in decision making outcomes
Understanding why variation in decision making exists is important for informing an overall understanding of behavioral variation. Decision making is involved in many behaviors impacting fitness – such as habitat choice, foraging, etc. Because of this, it follows that everyone should optimize decision making. However, what we observe is a great deal of variation – with animals making decisions that can negatively impact fitness all the time. So why isn't everyone great at making the optimal decision? One thing known is decision making is costly, both in terms of neural tissue and the time/energy spent information gathering and processing. There are limitations, because all time/energy spent on decision making is not spent maximizing other aspects of fitness. In addition, not all environmental cues have equal importance, and in cases where the fitness cost of making the wrong decision is particularly high, it may be beneficial to maximize response to certain stimuli. Divergent evolutionary histories and variation in stimuli importance can lead to certain cognitive biases, which skew an animal's assessment of environmental cues away from objective perception – meaning that decision making is not always an entirely objective process. So where is this variation coming from? Animals can vary both in general cognitive ability and bias – so what determines how this variation is generated and maintained? One thing expected to influence this is the degree of environmental variability experienced. To investigate, we compare two closely-related species that of Drosophila that differ significantly in the degree of environmental variability experienced: *D. sechellia* and *D. simulans*. Contact: mpb5@rice.edu Supported by a training fellowship from the Gulf Coast Consortia, on the IGERT: Neuroengineering from Cells to Systems, National Science Foundation (NSF) 1250104.

72-1 BURRESS, ED*; WAINWRIGHT, PC; University of California, Davis; *edb0014@auburn.edu*
Are Oral and Pharyngeal Jaw Diversification Rates Correlated in Cichlid Fishes?
It has been appreciated for some time that the oral and pharyngeal jaws of fishes decouple prey capture and processing functions and their physical independence may permit considerable evolutionary independence and promote trophic diversity. However, the degree of evolutionary independence of these jaw systems is rarely estimated and continues to be poorly known. We tested the independence of oral and pharyngeal jaw diversification rates in New World cichlids. We measured functional morphological traits of the oral and pharyngeal jaws of 218 individuals representing 84 species. We assessed multivariate branch-specific rates of evolution using Bayesian inference in RevBayes. Overall, oral and pharyngeal jaw diversification rates were only weakly correlated. We found that only a few traits (15%) were more correlated between the jaw systems than expected based on Brownian motion. These tended to be negative correlations between traits associated with the biting strength of the pharyngeal jaws and the magnitude of oral jaw protrusion. This pattern may be due to a functional trade-off between suction feeding on evasive prey (e.g., fish) and sessile prey that requires intensive processing by the pharyngeal jaws (e.g., molluscs, algae). We found several instances of conflicting evolutionary patterns between the two jaw systems. Some piscivores exhibit dramatic diversification of oral jaw traits (i.e., Petenia), whereas others exhibit dramatic diversification of pharyngeal jaw traits (i.e., Cichla). Substrate sifting lineages consistently exhibited low diversification rates of both oral and pharyngeal jaws. Diversification of oral and pharyngeal jaws has largely been independent during the Neotropical cichlid adaptive radiation.

35-1 BURROUGHS, RW; University of Chicago; *rburroughs@uchicago.edu*
Modeling rodent tooth morphogenesis reveals constraints on mammalian tooth evolution
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 insu cient to explain morphological diversi cation and convergence within mammalian molar evolution; suggesting that development and phylogeny also limit 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 that in uence molar morphology. Because rodents are the most diverse group of mammals with corresponding dental disparity they represent an excellent system for investigating how genetic interactions limit morphology. I find that lower molars are limited to a minimum of four cusps and a maximum of nine cusps. Multiple developmental pathways produce the same numbers of cusps, despite highly variable cusp morphologies, indicating the existence of limits on how morphological evolution can fill a morphospace defined by cusp numbers. These constraints are both developmental and phylogenetic in nature and the identifcation of their influence on rodent molar shape provides a framework for investigation of how tooth batteries evolved an array of functions despite fundamental structural limits. The data presented here increase predictability of cusp number and evolutionary outcomes of rodent cheek dentition.

94-2 BUSBY, MK*; DAVIDOWITZ, G; BRONSTEIN, JL; The University of Arizona, Tucson, AZ; *mkbusby@email.arizona.edu*
Thermolimit Respirometry Determines Relative CTmax Among Carpenter Bee Life Stages
Native bees are increasingly under threat from a wide variety of anthropogenic forces, including rising temperature. Warmer temperatures are already affecting organisms indirectly, through behavioral or range modification, or through adaptive plasticity as in advanced production of heat shock proteins. However, as temperatures approach organisms' critical thermal maxima (CTmax), they are more likely to directly impact survival, and understanding thermal tolerances will increase in importance. CTmax is most often measured in adult insects by observing knockdown while ramping temperature. However, in some cases it is the larval stages that are most vulnerable to thermal extremes, and bee larvae cannot easily be visually assessed for knockdown. Thermolimit respirometry solves this problem by measuring volume of CO_2 in air that passes over an acclimated larva in an enclosed chamber. This allows for respiration to be monitored, and pinpoints time or temperature of death. *Xylocopa californica*, the desert carpenter bee, nests above ground, leaving its larvae particularly exposed to the effects of temperature. In the Sonoran Desert of southern Arizona, carpenter bees are near the southernmost and hottest part of their range, and possibly near the edge of their thermal geographic range. To assess thermal tolerance of during development, I used thermolimit respirometry on all larval and pupal stages. The least thermally tolerant life stage died at 52.6 degrees C. Record high local temperatures in southern Arizona have reached 47 degrees C. Measurements of developmental thermal tolerances at each life stage suggest that this critical pollinator is close to the maximum it can physiologically tolerate in a warming world.

130-2 BUSER, TJ*; SUMMERS, AP; SIDLAUSKAS, BL; Oregon State University, Corvallis, OR, University of Washington, Friday Harbor Laboratories, Friday Harbor, Washington; *busert@oregonstate.edu*

Stags of the Sea? Cranial Weapon Morphology in The Fish Subfamily Oligocottinae (Pisces; Cottoidea)

Many vertebrate groups have weaponized their skulls and, though some cranial weaponry aids defense, intraspecific combat appears to drive the evolution of these structures in most terrestrial cases. Equally impressive weaponry adorns aquatic vertebrates, such as the sculpins in superfamily Cottoidea. The skulls of these diverse fishes bear antler-like preopercular spines of remarkable variation, and the males of many species show intraspecific agonistic behavior during the breeding season. Do the evolutionary trends in weapon morphology of these fishes follow those observed in ungulates, beetles, and other fighting fauna? If so, we predicted that their spine shape would show ontogenetic change, sexual dimorphism, and asymmetry. We tested these predictions in members of the sculpin subfamily Oligocottinae by quantifying spine shape with 3D geometric morphometric techniques applied to reconstructions from micro-CT scans of members of each species. We found that sexual dimorphism is not apparent in the preopercular spine shape of oligocottines but ontogenetic change in shape is evident in several species and that asymmetry is common in all species. Interestingly, the direction of change across ontogeny is inconsistent across species, with the spines of some species becoming proportionally larger and more complex with age, while in others the spines become reduced. Asymmetry also showed higher than expected variation, with ~48% of preopercles having a shape more similar to the preopercle of a different individual than to the other side of their own body. Taken together, these results suggest that sculpins use their spines at least partially for agonism and combat, but also for defensive purposes, with possible trade-offs in some species across ontogeny.

117-6 BUSH, JM*; ELLISON, M; SIMBERLOFF, D; University of Tennessee Knoxville; *jbush15@vols.utk.edu*

Are brown anoles bullies? Insights into interactions between an invasive and native lizard species

Invasive species often displace native species that they closely resemble or compete extensively with. The mechanisms behind invaders' competitive success can vary widely, ranging from aggressive dominance over resources (interference competition) to superior resource utilization (resource competition). In this study, we looked for evidence of interference competition between an invasive lizard species, the brown anole (*Anolis sagrei*), and a closely related competitor that it displaces in the wild, the green anole (*A. carolinensis*). We housed captive populations of green anoles in large outdoor structures in Oak Ridge, Tennessee, and recorded their display behaviors and habitat use for 10 days. We then introduced brown anoles and recorded the green anoles' behaviors for another 10 days, looking for differences in pre- and post-invasion behaviors. We also recorded behavioral interactions between the two species. To serve as a density control, we repeated the experiment in a second enclosure using green anoles to "invade" the first populations. We found no evidence that brown anoles behaviorally dominate green anoles. Although brown anole males regularly displayed at green anoles, green anoles were generally uninterested in brown anoles and were more likely to interact with newcomers of their own species. Green anoles also did not change their display behaviors or activity levels in the presence of brown anoles. This study provides insights into how a native species responds to a closely related invasive competitor and indicates that social relationships between species do not necessarily reflect ecological relationships.

25-1 BUSTAMANTE, J*; AHMED, M; DANIEL, TL; University of Washington; *jorgebjr@uw.edu*

Restricting abdominal flexion yields poor flight performance in hawkmoths

Historically, the analyses of flight control and maneuvering have focused largely on aerodynamic forces generated by wings. Yet body (airframe) deformations may also be important and are often associated with maneuverability and flight control. Examples of non-wing maneuvering behaviors include changes in leg posturing as well as abdominal flexion. Abdominal flexion in particular may contribute to maneuverability because the abdomen comprises a large proportion of the weight of an insect. Thus, both active and passive changes in abdominal position physically redirect the inertia of the animal. Recent multi-body dynamics models also suggest abdominal motions during flight may contribute to maneuverability. If indeed such motions are critical, restriction of abdominal movement would yield poorer flight performance. To test this hypothesis, we glued a carbon fiber rod between the thorax and abdomen, thereby restricting abdominal flexion during flight for hawkmoths (*Manduca sexta*). The moths were tasked with feeding from a 3-D printed flower in natural light and temperature conditions. Without any modifications, 45 of 89 animals flew successfully and approached the flower. Only 5 of 38 trials across 29 moths flew successfully and approached the test flower. We also developed a sham treatment with the same weight of carbon fiber but severed into two pieces—one piece glued to the thorax, and the other glued to the abdomen allowing abdominal flexion. Of these sham experiments, 8 of 16 trials across 12 moths. These results suggest that abdominal flexion is necessary for flight control in hawkmoths. Our results also suggest multiple actuators are critical for flight control in insects.

80-7 BUTLER, MW*; ARMOUR, EM; MINNICK, JA; ROSSI, ML; SCHOCK, SF; BERGER, SE; HINES, JK; Lafayette College, Easton PA; *butlermw@lafayette.edu*

Both Circulating Corticosterone Levels and Heme Oxygenase Expression Are Correlated With Circulating Triglyceride Levels in House Sparrows

When exposed to stressors, animals respond by secreting glucocorticoid hormones such as corticosterone (CORT), thus affecting a variety of physiological processes, including lipid metabolism. However, the factors regulating lipid metabolism, particularly during acute (i.e., short-term) stressors, are not well-characterized. To investigate one putative mechanism, we examined how expression of the enzyme heme oxygenase (HO), which primarily converts heme into biliverdin, changes during an acute stressor. Because HO also has links to decreased levels of triglycerides, we tested the hypothesis that an acute stressor increases HO expression, which would concomitantly decrease circulating lipid levels. House sparrow (*Passer domesticus*) nestlings exposed to a stressor had reduced circulating triglycerides consistent with an increase in rate of gluconeogenesis during an acute stressor. Concentrations of triglycerides were also negatively correlated with HO expression in the liver, which is consistent with mammalian studies. However, contrary to our predictions, exposure to a stressor did not affect HO expression, or biliverdin concentration in liver, spleen, or kidney. Overall, our results support a link between HO expression and triglyceride levels, though the molecular pathways connecting these two metrics still need to be elucidated.

18-4 BUTLER, JM*; HERATH, E; WHITLOW, SM; RIMAL, A; MARUSKA, KP; Louisiana State University; *jbutl48@lsu.edu*
Honey, I Ate the Kids: Role of Galanin in Maternal Care, Infanticide, and Energetics in a Mouthbrooding Fish
Galanin is a conserved neuropeptide involved in parental care and feeding. Ablation of preoptic area (POA) *gal* neurons induces infanticide behaviors in mice, while activating POA *gal* neurons promotes parental care. Within the mammalian arcuate nucleus (Arc), *gal* acts to promote feeding. Mouthbrooding is an extreme form of parental care in which the parent carries the developing offspring in their buccal cavity for the duration of development. In the cichlid fish *Astatotilapia burtoni*, females brood their young for ~2 wks, during which time they refrain from eating. After release of juveniles, females perform maternal care by collecting them into their mouth when threatened. Maternal care is observed for several days post-release, but females will cannibalize their brood after ~5 days. As such, maternal care and feeding are integrally linked. To examine the role of *gal* in feeding and maternal care, we collected 5 groups of females: (1) mouthbrooding for 12 days; (2) starved for 12 days; (3) fed for 12 days; (4) females displaying post-release maternal care; and (5) females who cannibalized ~50% of their brood. In *A. burtoni*, *gal* is expressed in the POA and lateral tuberal nucleus (NLT, Arc homolog). Although the number of *gal*-expressing cells does not vary among conditions, activation of *gal* neurons is condition-dependent. Females displaying maternal care have more activated POA *gal* neurons. In contrast, fed females have high activation of NLT *gal* neurons, with little to no activation in brooding fish. Preliminary results suggest that females displaying infanticide have little to no activation of POA *gal* neurons. Overall, these data suggest a functional conservation of *gal* across vertebrate taxa with POA *gal* neurons promoting maternal care and NLT *gal* neurons promoting feeding.

P1-234 BUTLER, JM; WAYNE, CR*; MARUSKA, KP; Louisiana State University, Baton Rouge; *cwayne1@lsu.edu*
If fish could talk: Using cartoons and comics to disseminate and enhance science literacy
Hi everyone! My name is Burt. I'm a cichlid fish from the Maruska lab at LSU. Did you know that education outreach and public engagement helps scientists expand the reach of their work and make it more relevant to society? Most people do this through public talks and dialogue-focused forums in which scientists and the general public participate in interactive opportunities for exchange. Despite an increase in communication and accessibility to scientific knowledge, it is difficult to keep the public engaged when presented with traditional scientific literature. Those fancy papers you scientists all write are highly stylized, difficult to read even among experts, and intimidating for the general public. That's where I come in! My friends - Toni, Tyrone, and Gilgamesh – and I have a public blog. The blog is written from our perspective, the fish, and explains basic fish science, neuroscience, and the research being done in the lab. Our research scientists are also in the process of creating a comic book based off the labs published literature. Their goal is changing the publics' perception of their own ability to understand scientific literature while also educating them about how science is relevant to their lives. To test this, they are conducting a pilot study to assess understanding and perception of research presented in two different formats: (1) the original scientific article, and (2) a comic book based on the article. To facilitate and maintain scientific literacy, the same information in scientific articles should be presented in more accessible formats. Come check out our poster to meet me, Toni, and Gilgamesh, and to get a sneak peek at the comic book!

P2-41 BYRNE, MZ*; ROSENBLOOM, JE; BHALODI, JA; GIGNAC, PM; GIDMARK, NJ; Knox College, Galesburg, IL, Vanderbilt University, Nashville, TN and Knox College, Galesburg, IL, Oklahoma State University Center for Health Sciences, Tulsa, OK; *mzbyrne@knox.edu*
Reconciling Anatomical and Physiological Models of Feeding Biomechanics Through Evolution in Centrarchid Fishes
Prey capture in fishes spans a continuum between ram- and suction-feeding. Ram feeders approach their prey at high speeds, snapping the jaw shut to secure their meal, whereas suction feeders rapidly expand the buccal cavity, forcing their food and the water around it into the mouth. An organisms' ability to be successful in prey capture in the wild is determined partially by jaw-closing force and jaw-closing velocity; these organismal metrics are in turn directly limited by muscle performance, such as the physiological limits of muscle's instantaneous length and shortening velocity. We empirically tested the interplay of jaw-closing velocity, force, and gape angle across five Centrarchid species that represent multiple points on the ram-suction spectrum. We found that ram-feeding fishes (largemouth bass and green sunfish) have faster jaw-closing muscles at a given force, and faster muscles overall than suction feeders (bluegills, redear sunfish). Preliminary analyses of the CT data for these species indicate that ram feeders have lower mechanical leverage (i.e. faster skeletal leverage) for jaw adduction than suction feeders. We are now developing a model to predict length-tension and force-velocity physiology using CT and diceCT data for all 47 species of the family Centrarchidae. Our goal is to examine the musculoskeletal anatomy and evolution of the jaw closing system across this iconic group.

P3-165 BYRNES, G*; LIM, NTL; Siena College, National Institute of Education, Nanyang Technological University; *gbyrnes@siena.edu*
Membrane shape changes during gliding in flying squirrels
Gliding has evolved at least nine times in mammals. Despite the diversity of gliding mammals, their convergent morphology and resulting mechanisms of aerodynamic control are poorly understood. Gliding animals are capable of a wide variety of agile aerial behaviors and their flight performance depends on the aerodynamic forces resulting from airflow interacting with a flexible, membranous wing (patagium). Despite the importance of this structure in the control of these animals' defining behavior, little is known of the posture or shape of the patagium during flight. To this end, three-dimensional patagium shape was characterized during glides of three flying squirrel species using a variety of structured light methods, including off the shelf depth cameras and projector camera pairs. Preliminary results show that membrane shape changes over the course of the glide. In particular, both camber and anhedral/dihedral of the wing change during glides. Understanding the shape changes of the patagium throughout a glide is a first step to understanding mechanisms of aerodynamic force control over the flexible wings of gliding mammals.

21-3 CADE, D E*; CAREY, N; DOMENICI, P; POTVIN, J; GOLDBOGEN, J A; Stanford University, Scottish Association of Marine Science, IAS-CNR, Istituto per l'Ambiente Marino Costiero, Saint Louis University; *davecade@stanford.edu*

Predator-informed looming stimulus experiments reveal how large filter feeding whales capture highly maneuverable forage fish

Forage fish have been involved in evolutionary tug-of-wars with predators for more than 100 million years yielding finely balanced predator-prey interactions with thin margins for error. Engulfment predation by gigantic filter feeding whales, in contrast, is a relatively recent (< 5 Ma) phenomenon that typically occurs at extreme predator-prey size ratios that mitigate the effect of prey escape responses (e.g. microphagy on krill). Rorqual whales, however, also commonly hunt forage fish whose performance capabilities suggest that they should easily evade whale-sized predators. To address this paradox we determined, in a laboratory setting, when individual anchovies initiated escape from virtually approaching whales, then used these results along with in vivo humpback whale attack data to model how predator speed and engulfment timing affected capture rates. Anchovies were found to respond to approaching visual looming stimuli at expansion rates that give ample chance to escape from a sea lion-sized predator, but humpback whales could capture as much as 40-50% of a school at once because the increase in their apparent size does not cross their prey's response threshold until their jaws are already rapidly expanding. Humpback whales are thus incentivized to delay engulfment until they are very close to a prey school, even if this results in higher hydrodynamic drag. This potential exaptation of a microphagous filter feeding strategy for fish foraging enables humpback whales to achieve nearly 7x the energetic efficiency (per lunge) of krill foraging, allowing for flexible foraging strategies that may underlie their ecological success in fluctuating oceanic conditions.

P3-240 CAHILL, AE*; BREEN, C; STANDER, R; JOST, S; HERNANDEZ, R; Albion College, Albion Colleg; *acahill@albion.edu*

Seasonal differences dominate spatial ones in an inland salt marsh community

Inland salt marshes are a rare habitat in North America, and in the Great Lakes region they are formed from Devonian salt deposits that are close enough to the surface to impact the plant community. However, little is known about the invertebrate community that lives there. To investigate spatial and temporal changes in an inland salt marsh in Maple River, we used transect sampling coupled with COI metabarcoding and morphological identifications in April, July, and October of 2018. Although the effect of space (distance from the salt seep) was important within seasons, there is a stronger seasonal effect. Summer sampling is notably different from spring or autumn, most likely due to the amount of water in the marsh. Diversity metrics change with salinity, but in a way that varies based on season and datatype.

P2-6 CAINE, P/B*; GIBSON, J/D; Bucknell University, Lewisburg Pennsylvania, Georgia Southern University, Statesboro Georgia; *pbc008@bucknell.edu*

Colony Recognition and Aggression in Invasive Argentine Ants (Linepithema humile)of Georgia

An invasive species with introduced ranges worldwide, Argentine ants outcompete local ant species, instigating potentially drastic changes in their introduced ecosystems and threatening the Georgia intercoastal plains. One factor enabling their success is the formation of "supercolonies" in introduced ranges, including a global supercolony with members across California, Japan and Europe. Though in their native range each colony aggressively defends one small territory from other colonies, this aggression occurs less in introduced ranges. Because Argentine ants recognize colony-mates by smelling hydrocarbons embedded in each ant's cuticle, and hydrocarbon differences are likely genetically based, one hypothesis for why Argentines form supercolonies invasively and not natively is that a genetic bottleneck occurred during introduction to new ranges, causing a subsequent loss in cuticular hydrocarbon diversity in introduced populations. This would limit each colony's ability to distinguish outsiders, and may be responsible for supercolony formation. To test this, we collected Argentine ants from 6 nest-sites across Georgia, extracted DNA from members of each nest-site, and amplified 8 microsatellites in order to understand our populations' genetic history. We also ran behavioral assays, pairing ants randomly, and observing interactions for three minutes. By combining the behavioral and genetic data, this project investigates how genetic diversity affects aggression.

13-7 CALEDE, J; The Ohio State University, Marion, OH; *calede.1@osu.edu*

Evidence for a Semi-Aquatic Ecology in a 30-Million-Year-Old Beaver and the Evolution of Locomotion in Castoridae

The family Castoridae is today represented by only two species, the Eurasian and the North American beavers. Both animals are large semi-aquatic rodents. The fossil record includes many more species; 70 are known from North America alone, some in deposits as old as 37 million years. The bulk of this diversity arose 30 million years ago with the evolution of many burrowing species. The oldest North American semi-aquatic rodent, the beaver *Monosaulax*, is 18.8 million years old. Despite the wealth of data on the locomotion of many burrowing beavers of the Oligocene and the semi-aquatic ones of the mid-Miocene to today, castorid evolutionary ecology remains enigmatic; the oldest species of beavers are known only from fragmentary craniodental remains. I here present the oldest postcranial remains of an anchitheriomyine beaver dated to 30 million years ago discovered in Montana. The dentition indicates that this animal is a new *Microtheriomys* species. I use a multivariate analysis of astragalus shape to infer its locomotory ecology. Based on a training set including 259 specimens representing 117 species of extant rodents and fossil beavers with known locomotion, I determine that *Microtheriomys* represents the oldest semi-aquatic rodent in North America. I also provide the first quantitative determination of the locomotion of three additional beaver species and the castoroid *Eutypomys*. I include the results of this ecomorphological analysis into an updated phylogenetic framework for 33 castoroid species with known locomotion. My ancestral character state reconstruction shows the evolution of the semi-aquatic ecology only once from terrestrial ancestors but hints at a more complicated evolution of burrowing.

P3-229 CALLE, E*; SCHENKER, E; DUPREZ, D; MYERS, M; LEE, V; GILCHRIST, SL; New College of Florida;
erika.calle16@ncf.edu
Adding STREAM to a Study Abroad Program in Honduras
High Impact Practices (HIPs) can propel students into STEM careers with a sense of confidence. Incorporating a common intellectual experience through study abroad offers a strong venue for HIPs such as collaborative assignments, research, global learning, and writing-intensive activities. Combining science, technology, engineering and math with the arts provides a well-rounded experience for students. However, there must also be an additional level of engagement including cRitical thinking and wRiting (STREAM). The Coral Reef Issues course brings students from the Arts and Sciences together to explore a reef system in an abroad setting. A series of readings and EXCEL exercises provides a common platform for the students. Each participant writes essays on selected topics, completes a critique of a science or science-related art paper from primary literature, and presents a PowerPoint on a research project completed in Honduras. Students also participate in service learning by working with local villagers to do two beach clean-ups. The readings incorporate both science and art. Students are introduced to the notion of allometry to understand architecture of shells and other objects. The montage of landscape is an excellent way to engage students in understanding elements and architectural guidelines. Projects this year ranged from examining wound healing of sponges to creating an art portfolio of Cayos Cochinos.

P3-170 CALLEGARI, K*; SHANKAR, A; SEITZ, T; DROWN, D; WILLIAMS, C; University of Alaska Fairbanks;
callegarikyle@gmail.com
Effects of Short Photoperiod and Carbohydrate Consumption on the Gut Microbiome of Diurnal Grass Rats
Circadian disruption in tandem with high-fat and high-sugar diets can cause sleep disruption and alter the composition of gut microbiota. This shift in gastrointestinal microbial homeostasis can alter signaling pathways and central nervous system function, causing or amplifying depressive behavior or disorders. Unlike common model systems, the African grass rat (Arvicanthis niloticus) is diurnal potentially making it a more appropriate system for studying the consequences of sleep disruption. The aim of this project is to examine the effects of altered photoperiod, associated sleep disruption, and sucrose consumption on the composition and diversity of the intestinal microbiome. We found that exposure to short photoperiods (4:20 Light:Dark) significantly altered sleep and activity patterns relative to neutral (12L:12D) controls, but did not have a significant effect on sucrose consumption. We predicted that exposure to shortened photoperiod and sucrose consumption will exhibit synergistic effects on gut microbial diversity. To test this prediction, we used 16S rRNA gene sequencing of fecal samples to characterize shifts in microbial community. In a subset of individuals, we used long read nanopore sequencing to explore changes in functional composition of the gut microbiome through different stages of photoperiod and diet treatments. Our findings will contribute to understanding of direct and indirect influences of photoperiod on the gut microbiome and will inform future studies examining how circadian disorganization, sleep disruption, and diet interact to affect mental health via the microbiome-gut-brain axis.

72-2 CAMARILLO, H*; MUñOZ, MM; Yale University;
henry.camarillo@yale.edu
Macroevolutionary patterns of morphological diversification in wrasses
In order to survive, grow, and reproduce organisms must interact with their physical environments through their morphology. A major question in evolutionary biology is whether patterns of form-function evolution are shared among different suites of morphological traits. For example, do we see traits associated with specific modes of feeding and swimming evolving in correlated or uncorrelated fashion? Using previously published datasets for species in the family Labridae, we compiled a list of morphological traits associated with different aspects of motion (feeding and swimming). Due to a large diversity in reef ecology within the wrasse family, labrids are an ideal system to test for correlated patterns of evolution between traits. Here, we use the program Bayou to reconstruct phylogenetic patterns of trait evolution for several morphological features, including cranial and post-cranial traits. We ask whether major shifts in morphological evolution are shared, or de-coupled, and how these patterns relate to the general ecology of the fishes. This study highlights the importance of a multi-trait perspective in macroevolutionary studies of form-function relationships.

P3-207 CAMILLIERE, M*; MCPHERSON, D/R; SUNY Geneseo;
mcpherso@geneseo.edu
Bimodal Effects of Serotonin on Cardiac Development in Japanese Quail Embryos
The heart is the first organ to develop in vertebrate embryos and is necessary for subsequent development. Disruption of cardiac morphogenesis can result in reduced cardiac function. Serotonin (5-HT), while not usually thought of as a developmental signal, plays an important role in cardiac development. To explore this further, we treated Japanese quail embryos with different concentrations of 5-HT. We chose to study quail because bird eggs are accessible to experimentation and quail embryos are small, can be imaged as whole mounts in a confocal microscope, and they are similar to mammals in cardiac development. After incubation for 52-64 hours (stage 17) ventricular septation is just beginning. We removed eggs from the incubator at this stage and injected them with a dose of 5-HT (2 mM in Tyrode's solution). We replaced a small volume of the albumen with the serotonin solution to achieve concentrations of serotonin ranging from 0-100 µM. After a total of six days of incubation, we dissected the hearts out of the embryos, fixed them in 4% formaldehyde, cleared them in BABB, and imaged them under a confocal microscope. We selected image slices from the middle depth of the heart and measured the length and width of the heart, the right and left ventricular wall thicknesses, and the septum thickness. Analysis of the data revealed interesting trends. A 5-HT concentration of 1 µM increased the length to width ratio, indicating a more elongated heart. The thickness of the septum increased at 10 µM but decreased below the control thickness at 100 µM. The ventricular wall thickness displayed a trend similar to septum thickness but to a lesser degree. Overall, stimulation of growth occurred at low doses while higher doses inhibited growth.

125-1 CAMPOS, S M*; ROJAS, V; WILCZYNSKI, W; Georgia State University, Universidad del Bío-Bío, Concepción; Universidad Catolica del Maule; *scampos1@gsu.edu*

Arginine vasotocin stimulates chemical communication and social behavior in Anolis carolinensis lizards

Social interactions in nonmammalian vertebrates are modulated by arginine vasotocin (AVT), which functions similarly to its mammalian homologue, vasopressin. AVT impacts the performance of and response to visual signals in reptiles, but whether AVT also operates within the chemosensory system as it does in mammals is unknown, despite social odors being potent modifiers of aggressive and reproductive behavior. Previous studies in green anoles (*Anolis carolinensis*) linked elevated levels of exogenous AVT in males (AVT-males) to lower rates of aggressive visual displays, whereas untreated females visually displayed to AVT-males more than to saline-treated Control-males. Here, we test whether exogenous AVT in Resident-males impacts the chemosensory or locomotor behavior of conspecifics (Intruders). We injected Resident-males with either AVT or a Control solution, and after 10 mins alone in their home tanks, we presented Resident-males with an untreated Intruder (male or female) for 30 mins. We found that Intruder-males performed more chemical behavior towards AVT-males than to Control-males, whereas AVT-males responded with a chemical display to Intruder-females faster than did Control-males. In contrast, visual behavior did not differ between treatment groups for either Resident-males or Intruders in this experiment. Our results demonstrate for the first time that AVT modulates chemosensory behavior in reptiles, having important evolutionary implications regarding multimodal communication and the mechanisms used by AVT to modulate animal interactions.

P2-19 CANADAY, EJ*; BROTHERS, CJ; SMITH, KE; AMSLER, MO; ARONSON, RB; SINGH, H; MCCLINTOCK, JB; Southern Adventist University, Walla Walla University, University of Exeter, University of Alabama at Birmingham, Florida Institute of Technology, Northeastern University; *ecanaday@southern.edu*

Underwater Islands: The Influence of Surrounding Sediment on Dropstone Ecology

Dropstones deposited on the ocean floor by melting icebergs can act as islands of hard substrate in the surrounding sediment. While dropstones are deposited across the ocean, their effects on benthic macrofaunal biodiversity are best understood on muddy substrates. During a photographic survey of the seafloor on the continental shelf and slope off the western Antarctic Peninsula in 2013, we imaged nine benthic transects in depths between 400 and 2100 m. We recorded the diversity of macrofauna inhabiting areas with and without dropstones, as well as the percentage of hard substrate making up the surrounding area. The abundance of many macrofauna including bryozoans, glass sponges, and sea stars varied according to the percentage of hard substrate making up the seafloor. Across all substrate categories, the presence of dropstones significantly increased the abundance of macrofauna, with the effect most pronounced in areas primarily comprised of hard substrate (>70%). These results suggest that settling on or near dropstones is advantageous to many macrofauna, regardless of the composition of the surrounding sediment.

P2-126 CANNIZZARO, D*; NAUGHTON, L; PASK, G; Bucknell University; *dnc008@bucknell.edu*

Making Sense of Evolution: Deciphering the Rapid Expansion of Ant Pheromone Receptors

Social insects rely heavily on their ability to decode specific olfactory cues, particularly cuticular hydrocarbons (CHCs). CHCs are critical for the maintenance of complex caste systems and dictating social behaviors such as nestmate recognition, coordinated foraging, and queen-only reproduction; all major factors in the success of the colony. For primitive eusocial organisms, such as our model ant *Harpegnathos saltator*, there are complex behaviors such as flexibility within the caste, that therefore require diverse detectors to discriminate a multitude of different signals. To better assess the effects of molecular evolution on olfactory sensitivity, due to the constant evolutionary pressure these CHC receptors are under, we will investigate the 9-exon subfamily of odorant receptors that has undergone a rapid expansion in ants and other social insects. By expressing target olfactory receptor genes of *Harpegnathos saltator* in *Drosophila melanogaster*, we will be able to characterize pheromonal sensitivity of three specific subgroups of 9-exon olfactory receptors, previously recognized as CHC detectors, using a panel of diverse CHCs. These findings will contribute to a greater understanding of olfactory receptor functional evolution in this communication system, and provide insight for further studies regarding structural differences in where CHC recognition is taking place in these olfactory receptors of eusocial insects.

34-4 CANNON, JT*; KOCOT, KM; VARNEY, RM; EERNISSE, DJ; SPEISER, DI; OAKLEY, TH; UC Santa Barbara, University of Alabama, Cal State Fullerton, University of South Carolina; *joie.cannon@gmail.com*

Target-capture phylogenomics of Polyplacophora and the origins of shell eyes

Chitons possess clusters of sensory cells called aesthetes within their eight overlapping shell plates. In some polyplacophoran species within a large unresolved subgroup, Chitonina, aesthetes are modified to include an eyespot, and in others, aesthetes are present in addition to eyes with a lens and retina. To address the evolution of complexity in chiton eyes, it is necessary to phylogenetically test the relationships between chitons with eyespots and chitons with lenses. Relationships within Chitonina have been difficult to resolve with traditional molecular markers, limiting our ability to test evolutionary hypotheses. To enable us to use ethanol-preserved collections, we took a target-capture approach. We designed a set of 19,980 probes using transcriptome data and predicted exon boundary information using three mollusk genomes (*Lottia*, *Octopus*, and *Crassostrea*). Preliminary maximum likelihood analyses show strong support for super-family relationships, and suggest the possibility of multiple origins for lenses in chitons. However, hypothesis testing and ancestral state reconstructions are necessary to further investigate this result.

S8-8 CAPANO, JG*; BRAINERD, EL; Brown University; *john_capano@brown.edu*

Reaction Forces and Rib Function During Locomotion in Snakes

Locomotion in tetrapods involves coordinated efforts between appendicular and axial systems, as limbs generate ground reaction forces (GRFs) that are transmitted to the axial system. In the absence of limbs, snakes experience locomotor GRFs in fundamentally different ways than their limbed-lizard ancestors. Without GRFs from limbs, the epaxials of early snakes were no longer required to stabilize against torsional GRFs and were modified to generate propulsive forces. These forces must be transmitted into the environment and since snakes locomote on their bellies, their ribs must play an inherent role in GRF transmission. Snakes locomote with at least two kinematic styles: (1) with no static contact points, i.e. lateral undulation, or (2) with static contact points, i.e. concertina, rectilinear, climbing, and sidewinding. Rib motions are crucial to this locomotor versatility: our XROMM work and previous studies show that ribs change cross-sectional body shape, deform to environmental irregularities, provide synergistic stabilization for other muscles, and differentially exert and transmit forces to control propulsion. Ribs are also used for lung ventilation in snakes, and we found that snakes are able to independently and regionally control ventilatory motions. We suggest that snakes co-opted the rib motions of ventilation to dynamically and passively participate in their diverse locomotor modes. Hence, removal of the constraints of limbed locomotion and new mechanics of limblessness may have influenced snake evolution and enabled snakes to modify rib motions to contribute to locomotion in innovative ways. Future comparisons with other limbless lizard taxa are necessary to tease apart the mechanics and mechanisms that produced the locomotor versatility observed within Serpentes.

50-1 CAPANO, JG*; CIERI, RL; WELLER, HI; BRAINERD, EL; Brown University, University of Utah; *john_capano@brown.edu*

Modular Lung Ventilation in Snakes

Most squamates rotate vertebral and sternal ribs to ventilate their lungs, whereas snakes lack sternal ribs and use only vertebral ribs to breathe. Rib rotations are described about a dorsoventral axis (bucket), a craniocaudal axis (caliper), and a mediolateral axis (pump). Our objectives were to use XROMM to quantify rib rotations of *Boa constrictor* during ventilation and compare their kinematics and musculature to three previously studied squamates: *Iguana iguana*, *Varanus exanthematicus*, and *Salvator merianae*. We compared the relative contribution of each rotational axis to overall rib motion by fitting a linear mixed effects model to the variance-normalized centroids. We found that *B. constrictor* breathe with predominantly bucket, with moderate caliper and substantial pump, that bucket and pump are opposite in polarity, and that these motion patterns were significantly different from *I. iguana* and *S. merianae*. In contrast, we found the motions of *B. constrictor* were not significantly different from *V. exanthematicus* and that both use cranial pump rotations during inhalation, opposite the other species. These similarities appear related to derived muscles in *B. constrictor* and *V. exanthematicus*: both have accessory costal muscles that run cranially from each rib to the next cranial vertebrae, i.e. levator costae, whereas the other species do not. Our data suggest that snakes evolved such accessory muscles to breathe without a pectoral girdle, a structure that may synergize with intercostals to rotate the ribs of most squamates. These accessory levator costae appear to enable snakes to breathe with spatially disparate regions of their body. This modular ventilation mechanism may have permitted the evolution of constriction and large prey ingestion in snakes and been a prerequisite to their extensive radiation.

P1-111 CAPSHAW, G*; SOARES, D; CHRISTENSEN-DALSGAARD, J; CARR, CE; University of Maryland, College Park, New Jersey Institute of Technology, University of Southern Denmark; *gcapshaw@umd.edu*

Acoustic reception in salamanders: Skull vibrations enable sound pressure detection

The evolution of a tympanic middle ear was a crucial sensory innovation that enabled terrestrial tetrapods to transduce airborne sound into fluid movement in the inner ear. Without a tympanic middle ear, airborne sound energy is expected to reflect off of the air-skin boundary, and atympanic species such as salamanders have long been considered functionally deaf in terrestrial environments. We measured the auditory sensitivity of salamanders to airborne sound pressure and seismic vibration using auditory brainstem response recording. We assessed several proposed extratympanic pathways for acoustic transmission to the inner ear, including via inertial bone conduction, and the mouth- and lung-ear routes. The resonant capacity of the air-filled mouth and lungs of the tested species had little influence on the range and threshold sensitivity of the ear. We used laser vibrometry to measure sound-induced vibrations in the skull and the substrate and compared our results to a model for sound translation of the skull. We found that threshold level sound pressure-induced vibrations of the skull are sufficient to stimulate the auditory end organs, and likely represent a key mechanism for terrestrial hearing in salamanders.

61-3 CAREY, HV*; REGAN, MD; CHIANG, E; SUEN, G; ASSADI-PORTER, F; University of Wisconsin-Madison; *HANNAH.CAREY@WISC.EDU*

Stable Isotope Assisted Labeling Reveals Seasonal Influence on Microbial Metabolite Incorporation in Ground Squirrels

Diet exerts a major influence on the composition and function of the gut microbiota and, therefore, host-microbial symbiosis. Thirteen-lined ground squirrels have seasonal metabolic cycles comprised of summer feeding - providing substrates for squirrel and microbiota metabolism - and winter fasting - when hibernators metabolize primarily stored fat and microbes have access only to host-derived metabolic substrates (e.g., mucins). To assess how seasonal dietary change affects the hibernator-gut microbe symbiosis, we used stable isotope assisted metabolomics to assess the capacity of the gut microbiota in degrading substrates and generating metabolites that are incorporated into the squirrel metabolome. After oral gavage of active season and hibernating (aroused) squirrels with ^{13}C-inulin (a substrate mammals cannot degrade), changes in ^{13}C:^{12}C ($\delta^{13}C$) are monitored in exhaled CO_2. We found that increases in $\delta^{13}C$ after ^{13}C-inulin gavage are high and similar in spring and summer squirrels, lower in aroused hibernators, and abolished when squirrels are pretreated with microbiota-depleting antibiotics. NMR analysis reveals multiple ^{13}C-labeled metabolites in gut contents, blood and liver of summer and hibernating squirrels including short chain fatty acids, β-hydroxybutyrate and carnitine, among others. Cluster analysis (PLSDA) indicates that liver ^{13}C-metabolites separate by season and by presence/absence of antibiotics. This approach provides a pathway for a molecular-based exploration of the seasonally changing hibernator-microbe symbiosis. Supported by NSF 1558044.

P1-134 CARLSON, TC*; CABRERA-GUZMÁN, EC; FOX, SF; Oklahoma State University; *taylor.carlson11@okstate.edu*
First Documentation of Breeding Aggregations of the Ringed Salamander, Ambystoma annulatum, in Oklahoma, USA

The ringed salamander, *Ambystoma annulatum*, is a cryptic ambystomatid species from the Ozark Highlands and Ouachita Mountains of Arkansas, Missouri, and Oklahoma in the United States. Breeding aggregations have been scientifically documented in Arkansas and Missouri, but not in Oklahoma. Individuals emerge *en masse* from underground burrows to breed in upland, ephemeral, fishless ponds during heavy, extended fall rains. From September to December, 2018, we performed nocturnal field surveys searching for *A. annulatum* at several sites along the Ozark Plateau in Oklahoma. We observed migration of hundreds of adult salamanders to ponds, documented courtship with waterproof digital cameras, marked individuals with elastomer tags, and photographed them to begin mark recapture studies. We found a heavily male biased sex ratio: 460 of the 683 individuals captured were males. We implemented photographic techniques to determine the efficacy of individual identification using pattern variation of the dorsal bands and other distinctive markings. We hope to use these photographic techniques as a less invasive way to identify individuals in the future, as current techniques involve invasive dye injection. This ongoing study has already provided new scientific information and we hope to continue to obtain more data on this understudied species of salamander to aid in its conservation in Oklahoma.

P2-111 CARON, DP*; SCIBELLI, AE; TRIMMER, BT; Tufts University, Medford, MA; *daniel.caron@tufts.edu*
Nociceptive strike behavior in Manduca sexta is mediated by multimodal sensory neurons

The caterpillar *Manduca sexta* produces a highly stereotyped "strike" behavior in response to noxious thermal or mechanical stimuli to the posterior abdomen. This rapid movement is targeted to the site of the stimulus, but the identity of the nociceptive sensory neurons is currently unknown. It is also not known if both mechanical and thermal stimuli are detected by the same neurons. Here we show that the likelihood of a strike increases with the strength of the stimulus. Recordings from nerves innervating the body wall show that sensory neuron spike activity increases rapidly in response to noxious stimuli. Mapping the sensitivity of the body wall to strong thermal stimuli reveals a broad receptive field suggesting a role of the multi-dendritic neurons. Both mechanical and thermal stimuli to the dorsal body wall activate the same spiking unit. Rapidly repeated thermal or mechanical stimuli cause depression of the response which is generalized across modalities. These results demonstrate that individual neurons in the body wall can respond to both strong thermal and mechanical stimuli.

38-6 CARRIER, DR*; BOYNTON, AM; CARRIER, ; University of Utah, School of Biological Sciences, Salt Lake City, UT; *carrier@biology.utah.edu*
The Neck is Part of the Human Core

The axial musculoskeletal core of tetrapods provides a stable base from which limbs exert forces on the environment. The human core is generally thought to be composed of the axial muscles that lie between the diaphragm and pelvic floor and to provide stability for the hindlimbs (i.e., legs). We hypothesized that the human core is actually composed of all the axial muscles extending from the pelvis to the skull. To test whether cervical muscles play a role in core stabilization, we used surface electromyography to measure the activity of a set of neck and jaw muscles during force manipulations of maximum effort counter-movement jumps. To determine whether cervical muscles function during jumps to control posture of the head or to assist in stabilization of the pelvis against the moments applied by the leg retractor muscles we compared muscle activity during control jumps to jumps in which we (1) reduced peak accelerations by approximately 30% by pulling downward on the subject's hips with elastic tethers, and (2) increased the mass of the head by approximately 100%. When subjects jumped with increased downward force, or with mass added to their heads, maximum and integrated activity of neck and jaw muscles was not different from that recorded during control jumps. 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 neck muscles contribute to core stability in response to moments imposed on the pelvis by the extrinsic muscles of the leg. The observation that neck muscles provide stability for the legs of humans has implications to the locomotor function of the tetrapod neck, prevention of spinal injury, and treatment of chronic cervical and back pain.

60-6 CARRUTHERS FERRERO, A*; OZKAN AYDIN, Y; GOLDMAN, DI; Georgia Tech; *alexandra.carruthers@gatech.edu*
Lateral bending and buckling aids earthworm locomotion in confined environments

Earthworms locomote in confined spaces and underground via retrograde peristaltic gaits where a transient substrate anchor is formed by the contraction of longitudinal muscles. Here, via laboratory studies of the earthworm *Lumbricus terrestris*, we reveal how the locomotion ability of the worms is enhanced via lateral bending and buckling of body segments. Depending on absence or presence of contact between the animal's body and environment, worms control the shape of their slender-flexible bodies (usually bending tip or tail) to generate thrust and maneuver in three dimensions. To study the benefits of this behavior, we allowed the earthworms ($L = 26.95 \pm 6.18$ cm and $m = 7.49 \pm 2.04$ g, $n = 10$) to crawl in a large acrylic tube ($d = 1.0$ cm, $l = 1$ m, $d >$ worm diameter) while varying the tube angle from 0 to 90°. We calculated the average body length per gait cycle (BL/cyc) over several cycles. At a 0° incline, the worms had the largest (0.201 ± 0.075) BL/cyc and mostly moved by peristaltic gait. The worms had the lowest (0.076 ± 0.016) BL/cyc at a 90° incline but could still climb without significant slipping. At higher degree angles, such as 75 and 90°, the body bending was more prevalent than at lower angles, providing extra anchoring points for the forward locomotion and reducing the occurrences of slipping. Our results reveal that adequate control of body shape can help limbless terrestrial animal locomote in diverse environments. Moreover, this movement strategy has aided design of the control system of a soft earthworm-inspired robot.

P2-30 CARSON, IR*; HALL, HR; KAHRL, AF; JOHNSON, MA; Trinity University, San Antonio, University of Virginia, Charlottesville, Stockholm University, Sweden; *icarson@trinity.edu*
Intraspecific Variation in Lizard Sperm and Testis Morphology
The production of functional sperm is the primary task of the testis, yet we know relatively little about the relationship between testis architecture and sperm morphology. Lizards in the genus *Anolis* (i.e., anoles) provide an excellent group in which to study spermatogenesis because they exhibit remarkable variation in sperm size both within and among species. Still, whether variation in testis composition is associated with variation in sperm morphology within species is unclear. For example, do individuals with larger testes produce longer sperm, and what components of the testis influence sperm size? In this study, we examined 15-20 males of six species of anoles from the Dominican Republic and Puerto Rico. For each lizard we measured the cross-sectional areas of testes, seminiferous tubules, and of the lumina within the seminiferous tubules of cryosectioned testis tissue. We also measured sperm head, midpiece, and tail lengths for each individual. We found that intraspecific correlations between testis size and tubule and lumen size were generally positive, although the strength of these correlations varied among species. Likewise, correlations between testis components and sperm measures were variable among the six species. These preliminary results suggest that even closely-related species and individuals within a species may vary in the mechanisms of spermatogenesis.

P3-156 CARTER, D.*; LEE-ROBINSON, B.; WILLIAMS, T.; FARINA, S.; Howard University; *dariuscarter98@yahoo.com*
Evolutionary Morphological and Behavioral Specializations for Jet Propulsion in Frogfishes
Frogfishes (Antennariidae) are a family of anglerfishes (Lophiiformes) that are capable of jet propulsion, a type of locomotion that involves shooting a jet of water out the gill openings to propel forward. Using the gill ventilation system, these organisms can avoid stereotypical locomotor movements that may be visual cues to predators and prey. Jetting is primarily accomplished by adduction of the opercular bones and branchiostegals, which compresses the gill chamber. Frogfishes have abnormally large branchiostegals for both jetting and gill ventilation. Our study aims to map the evolution of the size of branchiostegals among frogfishes to determine which rays are shaped by demands of jet propulsion and to determine the timing of movements of structures during jet propulsion. We grouped six branchiostegal rays into three groups of two, numbered anteriorly to posteriorly, and predicted rays 1-2 are used for inhalation, 3-4 are used for jet propulsion, and 5-6 are used for exhalation. CT scans and dissections were used to measure the rays, and phylogenetic generalized least squares models were used for comparisons. We found that branchiostegals within the same group were the same size (relative to head size), but there was a significant size difference among branchiostegals in different groups. Therefore, we concluded that each group of branchiostegals is evolving independently from the others. Additionally, we used video analysis to show that jet propulsion is dominated by compression, providing a long jetting phase, facilitated by branchiostegals three and four.

74-7 CARTER, AW*; SHELDON, KS; University of Tennessee; *acarte82@utk.edu*
The Climate Variability Hypothesis Predicts Thermal Plasticity Across Life Stages of Onthophagus taurus Dung Beetles
Most organisms live in thermally variable environments and climate change stands to increase this variation. However, studies often utilize constant temperatures and focus on a single life stage, which may undermine the accuracy of climate change predictions. One hypothesis that has been utilized to help predict organismal responses to temperature fluctuation is the climate variability hypothesis (CVH), which posits that increased temperature variation selects for increased thermal plasticity. Though the CVH has been tested along natural temperature gradients (e.g. latitude), it may also predict thermal plasticity across discrete life stages that experience varying degrees of thermal fluctuation. Here, we test the CVH across life stages of *Onthophagus taurus* dung beetles; pupa develop underground buffered from temperature extremes, whereas adults also inhabit open fields and dung pats with substantial temperature fluctuation. We reared F_2 full-siblings in either high (24 ± 8°C) or low (24 ± 4°C) temperature fluctuation treatments and quantified thermal plasticity at pupal and adult life stages. We compared shifts in thermal sensitivity of metabolism among treatments and life stages by measuring CO_2 production at 15, 20, 25, and 30 °C in pupae and adults. We found that adults exhibited thermal plasticity and pupae did not, supporting the CVH. In response to thermal variability, adults exhibited metabolic depression, which should conserve energy in fluctuating temperatures. This novel application of the CVH underscores the importance of considering stage-dependent thermal responses in climate change forecasting; predictions that are not based on the most critical life stage may overestimate the likelihood of persistence.

P2-92 CARTY, T*; PHILSON, C; DAVIS, J; Radford University; *tcarty1@radford.edu*
Sex, Food, and Friends in Daily Life: Learning and Transmission of Knowledge in Captive Zebra Finches
Have you ever gone to a vending machine and found it to be broken? Have you ever seen someone else hitting and yelling at a vending machine? Would you try that vending machine, or do you go the next one? Does it matter if you know the person? Can the same thought processes that underlie your snack choices be found in social populations of animals? This project explores how knowledge about value spreads through a community. In previous studies in our lab and others, birds have been shown to share and utilize information about food values and ease of access. In the current study we specifically explore how knowledge of valuation may be obtained and shared within a community in relation to sex, sociality and pair bonds. This study focused on aviary-housed zebra finches (Taeniopygia guttata) in a space equipped with two computer controlled "smart feeders" that enabled us to both control feeding access and monitor activity. One feeder was filled with high value food, while the other was equipped with less desirable, low value food. We monitored which animals approached the feeders and in what order, then correlated this to pair bonds and previous cage mate associations. We will discuss these findings and ongoing studies exploring patterns of learning when observational ability is restricted. Studying these feeding patterns has implications for mapping social networks and understanding how specific social connections may influence patterns of learning.

P1-37 CASEMENT, B.*; COX, C.; MCMILLAN, O.; LOGAN, M.; Heidelberg University, Georgia Southern, Smithsonian Tropical Research Institute, University of Nevada, Reno; *bcasemen@heidelberg.edu*

The effects of abiotic conditions on activity time in tropical forest lizards, a large-scale field experiment in the Panama Canal

Average global temperature is rapidly increasing and will continue to rise over the next several decades. This warmer climate is forcing organisms to either adapt or face extinction. Thermal specialists, including many tropical forest ectotherms, could be at an increased risk because they have evolved narrow thermal tolerance ranges in the thermally stable tropics. In order to cope with this increasingly hotter climate, animals, such as *Anolis* lizards, may have to alter the amount of time they spend active each day. Ultimately, decreases in activity time will reduce the capacity of individuals to find mates, acquire prey, or engage in other activities that are critical for reproduction. Substantial reductions in activity time may therefore precipitate a large reduction in population size. In order to determine how changes in abiotic variables (such as temperature and rainfall) may impact the activity times of a tropical ectotherm, we transplanted hundreds of Panamanian slender anoles (*Anolis apletophallus*) to eight islands in the Panama Canal, which vary in their abiotic conditions. Between 2017 and 2019, we conducted over 200 systematic surveys of lizard activity on random days and times across these islands. We paired these surveys with detailed measurements of environmental temperature, rainfall, solar radiation, wind speed, and lizard physiology to determine the abiotic factors that affect tropical ectotherm activity. These data will aid predictions for the responses of tropical forest ectotherms to climate change.

P1-114 CASLETON, R*; MORGENTHALER, M; SHAIKH, S; SORGE, M; TUCKER, B; ESSENDRUP, I; BERMAN, S; PEET, MM; AUKES, DM; HE, X; MARVI, H; FISHER, RE; Arizona State University, University of California Los Angeles, The University of Arizona College of Medicine-Phoenix; *Rachel.Casleton@asu.edu*

Chemoreception in Octopus bimaculoides

The goal of this study is to determine the time of onset, duration, and range of movements that occur when different regions of an amputated octopus arm are exposed to a noxious chemical stimulus. Randomized trials were conducted to assess the relative sensitivities of and movements elicited in the proximal oral, proximal aboral, distal oral, and distal aboral regions. It was hypothesized that the oral regions would be most sensitive due to the purported higher density of chemoreceptors on the suckers compared to the rest of the skin. Experiments were carried out on arms from 12 specimens of wild-caught *Octopus bimaculoides*, with five to six arms utilized per specimen. Animal husbandry and experimental protocols were based on guidelines developed by the international cephalopod research community, with ethanol utilized as an analgesic and anesthetic. Fifty percent acetic acid vapor was introduced through diffusion, at a distance of 5-10 mm, to a vertically suspended amputated arm. The movements elicited were video recorded at 30 frames per second and later coded qualitatively and quantitatively. A diverse array of arm movements were elicited, such as bends, helical twists, and shortening. Data were analyzed according to the four regions of stimulus, distal versus proximal regions, and oral versus aboral regions. The effect of arm identity was also examined. These data may provide insights into the degree to which arm movements are controlled by the nerves within the arm versus more centralized control centers, such as the brain or the interbrachial commissure, which connects the axial nerve cords of adjacent arms.

4-4 CASS, JA*; WILLIAMS, CD; KNIJNENBURG, TA; THERIOT, J; Allen Institute for Cell Science, Seattle, Allen Institute for Cell Science, Seattle and University of Washington, Seattle; *juliec@alleninstitute.org*

A Bayesian framework for the detection of diffusive heterogeneity

Cells are crowded and spatially heterogeneous, complicating the transport of organelles, proteins and other substrates. One aspect of this complex physical environment, the mobility of passively transported substrates, can be quantitatively characterized by the diffusion coefficient: a descriptor of how rapidly substrates will diffuse in the cell, dependent on their size and effective local viscosity. The spatial dependence of diffusivity is challenging to quantitatively characterize, because temporally and spatially finite observations offer limited information about a spatially varying stochastic process. We present a Bayesian framework that estimates diffusion coefficients from single particle trajectories, and predicts our ability to distinguish differences in diffusion coefficient estimates, conditional on how much they differ and the amount of data collected. This framework is packaged into a public software repository, including a tutorial Jupyter notebook demonstrating implementation of our method for diffusivity estimation, analysis of sources of uncertainty estimation, and visualization of all results. This estimation and uncertainty analysis allows our framework to be used as a guide in experimental design of diffusivity assays.

31-6 CASSAVAUGH, CM; SZUCH, CP; KEPHART, MK; SEVIGNY, JL; SIMPSON, S; LAMONT, S; CARFAGNO, A; BISHOP, BM; GILLEVET, PM; THOMAS, WK; COOK, GM*; New England College, University of New Hampshire, University of New Hampshire, George Mason University; *gcook@nec.edu*

Bioprospecting for Novel Antimicrobial Peptides in Corals and their Associated Microbiome

Coral reefs are renowned for their high-levels of associated biological diversity. Consequently, myriad reef inhabitants have been prospected for natural products, such as chemotherapeutic and antiviral compounds. Recent advances in culture-independent techniques have provided unparalleled insights into the structure of the coral-associated microbiome but our understanding of its functional role(s) remains incomplete. This gap in knowledge represents a legitimate frontier for seeking additional natural products that aim to improve human health. Given the emergent threat created by antibiotic resistant bacteria (ARB), alternative forms of treatment are needed. Antimicrobial peptides (AMPs) can defend a host against highly-adaptable microbial pathogens. In particular, cationic antimicrobial peptides (CAMPs) have recently gained recognition for their therapeutic potential. Natural selection has served to prescreen CAMPs through evolutionary processes that—for marine taxa such as the deep-water scleractinian *Lophelia pertusa*—have occurred over hundreds of millions of years in extreme environments. To aid in the quest for alternative treatments against ARB, we successfully adapted and employed a novel bioprospecting nanoparticle-assisted proteomics approach to harvest short peptides from specimens of *L. pertusa*. Additionally, we have generated the first known draft of the *L. pertusa* genome to seek the genetic source of putative CAMPs harvested from this coral. Such information will help guide the development of challenge experiments to ascertain CAMP efficacy and mechanism of action against known bacterial pathogens, which could lead to drug development.

P2-248 CASSAVAUGH, CM*; LAMONT, S; SZUCH, CP; CARFAGNO, A; GILLEVET, PM; BISHOP, BM; COOK, GM; New England College, George Mason University; *ccassavaugh_ug@nec.edu*

Combatting Antibiotic Resistance: Bioprospecting for Antimicrobial Peptides in the Deep-Sea Coral Lophelia pertusa

Bioprospecting for antimicrobial peptides (AMPs) has attracted more attention in recent years due to the growing threat of antibiotic resistant bacteria (ARB). The marine environment offers a wealth of untapped potential in the form of novel therapeutic chemical compounds. Scleractinian, or stony, corals are an order of marine organisms whose lineage may date back to the early Paleozoic Era. *Lophelia pertusa*, a member of the order Scleractinia, is a framework-builder for deep-sea coral reefs. This species is currently garnering growing interest due to its global abundance and ability to create highly biodiverse ecosystems. To isolate AMPs, samples of *L. pertusa* were crushed using liquid nitrogen. A protease inhibitor in 10 mM Tris-Cl buffer was added to create a homogenate. AMPs were then harvested from the coral homogenate using functionalized MA6A HA hydrogel microparticle beads that had an anionic charge. These particles attracted, filtered, and isolate small cationic antimicrobial peptides (CAMPs) from the coral homogenate. CAMPs were subsequently eluted, purified, and concentrated to allow for *de novo* sequencing using an Orbitrap Elite mass spectrometer equipped with electron transfer dissociation. Over 1000 peptides were isolated from these purified samples. PEAKS software was used to analyze the peptides and determine the probability of antimicrobial activity. Once available, the new draft genome of *L. pertusa* will be used in PEAKS to confirm, complete, and correct the *de novo* CAMP sequences as well as determine their origin. Putative novel CAMPs harvested from *L. pertusa* can then be synthesized, which could lead to trials that test their effectiveness against known ARB.

P2-177 CAVEY, LT*; SECOR, SM; University of Alabama; *ltcavey@crimson.ua.edu*

Larger Meals Generate a Disproportionate Greater Cost of Digestion

Mandatory to meal digestion is the expenditure of energy stemming from the breakdown, absorption and assimilation of that meal. The magnitude of this collective energy expenditure, termed specific dynamic action (SDA), is largely a function of meal size. Predictably, any increase in meal size would generate a corresponding increase in SDA. However, unknown is the nature of this relationship. Hypothetically there are three possible scenarios: (1) increase in SDA is matched to the increase in meal size; (2) SDA increases at greater rate compared to the increase in meal size; and, (3) SDA increases at a lesser rate compared to the increase in meal size. We tested among these competing hypotheses by feeding snakes different size meals (5-25% of body mass) and quantifying for each meal size the maximum postprandial metabolism, duration of significant metabolic response, and SDA. We quantified for each of these variables a response coefficient, defined as the factorial increase of that response with a doubling in demand (i.e. meal size). For four species of pythons (*Python molurus, P. sebae, P. reticulatus, Morelia viridis*), four species of boas (*Boa constrictor, Eunectes murinus, Eryx colubrinus, Epicrates cenchria*), and the colubrid *Pantherophis guttata* the response coefficient for maximum postprandial metabolism averaged 1.41 (1.23-1.70) and for duration averaged 1.47 (1.15-2.13). The response coefficient for SDA averaged 2.35 (1.85-2.90). For these snakes, a doubling in meal size resulted on average in a 41% increase in peak postprandial metabolism and a 47% increase in duration that combined to generate a 135% increase in SDA. These findings support the second scenario that with an increase in relative meal size, snakes spend a disproportionately greater amount of energy in digesting and assimilating larger meals.

61-2 CAVIEDES-VIDAL, E*; BRUN, A; MAGALLANES, ME; BARRET-WILT, GA; KARASOV, WH; Consejo Nacional de Investigaciones Científicas y Técnicas - Universidad Nacional de San Luis, Universidad Nacional de San Luis, Consejo Nacional de Investigaciones Científicas y Técnicas, University of Wisconsin-Madison; *enrique.caviedes@gmail.com*

Dietary Adaptation to High Starch Involves Increased Abundance of α-Glucosidase and its mRNA

Dietary flexibility in digestive enzyme activity is widespread in vertebrates, but mechanisms are poorly understood. Fragmentary evidence indicates that laboratory rats modulate intestinal α-glucosidase (AG) activity mainly by relying on rapid increase in enzyme transcription followed by translation and translocation to the intestine's apical, brush border membrane (BBM). We performed the first unified study of this overall process, relying on activity, transcriptomic and proteomic data from the same animals. We used as our model nestling house sparrows (Passer domesticus), which increase their intestinal AG activity as they switch naturally from low starch insect diet to higher starch seed diet. Twenty-four hours after a switch to a high starch diet, intestinal AG activity and mRNA were increased. The protein sucrase-isomaltase (SI), which is responsible for all maltase and sucrase activity, was the only hydrolase increased in the BBM, and its abundance and activity were positively correlated. This is the first demonstration that birds may rely on rapid increase in enzyme abundance when adjusting to high starch diet.

81-4 CEJA, AY*; WAY, MJ; KANE, SR; University of California, Riverside, NASA Goddard Institute for Space Studies, New York, NY; *aceja005@ucr.edu*

PEACH: The Physiology Exoplanet Astroecology model for Characterizing Habitability

A primary objective of astrobiology is to identify habitable exoplanets. Here, I apply an integrative approach between astrophysics, climate modeling, and ecophysiology to explore the relationship between alien environments and terrestrial life. I discuss the development of a novel system to be used as a tool to assess the habitable regions on exoplanet surfaces. In this model, simulated exoplanet environments are convolved with a real biological layer. Exoplanet environments are simulated using the climate model, Resolving Orbital and Climate Keys of Earth and Exoplanet Environments (ROCKE-3D, Way et al. 2018). ROCKE-3D is a fully-coupled 3-dimensional oceanic-atmospheric general circulation model (GCM) featuring interactive atmospheric chemistry, aerosols, the carbon cycle, vegetation, oceans, sea ice, and land surface components. The GCM output is coupled in the astroecology model with empirically-derived thermal performance curves of 1,627 cell strains representing extremophiles from all six Kingdoms, termed the biokinetic spectrum for temperature (Corkrey et al. 2016). The spectrum arises from a meta-analysis of cellular growth rate as a function of temperature. In this agent-based model, created with the software NetLogo, the survivability of an organism is determined by its thermal response to simulated temperatures. This model can be applied to predict exoplanet conditions compatible with terrestrial-based thermophysiology, as well as surface maps highlighting potentially habitable regions. Life, however, is dependent upon multiple variables including the presence of liquid water, nutrient content, and an energy source. Caveats of the methodology and application of results are discussed with implications for observable biosignatures.

6-2 CELLINI, BO*; MONGEAU, J-M; The Pennsylvania State University; *boc5244@psu.edu*

Flexible visual control of gaze via head saccades in Drosophila flight

Flying insects guide their body by generating smooth movement and rapid, ballistic turns, named "body saccades". After the onset of a body saccade, an ensuing head saccade presumably helps to stabilize gaze more rapidly by reducing the period of motion blur. Whereas the visual control of body saccades has been described previously, less is known about the dynamics and control of head saccades and whether head saccades can operate independently from the body. Specifically, can head and body saccades be uncoupled? We investigated yaw head saccade dynamics and control during the optomotor response in rigidly tethered *Drosophila* in virtual reality. Head saccade dynamics were stereotyped for a moving panorama, however saccade speed and rate decreased for a static panorama, suggesting influences of visual motion. Head saccades were almost entirely anti-directional with respect to visual motion direction, suggesting that they act to 'reset' visual gaze. Reset saccades allow flies to maintain low retinal slip speed as flies are physically unable to maintain a fixed velocity due to the restricted range of motion in yaw. Head saccades were triggered when the temporal integral of the retinal error reached a threshold, rather than by absolute retinal position error. This result suggests an integrate-and-fire trigger. More than 60% of head saccades were triggered independently of Δwingbeat amplitude spikes, suggesting uncoupled trigger of head and body saccades. For synchronous wing-head saccades, the wings led the head by 5 ms, but approximately 25% of head and wings saccades occurred in opposite directions. Our results point to convergent mechanisms for visual control of head and body saccades. We propose a parallel control system for visual control of head and body saccades.

127-5 CERDA, PA*; CROWE-RIDDELL, J; LARSON, JG; NAGESAN, R; CALLAHAN, S; RABOSKY, DL; DAVIS RABOSKY, AR; University of Michigan; *pacerda@umich.edu*

Comparisons of Interspecific and Intraspecific Variation in Rear-Fanged Snake Venom Expression

Understanding the evolution of a highly variable trait among species can be difficult if an inaccurate trait value is assigned. One such trait that contains tremendous variation is venom, a toxic substance typically used by organisms for prey capture and/or defense. Variation in venom composition among snake species is attributed to strong selective pressures acting on venom genes and gene families which result in restructured gene families and changes in expression. Furthermore, venom is known to be variable within a species, often due to geographic variation among populations. Additionally, ontonogenic shifts in venom composition and short-term changes in venom expression after feeding contribute to variation in venom within an individual. Due to these sources of intraspecific variation, it might be difficult to make generalized statements about the venom composition of a single species and make comparisons across species. However, it is also possible that within-species variation is fairly low despite sampling variation in location, age, or feeding status. Here I describe the venom expression profiles of several species of rear-fanged snakes, which until recently had been largely understudied, and compare among and within species variation to determine if an accurate trait value can be assigned regardless of potential sources of variation.

P1-220 CHADWELL, BA; OLSON, RA*; MONTUELLE, SJ; WILLIAMS, SH; Idaho College of Osteopathic Medicine, Ohio University, Ohio University Heritage College of Osteopathic Medicine, Ohio University Heritage College of Osteopathic Medicine; *ro603313@ohio.edu*

FeedCycle: Facilitating rapid post-processing of XROMM data from mammalian feeding experiments

XROMM studies of mammalian feeding have produced a daunting amount of kinematic data. From temporomandibular joint kinematics to individual tooth cusp trajectories, there are a myriad of ways to quantify the movements that occur during feeding in mammals. To facilitate and standardize post-processing of XROMM data, consisting of synchronized movements of craniomandibular joint coordinate systems (JCS; i.e., rotations and translations) and locators, we developed FeedCycle, a metadata management and data analysis program. FeedCycle uses the gape cycle, determined from Rz (jaw open/close), and intra-cycle phases, determined from the second derivative (acceleration) of Rz, as the basis of analysis of all JCS and locator data. In the primary panel for identifying cycles and phases, users can adjust a threshold and smooth waves with a Butterworth filter to accurately detect cycles. A separate panel showing synchronized graphs of Rz and Ry with imported XROMM, fluoro or light videos allows annotation and manual event marking of individual cycles. Users can move by frame or cycle to verify or override auto-detected parameters such as chewing side, based on Ry, as well as annotate cycles with behavioral data. For each degree of freedom and locator, the following are exported for each cycle and phase along with corresponding metadata as .csv files: frame #, time, duration, maximum, minimum, start and end values. Using examples from 1 and 2 JCSs from our datasets, we demonstrate that FeedCycle accurately and rapidly standardizes data extraction based on fundamental features of mammalian feeding cycles in order to prepare data for subsequent statistical analysis.

P3-126 CHAMANLAL, A*; SAYEGH, N; MARTINEZ, D; MAIA, A; Rhode Island College; *achamanlal_4973@email.ric.edu*

Function of the Erector Muscles of the Spiny Dorsal Fin in Bluegill exposed to Turbulence

We exposed bluegill *Lepomis macrochirus* to turbulence and no turbulence after the injection of gallamine triethiodide (Flaxedil, non-depolarizing neuromuscular blocking agent), lidocaine (afferent nerve blocker) or saline solution (control) into the dorsal fin erector muscles. We expect that when motor control or afferent information are compromised, fish exposed to turbulence will show no activity in the erector muscles and erratic behavior will occur. We quantified fin erector muscle activity using electromyography and high-speed video of dorsal and lateral views. Under control conditions, lateral video kinematic data show that the erector muscles of the spiny dorsal fin are responsible for moving the fin up, as onset and offset of muscles coincided with changes in fin height. Under turbulent conditions, fish displayed erratic behavior when afferent information was removed, suggesting its inability to effectively control the dorsal fin. This effect was only partially seen in Flaxedil treatments. Electromyographic recordings show higher magnitude of muscle contraction during turbulence in both the control and Flaxedil treatments but not in the lidocaine treatment. Frequency and duration of contraction were kept constant under turbulent and non-turbulent conditions for both lidocaine and Flaxedil, however they were significantly different under control conditions. We can conclude that when sensory information is removed the fish is unable or unwilling to erect the spiny dorsal fin to recover stability. When a muscle relaxant is applied, there were some changes in muscle recruitment indicating that not all muscle fibers had been completely blocked. Bluegill rely on the spiny dorsal fin deployment to correct positioning in the water column when faced with turbulence and sensory information is essential to avoid overcompensation.

P3-69 CHAMBERLAIN, JD; Southern Arkansas University; *jchamberlain@saumag.edu*

The Role of a Thiamine-degrading Enzyme in Shaping Trophic Ecology of Watersnakes

Thiaminase is a relatively understudied protein that is present in a variety of plant and animal tissues including some ferns, bivalves, and fish. While there has been a growing body of work examining the mechanisms of how this enzyme degrades thiamine (vitamin B1) or makes it biologically unavailable, less attention has been payed to its ecological significance. We are interested in understanding how animals containing thiaminase fit into the trophic systems within their habitats. Previous work has demonstrated that predatory fish populations in the Great Lakes have declined as a result of feeding extensively on introduced prey fish that are rich in thiaminase. Because of thiamine's central role as a cofactor in the citric acid cycle, thiamine deficiency can lead to severe metabolic and neurological issues and eventual death. Theoretically, the risk of thiamine deficiency should shape natural trophic systems of predators feeding on prey containing thiaminase. To test this idea, we identified fish species in the gut contents of diamond-backed watersnakes (*Nerodia rhombifer*) to examine if snake prey items contained thiaminase. Simultaneously, we measured the thiaminase activity in fresh fish tissue of all species that co-occur with this population of watersnakes. Lastly, we collected historical data on the relative abundances of each fish species within the same watershed. While data collection and analysis are still underway, preliminary data suggest that diamond-backed watersnakes within the Lake Columbia watershed preferentially forage on fish species low in thiaminase activity despite other fish species containing thiaminase being relatively abundant within the habitat.

65-2 CHAMBERS, NM*; WILLIAMS, CM; West High School, University of California, Berkeley; *chambers.nikki@tusd.org*

The Beetle Project: Bringing Authentic Research Into High School Classrooms

The future of any scientific discipline depends on nurturing understanding of both discipline-specific core ideas and the nature of scientific thought in the next generation of scientists. Education/outreach continues to be emphasized as a core component of research grants. Efforts to bridge the formidable gap between K-12 science education, and scientific research and teaching at the post-secondary level, benefit from active collaboration between researchers and K-12 teachers. A successful exemplar is the "Beetle Project" spearheaded by the Williams Lab at the University of California, Berkeley. A two-month teacher-as-researcher experience funded by the NSF/SSE has yielded a published, NGSS-aligned instructional module using insects as a model system to illustrate biological impacts of climate change. The curricular goal is engaging students with a range of hands-on and minds-on activities that increase their understanding of how science works, evolutionary processes, and the impacts of climate change. We will model the curriculum, present ongoing results of implementation in high school classrooms, and discuss the benefits to both students and teachers of bringing authentic research into the classroom. Module components include: 1) a set of whole-organism/behavior and molecular lab activities using ladybird beetles; 2) a paper-and-pencil Data Nugget activity; and 3) an illustrated case study on the willow leaf beetle research that inspired the module, with extension materials for AP classrooms. The full module is hosted on the UC Berkeley Understanding Evolution website (https://tinyurl.com/y6bk9pzc). Detailed lesson plans suggest different scaffolding options for students from a variety of levels (middle school – AP Biology) and for classrooms with greater or lesser access to lab resources. We are partnering with teachers to develop, test, and disseminate the modules.

S2-9 CHAMPAGNE, FA; University of Texas at Austin, Austin, TX; *fchampagne@utexas.edu*

Epigenetics and Reproductive Trade-offs in Response to Stress

Exposure to stress during development can shape a broad range of phenotypic outcomes. In addition to programming response to stressors, these early experiences shape later life reproductive outcomes. Theoretical explorations of this phenomenon, drawing on life-history theory, suggest that both within-species and across-species variation in reproductive strategies would be predicted to be influenced by ecological factors indicative of resource availability and stressors (both physical and social). Endocrine, neurobiological and molecular studies suggest that the quality of the early environment – particularly qualities indicative of stress or threat - can have lasting effects on multiple biological systems. Epigenetic changes induced by these environmental exposures may mediate the link between stress and subsequent phenotypic outcomes. We have examined the epigenetic, neurobiological and behavioral consequences of early life stressors in rodents (rats and mice) with correlational studies also conducted in humans. Prenatal stress is associated with increased stress responsivity, altered neurodevelopmental trajectories and impairments in social and reproductive behaviors. These phenotypic outcomes are predicted by epigenetic variation in the placenta and associated with region-specific changes in gene expression and DNA methylation in the brain. Postnatal exposure to low vs. high stress environments is predictive of reduced maternal behavior and increased sexual behavior in later life. Altered DNA methylation of hormone sensitive genes in brain regions that regulate reproductive behavior may account for these effects. Future work on the trade-offs in phenotypic outcomes and the molecular mechanisms that shape these outcomes may provide further insights into the within and across-generation emergence of stress-induced reproductive strategies.

90-4 CHAN, KYK*; WONG, E; WONG, JY; XU, K; KOEHL, MAR; Swarthmore College, Hong Kong University of Science and Technology, Academia Sinica, University of California, Berkeley ; *kchan1@swarthmore.edu*

Hydrodynamics of barnacle nauplii shape evolution of body form

Many types of zooplankton have spines but their functional consequences are debated. Using naupli larvae of barnacles, we studied the hydrodynamic effects of spines and their impact on swimming, sinking, and feeding performance of these microscopic animals operating in a size and speed range at which the fluid dynamics is poorly understood. Barnacle nauplii are unique among crustaceans by having frontal horns and some have long tail spines. Naupliar form can range from parasitic species whose naupli have globular bodies with small horns and tails, to gooseneck species whose nauplii have slender bodies and long, fine horns and tail spines. Such diverse forms enable us to study the effects horn, tail, and body shape on hydrodynamic performance. By measuring hydrodynamic forces and torques on, and flow fields around dynamically-scaled physical models of nauplii for which morphology can be altered, we tested the hypothesis that long body extensions (horns and tail spines) increase drag on and resist tumbling by nauplii, These model experiments and our high-speed, micro-Particle Image Velocimetry analysis of live larvae showed that a globular body with small horns and tail spines (the parasitic *Polyascus plana*) experience lower drag and disturb the water less when they move than does a slender body with long tail spines and horns (the gooseneck *Lepas sp.*).Low-drag shapes can enhance swimming performance, whereas high-drag shapes can reduce sinking rates and enhance feeding by acting as sea anchors so flapping appendages can sweep through the water to filter particles. Thus, tradeoffs between different ecological functions impose constraints on the evolution of larval forms.

P3-73 CHANDLER, KL*; DAVIS , J; WOLFORD, D; Radford University ; *kchandler11@radford.edu*

Arthropod Thunderdome: Antipredator responses of Gromphadorhina portentosa in relation to predator species and relative size differential

Given their size and relative trophic level, many insect species occupy a relatively basal position on the food chain. They act as potential prey items for a variety of predators and it would often seem that they have little choice in the matter. However, recent studies have shown that cockroaches and other insects can employ a wide array of antipredator behaviors that can substantially impact their odds of becoming dinner. In this study we examined potential antipredator behavior of the Madagascar hissing cockroach (*Gromphadorhina portentosa*) to two representative, but physiologically and behaviorally distinct, predators, the Brazilian pink-toed tarantula (*Lasiodora parahybana*) and the Asian forest scorpion (*Heterometrus spinifer*). These two predatory species have opposing sensory structures for attacking prey, different predation strategies and different feeding patterns. As such we predicted that predator species could be associated with contrasting *Gromphadorhina portentosa* defensive behaviors. Additionally, we explored patterns of aggression and defense in relation to various size differentials between predators and prey. Positing that the potential prey might alter their strategies in relation to the relative size differences between themselves and the predator. We captured the range of antipredator responses used in these interactions, and their efficacy, through the use of time-lapse and high-speed video. Here we discuss these results and their implications for predator-prey interactions and evolution.

51-6 CHANDRASEGARAN, K; WYNNE, N; VINAUGER, C*; Virginia Tech, Blacksburg, VA; *vinauger@vt.edu*

Visual Avoidance Behavior in Mosquito Larvae and Adults

Mosquitoes are the deadliest animals on earth and the diseases they transmit, such as zika, chikungunya and malaria, are responsible for at least one million deaths each year. Current strategies to control populations of disease vector insects are being challenged, in part because of rising insecticide resistance. Therefore, novel strategies, informed by improved knowledge of mosquito biology, are urgently needed. However, progress in identifying new targets for vector control has been hindered by a lack of understanding of the mechanisms that regulate mosquito-host interactions. Multiple sensory modalities enable mosquitoes to navigate through their environment and locate suitable hosts. Although mosquitoes' responses to olfactory cues have been well characterized, comparatively less is known about the way visual stimuli are processed and integrated by these insects. Furthermore, in most cases, the visual sense of mosquitoes has been investigated in the context of their attraction to host-like objects. But visual cues can also signal threats such as a swatting hand. Leveraging a combination of freely moving and tethered preparations, we analyzed the avoidance behavior of multiple mosquito species to threat-like stimuli across developmental stages. Electrophysiological recordings in tethered-behaving individuals were then performed to unravel the underlying neural mechanisms. The significance of these results will be discussed relative to the design of control tools.

67-1 CHANG, ES*; GONZALEZ, P; SCHNITZLER, CE; BAXEVANIS, AD; NHGRI/NIH, U. Florida; *sally.chang@nih.gov*

Diverse patterns of human disease gene emergence and loss across the Metazoa

The increasing ease of generating genome-scale data has led to a huge increase in the number of organisms being developed as models for studying human biology. Given this increase, it is important to evaluate whole-genome sequence data from a broad array of organisms to determine their possible utility in investigating a particular human phenotype or disease. To address this, we have taken an evolutionary genomics approach to investigate patterns of disease-gene emergence and loss across the Metazoa, with a particular focus on these patterns in non-bilaterians, a group that is relatively underexplored in relation to questions in human health. We have identified orthologs across 49 taxa using a phylogenetically aware algorithm, then used these data to infer the age of origin of orthogroups containing a known human disease gene. On average, human disease genes appear to have a more ancient origin than the human genome as a whole, suggesting that a broad range of metazoans may be suitable genomic models for understanding these phenotypes. Some non-bilaterians, such as the cnidarians, have approximately the same percentage of these disease genes as some well-established model organisms, suggesting that they may be more suitable models when studying certain genetic pathways. Our work confirms that distinct subclasses of genes have distinct evolutionary histories, reinforcing the importance of considering different taxa in the context of specific biological questions. Finally, we have investigated the effects of methodological choices such as whether or not to include splice variation on our final inferences. Our results suggest that a broader range of metazoans than those currently used may prove to be useful for understanding the genomic bases of human diseases.

P3-84 CHANG, ES*; TRAVERT, M; SANDERS, SM; KLOMPEN, AML; GONZALEZ, P; BARREIRA, S; MULLIKIN, J; CARTWRIGHT, P; BAXEVANIS, AD; NHGRI/NIH, U. Kansas, U. Pittsburgh, U.Kansas; *sally.chang@nih.gov*

The genome of the hydrozoan Podocoryna carnea: An emerging resource for comparative biology

Cnidarians provide an excellent opportunity to study the evolution of complexity and novelty as they possess an astounding diversity of habitat usage, body plan organization, and life history strategies. Building on the advances made possible by the *Hydractinia* genome sequencing project, we are generating high-quality whole-genome sequencing data for the closely related hydrozoan, *Podocoryna carnea*. In contrast to *Hydractinia,P. carnea* has a pelagic medusae (jellyfish) phase. This provides a unique opportunity for comparative studies aimed at identifying the genomic toolkit specific to production of this life cycle stage, one that is characterized by unique cell types, some of which are potentially convergent to cell types within the Bilateria. This genome project will also extend current work in *Hydractinia* on questions regarding allorecognition, sex determination, and population genomics in the context of a cnidarian possessing a pelagic life cycle stage. Further, these hydrozoans are easily culturable in the lab, allowing for additional experimentation on environmental effects and phenotypic plasticity. Our overall sequencing strategy involves a trio-binning assembly approach using both Illumina and PacBio data; this approach takes advantage of the high apparent heterozygosity revealed by preliminary sequencing data from *P. carnea* to produce a fully phased genome sequence. These high-quality genomic data, along with RNAseq data being generated in the context of functional experiments will provide a strong foundation for establishing *P. carnea* as an important model for evolutionary genomics.

139-4 CHANG, B*; NOWAYTI, W; HSIEH, ST; Temple University; *brian.chang@temple.edu*

Force response of climbing sand dunes

Running up a sand dune is a challenging task due to several factors. First, sand fluidizes when an external force exceeding the material yield stress is applied. Second, at the angle of repose, the sand pile is unstable, such that small perturbations will cause fluidization. Ongoing studies in the lab show that sand specialist lizards exhibit lower running speed decrements than desert generalist lizards when running up inclined sand. Preliminary evidence indicates that impact angles of the foot relative to the sand differ between sand generalists and specialists, suggesting that differences in foot and leg movement can have dramatic effects on force generation. In this study, we experimentally examine the impact force normal to a flat plate against a bed of poppy seeds (~1 mm diameter). We test a range of impact speeds (0.01-1.2 m/s), substrate angles (0-40 degrees from the horizontal), and impact angles (0-40 degrees from gravity). When comparing the magnitude of force acting normal to the plate at varying substrate and impact angles, two regimes become apparent: 1) the gravity regime and 2) the inertial regime. In the gravity regime, the weight of particles dominates granular motion and causes fluidization of the substrate which correlates to divergences in the force depth relation when comparing force responses between substrate angles and intrusion angles. However, in the inertial regime, particle motion is dominated by the inertia of the intruder, which results in the force depth relation to converge between substrate and intrusion angle. Based on these results, we discuss the implications for the efficacy of lizards running up sand dunes.

P3-227 CHANG, ML*; ABALUSI, D; MCFARLANE, DA; SCHMITZ, L; Scripps College, Claremont, CA, Pitzer College, Claremont, CA, Claremont McKenna, Scripps, and Pitzer Colleges, Claremont, CA, Claremont McKenna, Scripps, and Pitzer Colleges, Claremont, CA; *mchang5063@scrippscollege.edu*

Exploring the Tempo of Eye Evolution through a Web Interface Application

The origin of "organs of extreme perfection" has been central to evolutionary debate since Darwin, who famously commented "Reason tells me, that if numerous gradations from a simple and imperfect eye to one complex and perfect can be shown to exist, each grade being useful to its possessor, …. then the difficulty of believing that a perfect and complex eye could be formed by natural selection, though insuperable by our imagination, should not be considered as subversive of the theory." In 1994, Nilsson and Pelger published a landmark paper that estimated the number of generations it took for a complex camera-type eye to evolve from a patch of light-sensitive cells, suggesting it takes ca. 364,000 generations for an eye to evolve. Given the popularity of eye evolution, we developed a web interface app that enables users to explore the Nilsson and Pelger model and perform sensitivity analyses. Results are visualized by comparing the estimated time it takes to evolve an eye against the fossil record. Our preliminary analyses support Nilsson and Pelger's results, but a current limitation might be that only the geometry of an isolated eye is taken into account. For more exact estimates of the time required to evolve an eye, the neural circuitry of the eye and other structures crucial to vision should be considered. We conclude that future research on complex organ evolution and the teaching of such complex topics can be enhanced through web interface apps. Such apps are useful because they interactively and visually demonstrate the evolutionary factors that affect model outcomes in a much more accessible way.

53-2 CHANG VAN OORDT, DA*; TAFF, CC; RYAN, TA; VITOUSEK, MN; Cornell University, Ithaca, NY; *dac385@cornell.edu*

Raising Defenses: Are There Costs to Stronger Immunity in Breeding Tree Swallows?

Life history theory predicts that, when resources are limited, energy allocation will be split between somatic and reproductive effort. In order to maximize fitness, organisms should invest these limited resources optimally into either of these efforts via a wide range of traits. This split allocation creates trade-offs when investing in some traits over others such as predator evasion over parental effort, or egg production over immunity. Here, we evaluate the evidence supporting a trade-off between the strength of immunity and life history traits in female Tree Swallows, *Tachycineta bicolor*, from a breeding population in Ithaca, NY. We hypothesize that there should be a trade-off between immunity, the ability to respond to stressors and reproductive effort during demanding life history events such as breeding. Individuals with investment closest to the optimal should have higher lifetime fitness. Bacteria killing assays run using blood plasma, which provide an index of the strength of the innate immune response, revealed wide variation in the response to an *E. coli* challenge. Killing capacity varied from 0 to 100%, with a mean of 47%. Here, we report the relationship between killing capacity and a suite of behavioral (e.g., provisioning rate), physiological (e.g., baseline and stress-induced corticosterone, plasma glucose), and fitness (e.g., clutch size and number of chicks fledged) metrics. We anticipate that this study will provide a better understanding of resource allocation in a migratory bird with a fast pace of life.

37-1 CHAPMAN, BR*; WILSON, LE; Fort Hays State University, Hays, KS; *brchapman@mail.fhsu.edu*

Predicting habitat preferences of Hesperornis (Aves: Hesperornithiformes) in the Western Interior Seaway through occupancy modeling

In the Late Cretaceous, North America was divided by the Western Interior Seaway (WIS), a shallow epicontinental sea. Native vertebrate life included marine reptiles, fish, and seabirds such as *Hesperornis*, a flightless avian with a foot-propelled diving lifestyle similar to cormorants. Occupancy modeling predicts occupancy and detection probabilities for the taxa of interest at sampled sites and is used here to understand environmental and biological factors influencing *Hesperornis* distribution. Campanian WIS vertebrate occurrences and sedimentological data were gathered for the United States and Canada from peer-reviewed literature, museum collections, and online databases. Occurrences consist of taxa found with and without *Hesperornis* and include known predators and other contemporaries. The statistical modeling software PRESENCE was used to create and evaluate the performance of occupancy models across the WIS with covariates of local faunas and sedimentary rock type for a single season (Campanian) and multiple seasons (early, middle, and late Campanian). Detection probabilities were allowed to vary across lithologies and seasons to model preservational biases. Results showed higher predicted *Hesperornis* occupancy for sites with chondrichthyans, plioplatecarpine mosasaurs, polycotylid plesiosaurs, and offshore shale-forming environments. Increased occupancy estimates with these taxa may reflect a fauna where predation pressures did not significantly affect *Hesperornis* biogeography. Regions of intense study and collection and variable preservation of Campanian outcrops likely inflated the preference for mud-rich offshore environments. This research represents one of the first applications of occupancy modeling to marine vertebrates in the WIS.

51-2 CHAPPELL, DR*; SPEISER, DI; University of South Carolina, Columbia, SC; *danielrc@email.sc.edu*

Neural processing in distributed visual systems – many eyes, many solutions

Most research on visual systems has focused on animals with paired cephalic eyes; however, some animals have distributed visual systems in which many eyes are distributed across their body. Compared to animals with paired cephalic eyes, these animals have nervous systems that are less centralized and less cephalized, which seems at odds with their multitude of eyes and the common notion that vision is an information-rich modality. In most cases it is unknown how these animals process the large amount of information being gathered by their visual systems. To compare neural processing in animals with different distributed visual systems, we studied the bay scallop *A. irradians* and the chiton *A. granulata*. *A. irradians* has dozens of mirror-based eyes, and *A. granulata* has hundreds of eyes embedded in its dorsal shell plates. In both species, we injected fluorescent dyes into eyes to trace the optic nerves to their site of innervation. We found that optic nerves from the eyes of *A. irradians* lead centrally to the parietovisceral ganglion, suggesting central processing of visual information in scallops. In contrast, we found the optic nerves of *A. granulata* lead locally to the lateral nerve cord, suggesting distributed processing of visual information in chitons. Thus, we find two species with distributed visual systems use different strategies for neural processing, with scallops employing centralized processing and chitons employing distributed processing. These different processing strategies may represent underlying differences between nervous systems in which processing occur in ganglia (e.g. scallops and other bivalves) and those in which processing occurs in medullary cords (e.g. chitons and other molluscs).

135-4 CHARIFSON, DM*; BOURDEAU, PE; PADILLA, DK; Stony Brook University, Humboldt State University; *david.charifson@stonybrook.edu*

Shell remodeling may circumvent limits to phenotypic plasticity in the marine gastropod, Nucella lamellosa

The adaptive value of phenotypic plasticity can be limited by several factors, such as the epi-phenotype limit, which is when a newly induced phenotype is not fully integrated with the previous phenotype. Additionally, some inducible morphologies are irreversible, which can result in phenotype-environment mismatch when environmental conditions change. Many marine gastropods thicken their shell in response to shell-crushing predators, an inducible defense, and some are capable of remodeling shell that has already been deposited. However, previous studies of inducible defenses tend to examine only recent shell growth, and not secondary modifications to older parts of the shell (i.e., remodeling). Shell remodeling could allow for reversibility in inducible shell thickening and mitigate epi-phenotype limits. Therefore, we examined plasticity in shell construction and remodeling in *Nucella lamellosa*, which displays a strong inducible shell thickening response to the predatory crab, *Cancer productus*. In response to this predator *N. lamellosa* constructed a thicker shell at the aperture and body whorl, with an increase in both shell microstructural layers at the aperture, but only in one layer in the body whorl. Snails also exhibited shell remodeling in response to *C. productus*; producing an overall thicker shell in older apical whorls. Thus, snails produced the thick or thin shell phenotype throughout all parts of the shell depending on treatment, circumventing the epi-phenotype limit, and suggesting reversible phenotypic plasticity in shell thickness in *N. lamellosa*.

110-4 CHASE, HT*; TOBALSKE, BW; University of Montana; *hilatzipora@gmail.com*

Bird to the Bone: Functional Adaptation in the Avian Wing

Though birds have long been admired by biologists and engineers alike for having lightweight bones with specialized "reinforcements," very little work has been done to investigate this internal substructure (i.e. trabecular bone). Trabecular bone, a complex 3D matrix, mechanically adapts to an organism's behavior over its lifetime. This has facilitated success in using trabecular structure to interpret function in fossil mammals, though no attempt has been made in birds. We thus collected high-resolution microCT scans of the humerus across a broad, comparative set of 51 species which vary in flight mode on a continuum from flapping to soaring. Whole bones were segmented and trabecular matrix parameters were measured for the humeral head. We developed a new parameter (Trabecular Extent, Tb.Ex) to holistically assess the extent of reinforcing structures in the bone. Across corvids, increases in trabecular thickness, ellipsoid factor, and the degree of anisotropy significantly covaried with increases in gliding/soaring behavior, while volume fraction did not vary. Similar patterns were found in a preliminary analysis across the phylogeny. Tb.Ex scaled allometrically within, but not across clades, and also varied with flight mode and ecology. Preliminary comparison of cross-sectional geometry and Tb.Ex suggests a mechanical tradeoff between trabecular and cortical bone. Our results support that trabecular bone in the wing maximizes volume while minimizing mass, but the specific architecture and extent relates to more nuanced differences in kinematics and loading across flight modes and ecologies. Ongoing work will explore the mechanical role of trabecular bone as well as apply our results to fossil interpretation, and overall provides both crucial insight into flight mechanics as well as a robust, novel approach to understanding the evolution of avian flight.

110-6 CHAUMEL, J*; SCHOTTE, M; BIZZARRO, J; ZASLANSKY, P; FRATZL, P; BAUM, D; DEAN, M; MPIKG, ZUSE, UCSC, Charité Hospital; *juliachaumel@mpikg.mpg.de*

Are the cells in stingray mineralized cartilage performing the roles of bone cells? Quantitative analysis of the lacuno-canalicular network in stingray tesserae

In most vertebrates the embryonic cartilaginous skeleton is replaced by bone during development. During this process cartilage cells (chondrocytes) mineralize the matrix and die, giving way to bone cells (osteocytes). In contrast, sharks and rays (elasmobranchs) have cartilaginous skeletons throughout life, where only the surface mineralizes forming a layer of tiles (tesserae). Elasmobranch chondrocytes survive cartilage mineralization and are maintained alive layers in tesserae. However, the roles of the chondrocytes in the mineralized tissue remain unknown. Applying a custom analysis workflow to microCT scans of tesserae, we characterize how morphologies and arrangements of stingray chondrocyte lacunae vary. We show that the cell density is the same between the unmineralized and mineralized tissue and the cells maintain the same volume indicating they do not hypertrophy and undergo apoptosis during mineralization, as in other taxa. The cell density is higher near pores passing through the tesseral layer, suggesting these may constitute a nutrients source. Tessera lacunae also show zonal variation in their shapes and strong orientation toward neighboring tesserae, perhaps providing a fingerprint of the tesserae formation process, while indicating local variation in tissue strain and cell function. Lacunae are linked by small passages (canaliculi) in the matrix, connecting lacunae in series or tight clusters in the center of the tesserae, creating connectivity among cells and suggesting avenues of communication within and between tesserae. This network arrangement and the shape variation of chondrocytes in tesserae indicates that these cells may interact and manage mineralization differently from chondrocytes in other vertebrates, perhaps performing analogues roles to osteocytes in bone

P1-1 CHAVARRIA, R*; SMITH, FW; University of North Florida; *n01391506@unf.edu*

The loss of several Wnt genes is correlated with the loss of posterior growth in Tardigrada

Recent analyses of Hox genes have revealed that tardigrades have lost mid-trunk segments. The segments that are missing in tardigrades develop by posterior growth in most panarthropods (Arthropoda, Onychophora, Tardigrada). Posterior growth is thought to be an ancestral mechanism of Nephrozoa. This process is regulated by the canonical Wnt signaling pathway (cWnt) in nephrozoans that have been investigated. Tardigrades lack posterior growth, suggesting that the loss of this process may explain the loss of mid-trunk segments in tardigrades. We analyzed the genomes of two representatives of Eutardigrada, *Hypsibius exemplaris* and *Ramazzottius varieornatus*, to identify genomic signatures of the loss of posterior growth in tardigrades. We identified conserved intracellular components of cWnt signaling in the genomes of both species. We identified a full complement of Frizzled genes in both tardigrade genomes, genes that code for the receptor component of the cWnt signaling pathway. However, we were unable to identify several cWnt signaling ligand-coding genes—*wnt1*, *wnt3*, *wnt6*, *wnt7*, *wnt8*, and *wnt10*. *Wnt1*, *wnt7*, and *wnt8* have been implicated in regulating posterior growth in arthropods. In order to test whether these gene losses are ancestral losses for Tardigrada, we sequenced the genome of *Batillipes penakki*, a representative of Heterotardigrada, which, with Eutardigrada, spans Tardigrada. We identified an ortholog of *wnt1* in the genome of *B. penakki*. Therefore, our results indicate that the loss of several Wnt ligand-coding genes is correlated with the loss of posterior growth and mid-trunk segments in tardigrades, while the loss of wnt1 occurred specifically in the eutardigrade lineage.

25-5 CHENEY, JA*; SONG, J; WINDSOR, SP; STEVENSON, JPJ; DIERKSHEIDE, D; NILA, A; BOMPHREY, RJ; USHERWOOD, JR; Royal Veterinary College, Hatfield, UK, Royal Veterinary College, Hatfield, UK & Dongguan University of Technology, China, University of Bristol, UK, University of Bristol, UK, LaVision GmbH, Gottingen, Germany, LaVision UK Ltd, Bicester, UK; *jcheney@rvc.ac.uk*

The tails of gliding birds disrupt induced drag minimization and instead approach optimal viscous drag minimization

Textbook descriptions of bird flight discuss the relatively elliptical planform of avian wings as evidence that birds achieve minimum induced drag by enabling constant downwash from tip to tip. To test this description, we measured the wakes of gliding birds by tracking up to 22,000 neutrally buoyant helium-filled soap bubbles at each time point. Our hypothesis was that the action of the tail would compensate for lift lost over the body and enable constant downwash from wingtip to wingtip, minimizing induced drag. Instead, we found that the spread and pitch of the tail produces a strong jet of air that far exceeds the expected downwash; that is, the birds are not elliptically loaded at these slow, self-selected glide speeds. A frequently overlooked action of the tail is to minimize viscid drag, which, in aircraft, is typically a negligible contribution due to higher Reynolds numbers. We found that, at the intermediate Reynolds numbers of avian gliding, the contribution of viscous drag is of the same magnitude as the induced (inviscid) drag. Viscous drag minimization predicts constant area loading, with downwash proportional to chord length at each spanwise position. The measured downwash distribution behind our birds, with a strong downward jet behind the body/tail, is consistent with drag minimization, but reveals a compromise between elliptical loading and constant area loading.

P1-226 CHENNAULT , M*; MARTINEZ , C; WAINWRIGHT , P; Howard Univeristy , University of California, Davis , Howard University; *machennault@yahoo.com*

Comparing Functional Traits in Feeding Morphologies of Hybrid Sunfish

Hybridization between species is a common occurrence in nature that has the potential to enhance genetic and phenotypic variation, and it may play a significant role in the evolution of functional systems. We investigated the functional morphology of feeding in bluegill and green sunfish and naturally occurring F1 hybrids between the two species. Five individuals each of the two species and the hybrid were filmed at 2000 frames/sec feeding in the lab. We used landmark morphometrics to quantify the cranial movements during prey capture sequences. As expected, the hybrid was intermediate in feeding kinematics between the two parent species. However, hybrid kinematics were distinctly more similar to the green sunfish than the bluegill, indicating that, while the hybrid possesses a 50:50 genetic combination of the parent species this does not translate into feeding kinematics that are perfectly intermediate. This may be due to non-linear relationships between morphology and kinematics.

123-5 CHEU, AY*; BERGMANN, PJ; Clark University; *acheu@clarku.edu*

Ontogenetic allometry of locomotor performance in basilisk lizards

For precocious vertebrates, the need for locomotor activity begins soon after hatching or birth. Juveniles may occupy the same habitat as their adult counterparts and therefore, compete for the same resources. Consequently, juveniles must be able to perform multiple locomotor tasks at a reasonably similar level, despite their smaller size. Most animals grow allometrically, where their body proportions change as they get larger. These changes potentially impact their performance in various locomotor tasks. Scaling models have been proposed to predict the relationships between body size and performance variables, where velocity increases with a slope of one, increasing at the same rate as linear body dimensions. While these predictive models do apply in some cases under specific conditions, many empirical studies have shown that the relationship between length and velocity does not always follow the predicted trajectory and slopes may vary between multiple modes of locomotion. Therefore, if a performance variable does not scale as predicted, what are the potential reasons for this deviation? Locomotion can be explained intrinsically by not only the length of body parts, but also cross sectional surface area of muscle fiber types and muscle force generation, all of which scale with different predicted values. This study aims to address (1) if running, jumping, swimming, and climbing performance in brown basilisks, *Basiliscus vittatus*, meet predicted scaling models and (2) which phenotypic traits or kinematic variables best explain potential allometric relationships. Preliminary results show that climbing maximum velocity scales isometrically with body length, but running and swimming velocities scale negatively allometrically. Jumping maximum acceleration has no relationship with body length.

P3-28 CHEUNG, JA*; ROSE, CS; James Madison University; *cheun2ja@dukes.jmu.edu*

The hormonal control of anuran ossification sequences

Amphibians acquire bones postembryonically, over larval growth and metamorphosis. They also show considerable interspecific variation in ossification sequence. Most postembryonic changes in metamorphosing amphibians are mediated by thyroid hormone (TH) and many frogs have developmental patterns that follow a universal (Gosner) staging system. This conservancy implies that most TH-mediated development remains tightly coordinated across frogs, and that interspecific variation in ossification sequence is more likely the result of changes in TH sensitivity than in TH production. This study quantifies the effects of TH type (T4 and T3), dose and larval stage on bone development in Xenopus laevis with the aim of comparing induced and natural ossification sequences in this and other species. We examined a developmental series of untreated specimens as well as specimens from a study of TH-induced cartilage development that were treated at early, mid and late larval stages with 1, 5, 10 and 50 nM T4 or T3. The thyroid inhibitors methimazole and iopanoic acid were additionally used to isolate the effect of each hormone. With the exception of T4 at the lowest dose and stage, both hormones only induced more ossification than in controls at late larval stages. TH-induced sequences were generally similar to natural sequences, with earlier appearing bones being induced at low stages and doses, and later ones being induced at higher stages and doses. The maxilla, nasal, premaxilla, and vomer were sometimes omitted, and the orbitosphenoid induced ahead of others. These results are consistent with tissue sensitivity accounting for variation in ossification sequence. This study emphasizes the value of interpreting amphibian ossification sequences in the context of the neuroendocrine mechanisms regulating developmental and life history stages.

P2-193 CHEVALIER-HORGAN, C*; PIERCE, SE; HUTCHINSON, JR; DIOGO, R; MOLNAR, JL; NYITCOM, Harvard University, Royal Veterinary College, Howard University; *cchevali@nyit.edu*

Biomechanical modelling of tetrapods: the structural and functional adaptation from aquatic to terrestrial life

The evolution of hindlimb bone morphology, muscle attachments, and joint geometry in the tetrapod lineage tells a story of adaptation to the environment through structural modification. We compared the pelvic appendages of three stem tetrapods and closely related fish spanning the fin-limb transition (*Eusthenopteron, Acanthostega,* and *Pederpes*) with two extant lobe-finned fish and two extant tetrapods using musculoskeletal modeling. We estimated osteological range of motion of the hip and knee joints and mapped muscles onto the skeletons based on osteological correlates of muscle attachment from the literature and plotted the leverage of individual muscles over a range of motion. Similar to prior reports on forelimb evolution, a "bottleneck” in range of motion, particularly long-axis rotation, coincided with the origin of tetrapods. We also observed a trend towards increased leverage of hip depressors and retractors in tetrapods - potentially reflecting a shift to limb-driven locomotion - which was especially noticeable in post-Devonian taxa. In contrast, the fish had greater leverage for elevation and depression than any other type of movement. These results help to refine our understanding of how the roles of how the roles of the forelimb and hindlimb changed as tetrapods increasingly adopted a more terrestrial way of life, as well as the evolution of structure-function relationships over macroevolutionary timescales.

130-6 CHINN, SM*; BEASLEY, JC; University of Georgia; *sarahchinn@uga.edu*

Parental investment strategies in a highly polytocous species: maternal attributes and resource availability modulate litter size and sex ratio

Female condition significantly influences timing of reproduction, age at first breeding and offspring survival, and is proposed as a driver of offspring sex ratio. The Triver's-Willard hypothesis (TWH) predicts high-quality mothers should invest more into sons because males have higher variance in individual fitness for species in which reproductive success is more variable in one sex. Thus, females should adjust offspring sex ratio in response to factors that could modify both their own lifetime reproductive success and that of their progeny. Though well studied in vertebrates, it is poorly understood if or how the TWH applies to polytocous species, those that produce several offspring per litter, because the trade-offs between size and number of offspring must also be taken into consideration. Williams' hypothesis (WH) accounts for these possible trade-offs on sex ratio variation. The extrinsic modification hypothesis (EMH) predicts modulation of offspring sex ratio in response to environmental conditions. Using wild pigs as a model, we tested whether (1) maternal attributes modulated litter sex ratio (TWH), (2) maternal mass influenced production cost, based on litter size and sex-ratio (WM), and (3) environmental conditions influenced litter size (EMH), in a polytocous species. Older females, generally larger and with more parental experience, had male-biased litters, providing support for the TWH. Increased maternal size and condition (an index of resources) both positively influenced litter production cost, supporting the WH and EMH. Increased maternal size and condition also positively influenced litter size but not sex ratio. Our results suggest that for species with large litters, the benefits from adjusting litter size outweigh those from modulating offspring sex ratio.

S11-4 CHITTKA, L; Queen Mary University of London; *l.chittka@qmul.ac.uk*

The Mind of the Bee

Bees have a diverse instinctual repertoire that exceeds in complexity that of most vertebrates. This repertoire allows the social organisation of such feats as the construction of precisely hexagonal honeycombs, an exact climate control system inside their home, the provision of the hive with commodities that must be harvested over a large territory (nectar, pollen, resin, and water), as well as a symbolic communication system that allows them to inform hive members about the location of these commodities. However, the richness of bees' instincts has traditionally been contrasted with the notion that bees' small brains allow little behavioural flexibility and learning behaviour. This view has been entirely overturned in recent years, when it was discovered that bees display abilities such as counting, attention, simple tool use, learning by observation and metacognition (knowing their own knowledge). Thus, some scholars now discuss the possibility of consciousness-like phenomena in the bees. These observations raise the obvious question of how such capacities may be implemented at a neuronal level in the miniature brains of insects. We need to understand the neural circuits, not just the size of brain regions, which underlie these feats. Neural network analyses show that cognitive features found in insects, such as numerosity, attention and categorisation-like processes, may require only very limited neuron numbers. Using computational models of the bees' visual system, we explore whether seemingly advanced cognitive capacities might 'pop out' of the properties of relatively basic neural processes in the insect brain's visual processing area, and their connection with the mushroom bodies, higher order learning centres in the brains of insects.

26-2 CHMURA, HE*; DUNCAN, CM; BARNES, BM; BUCK, CL; CHRISTIAN, HC; LOUDON, AS; WILLIAMS, CT; Institute of Arctic Biology, University of Alaska Fairbanks, Institute of Arctic Biology, University of Alaska Fairbank, Northern Arizona University, Oxford University, University of Manchester; *hchmura@alaska.edu*

Reimagining the hibernating brain: Hypothalamic remodeling in an arctic hibernator

Mammalian hibernation is normally viewed as a state of relative stasis as animals dramatically reduce activity and metabolic rate to weather periods of low resource availability. However, in many species, the end of hibernation involves a transition from fasting to a fed state and is closely followed by seasonal reproduction. These transitions require extensive changes to the brain, physiology, and behavior. This raises the question: does the hibernating brain anticipate this seasonal transition and begin to prepare for spring activity before hibernation ends? We used in-situ hybridization, immunohistochemistry, and electron microscopy to examine neuroendocrine and structural changes in the brains of hibernating male and female arctic ground squirrels. We found significant changes in gene expression across hibernation within the thyroid hormone signaling pathway, including upregulation of TSH-β and changes in deiodinases in the mediobasal hypothalamus. Additionally, ependymal tanyctes lining the third ventricle exhibited striking changes; during early hibernation, tanycytic processes were scant within the mediobasal hypothalamus but process density increased late in hibernation. This suggests that the hibernating brain, instead of remaining in stasis, undergoes extensive remodeling. We propose that periodic arousals from torpor, which are typically viewed as functioning in maintaining homeostatic processes, also enable circannual modulation of hypothalamic plasticity.

S5-7 CHO, MS*; NEUBAUER, P; FAHRENSON, C; RECHENBERG, I; Technical University of Berlin, Bionics and Evolution Techniques; *m.cho@campus.tu-berlin.de*

A Filament-like Structure for Flight?: The Ballooning Flight of Spiders

Many flying insects utilize a membranous structure for flight, which is known as a "wing." However, some spiders use silk fibers for their aerial dispersal. It is well known that spiders can disperse over hundreds of kilometers and rise several kilometers above the ground in this way. However, little remains known about the ballooning mechanisms of spiders due to the lack of quantitative data regarding spiders' ballooning. From our observation in the field and the laboratory using a wind tunnel, we acquired knowledge of the types and physical properties of spiders' ballooning silks, previously unknown. A crab spider weighing 20-25 mg spins 50-60 ballooning silks, which are about 200 nm thick and 3.22 m long. Silks of this size can lift large spiders (5-150 mg) into the air even with light upward air currents. In the presentation, the physical signification of these filament-like structures will be discussed in relation to the following questions: (i) Why do spiders use filament-like structures for their flight? (ii) Why do large spiders spin multiple fibers? (iii) Is there any meaning of the thickness of 200 nm?

P1-247 CHOI, MP*; RUBIN, AM; WADA, H; Auburn University; *mpl0011@auburn.edu*

Effects of Incubation Temperatures and Restraint on Beak Coloration in Zebra Finches

Developmental environment can have a strong influence on offspring phenotype. In oviparous species, incubation temperature is known to influence sex, physiology, and survival. In birds, incubation temperature varies daily and among nests; however, little is known about how fluctuating incubation temperatures influence offspring, particularly its long-term effects on fitness-related measures. Beak color is a secondary sex characteristic that indicates health status and influences successful mating for both male and female zebra finches (*Taeniopygia guttata*). We assessed whether periodic cooling during embryonic development 1) has a persistent effect on beak coloration into adulthood and 2) alters coping behavior, which was tested by a handling bag test. Embryos were incubated at one of the three temperatures: constantly low (36.4°C), periodic cooling (average 36.4°C), and control (37.4°C) temperatures. A year later, females underwent a handling bag test to measure activity levels and potential changes in beak color due to repeated handling and restraint. Birds in the periodic treatment had significantly darker and duller beak color compared to the controls, while no effect on hue or saturation was observed. Incubation temperature did not influence coping behavior, and repeated handling and restraint did not have any significant effects on any parameters of beak color. Since value (brightness) was not affected by treatments at 95 days post-hatch but was significant 300 days post-hatch, the periodic cooling treatment appears to have a latent effect on beak color after sexual maturity.

92-4 CHOI, W*; WADA, H; Auburn University; *wzc0028@auburn.edu*

Eggshell Pore Density as an Important Determinant for Avian Embryonic Development

Avian eggs protect embryos from desiccation and trauma while allowing exchange of gases. Although previous studies have shown that environmental factors such as temperature and humidity alter eggshell characteristics, little is known about the importance of those characteristics on embryonic growth and physiology. Here, we assessed how blockage of eggshell pores can affect zebra finch (*Taeniopygia guttata*) embryo hatching success and development pre-hatch. Eggs were divided into four groups: control, fifteen percent, thirty percent, and forty-five percent surface area coverage; the treatment groups were dipped in paraffin candle wax according to their assigned percentages. Eggs were then incubated at 38.6°C, and their heart rates were measured on day 4 and day 10. Hatching success shows a sigmoidal curve where control and 15% coverage have similar hatching success while 30% and 45% having extremely low success. There appears to be a threshold between fifteen and thirty percent where the embryos are able to tolerate this stress.

S8-11 CHOSET, HM; Carnegie Mellon University; *choset@cs.cmu.edu*

Geometric Methods for Locomotion in Limbless and Legged Systems

Geometric Methods for Locomotion in Limbless and Legged Locomotion Organisms generate patterns of periodic self-deformations, which we will refer to broadly as "gaits," to locomote through their environments. Inspired by this, the robotics community has created a variety of limbless (e.g., snake) and limbed systems that also use gaits to locomote. Our group has been building upon a branch of mathematics called geometric mechanics that we use to design gaits in mechanical systems, as well as model gaits in biological ones. In this talk, we will show that geometric mechanics facilitates systematic discovery of locomotor templates in diverse living systems, and provides candidate high level control targets for robot control in natural environments. Essentially, our approach establishes a functional relationship, called a connection, that maps changes in the system's internal shape, ie self-deformations, to displacements in position. More specifically, the connection can be used to "map" a closed loop, ie., a gait, in the shape space to displacement. With this technique, we were able to optimize criteria to determine gaits that modeled biological motion. Recently, we have extended the approaches, originally designed for limbless snake-like systems, to multi-legged ones, both biological and robotic. In particular, we are interested in legged systems that also bend their backs, e.g., salamanders, as they have both a "legged" portion and a "undulatory" portion of locomotion.

P3-64 CHOUDHRY, A*; LO, B; FREEMAN, A; OPHIR, A; Thomas Jefferson High School for Science and Technology, Cornell University; *dogwood25@outlook.com*

Female African giant pouched rats scent mark at similar rates despite reproductive differences

Finding reproductively available mates is an important part of reproductive behavior for animals. For female rodents, signals of reproductive receptivity are often scent-based, enabling perception by males when the female is not present. In African giant pouched rats (Cricteomys ansorgei), females have variable vaginal patency and can exhibit no vaginal opening in adulthood even though by other metrics they appear sexually mature. Males can perceive signals of patency through female urine, but we do not know if females are also changing their behavior to alter their signaling rate. We hypothesized that patency would influence sexual 'advertizing' by females. We predicted that non-patent (i.e. reproductively unreceptive) females would advertise via scent marking less often than patent females. We exposed females in a novel arena to artificially placed male urine marks and observed their scent marking behavior. Both types of females investigated the male scent, and scent marked using urine and anogenital rubbing. Notably, we observed a 'hop-skip' behavior reported in C. gambianus, which is only elicited in females with contact to non-volatile components of male urine. We detected no statistical difference between patent and non-patent females' behavior, although a small preliminary sample limits our statistical power. Potentially, non-patent females might scent mark to signal to other females in addition to males. Taken together, our data show that pouched rat females advertize via scent marking irrespective of their reproductive state.

P1-255 CHRISLER, AD*; ANTUNES, IK; KIMBALL, MG; MALISCH, JL; St. Mary's College of Maryland, Louisiana State University; *adchrisler@smcm.edu*

Modeling glucocorticoid physiology, glucose mobilization, and return rate in migrating Mountain White-crowned Sparrows (Zonotrichia leucophrys oriantha)

Natural environments are unpredictable and the survival of organisms depends on their ability to respond to environmental challenges and perturbations. Therefore, energy mobilization in response to challenges could be a good predictor of survival. 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 and therefore may influence return rate. We utilized a free-living population of Mountain White-crowned Sparrows to characterize the glucocorticoid and hyperglycemic response to acute challenge. We then modeled predictors of these responses and individual return rates over several years. Potential predictors of glucose and glucocorticoid mobilization were scaled body mass, fat score, hematocrit, sex, date, year, and bleed delay time. Potential predictors of return rate were glucose and glucocorticoid mobilization as well as body condition (fat, mass, and scaled mass) and year. We predict that blood glucose and glucocorticoid levels will respond positively to challenge, as seen in previous studies, and that body condition and fat score will be positive predictors of glucose mobilization. For return rate, we expect a positive relationship with glucose mobilization and body condition. This study is unique in that we investigate the potential link between energy mobilization and year-to-year survival in a free-living migratory species.

64-5 CHRISTENSEN , BA*; SCHWANER , MJ; FREYMILLER, GA; CLARK, RW; MCGOWAN, CP; University of Idaho, Moscow , San Diego State University, CA , San Diego State University, CA; *chri4094@vandals.uidaho.edu*

Exploring Reaction Time in Desert Kangaroo Rats

Desert kangaroo rats (*Dipodomys deserti*) exhibit highly successful escape maneuvers when subject to a predatory attack. Prior studies have loosely attributed the species' success to the unpredictable nature of their evasive response, yet the exact mechanisms remain unknown. Based on literature emphasizing the role of auditory sensitivity in predator-prey dynamics, our goal was to compare kangaroo rat reaction times between auditory and visual cues in the field. For analysis, we used high-speed video cameras (240 fps) to record locomotor response prompted by a rattlesnake strike simulator (RSS). Although the RSS was originally developed to investigate overall escape kinematics, this analysis focused solely on reaction time. Our modified RSS included both auditory and visual triggers, deploying at staggered intervals. For auditory stimulus, we found an average reaction time of 102 ± 6.9 ms (n = 9), slower than past studies have determined. Visual stimulus resulted in an average reaction time of -4.56 ± 6.0 ms, with over half of individuals responding prior to a visual cue. This result indicates the significance of auditory sensitivity over visual sensitivity in kangaroo rat reaction speed. The discrepancy between studies is likely due to design differences as the original RSS required a reliance on visual cues alone and could not quantify auditory involvement. Future analysis will manipulate acoustic frequency to test the lower limits of kangaroo rat hearing threshold, as well as include anatomical data such as auditory bullae size to better explore the links between morphological adaptation and predation pressure.

125-2 CHRISTIANO, BM*; HOWEY, CAF; University of Scranton, University of Scranton and Penn State University; *brandi.christiano@scranton.edu*

Timber rattlesnakes (Crotalus horridus) that move more often maintain higher baseline corticosterone levels

Glucocorticoids are hormones that free up energy which allows organisms to deal with challenging events. Challenging events, or "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 more active times of the year such as foraging or the mating season. The objective of our study was to determine if individual timber rattlesnakes (*Crotalus horridus*) that maintain greater movement rates also maintain elevated baseline corticosterone (CORT) levels. We radio-tracked timber rattlesnakes (n = 12) every 2-3 days for two years (2016 and 2017) and collected blood samples from individuals during mid-summer (reproductive season) of each year. We determined CORT levels for each blood sample using a competitive enzyme immunoassay. We determined movement rates and home range sizes using ArcGIS. We compared individual movement rates with baseline corticosterone levels using a mixed-model linear regression. Individuals with greater movement rates also had higher baseline CORT levels ($F_{1,3}$= 23.76, P = 0.017). Although males tended to have higher baseline CORT levels compared to females ($F_{1,3}$ = 7.95, P = 0.067), it is important to note that not all male snakes had high movement rates (and thus did not maintain elevated baseline CORT levels). Snakes that moved more often maintained larger home ranges (t = 4.48, df = 18,P <0.001). 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”.

2-4 CHUNG, AK*; COX, RM; LOGAN, ML; MCMILLAN, WO; COX, CL; University of California, Los Angeles, University of Virginia, University of Nevada, Reno, Smithsonian Tropical Research Institute, Georgia Southern University; *akc9ab@g.ucla.edu*

Sex-biased Gene Expression and Sexual Dimorphism in Anole Lizards

Adult males and females of a species often possess differences in body size (sexual size dimorphism, SSD) despite the genomic constraint of a single, shared genome. SSD results from a variety of evolutionary pressures that result in the sexes possessing differing body size optima and represents a form of intersexual conflict. One genetic mechanism that may allow the sexes to overcome the constraint of a shared genome and achieve their body size optima is differential expression of shared genes (i.e. sex-biased gene expression). To understand the role of gene expression in the evolution of SSD, we compared transcriptome expression in a lizard species with extreme male-biased SSD (brown anole) and a species that is sexually monomorphic in body size (Panamanian slender anole). We sampled two tissues that differ in phenotypic expression between the sexes in brown anoles (liver and muscle). We predicted that brown anoles would 1) exhibit high levels of sex-biased expression of the entire transcriptomes of liver and muscle and 2) express growth regulatory networks dimorphically relative to the monomorphic slender anoles. We found that brown anoles do indeed exhibit higher levels of sex-biased expression of both entire transcriptomes and growth regulatory networks in the liver and muscle compared to slender anoles. Ultimately, this work will increase our understanding of the gene expression mechanisms that could resolve intersexual conflict and facilitate the evolution of sexual dimorphisms.

45-6 CHURCHMAN, EKL*; HAIN, TJA; KNAPP, R; NEFF, BD; University of Western Ontario, London, ON, University of Oklahoma, Norman, OK; *echurchm@uwo.ca*

Perceived paternity affects parental care behaviour in bluegill sunfish (Lepomis machrochirus)

Understanding the mechanisms that lead to adaptive behaviour is an exciting interface between levels of analysis in behavioural ecology. Here we manipulated perceived paternity of nest-tending parental male bluegill (*Lepomis macrochirus*) and examined the effect on circulating hormone concentrations and parental care behaviour. Males' perceived paternity was reduced using either an indirect cue of the presence of cuckolder males during spawning, or a direct cue of swapping a portion of the eggs in males' nests. When compared to control males, we found that reduced paternity led to a decrease in males' aggressive behaviour directed towards a brood predator. However, we found no apparent effect of the manipulation on circulating 11-ketotestosterone concentrations. We will discuss the effect of prolactin with the goal of understanding the mechanisms influencing adaptive parental care decisions.

28-3 CIERI, RL*; FARMER, CG; University of Utah; *bob.cieri@gmail.com*

Net-unidirectional airflow patterns vary with pulmonary anatomy in monitor lizards (Varanidae): insights from a multi-species computational fluid dynamics investigation

Varanids are a remarkable group of lizards that exhibit great variation in body mass, ecological niche, and aerobic capacity but retain a conserved body plan. Their lungs also vary and are an ideal group in which to investigate the functional and ecological significance of pulmonary traits. Our group reported unidirectional flow in the larger chambers of *Varanus exanthematicus* but detailed flow patterns and how these patterns vary among species remains unknown. Studying airflow in varanid lungs is difficult because much of the lung is dense parenchyma that cannot be accessed with flow probes. Computational fluid dynamics (CFD) can overcome these difficulties by generating simulations of pulmonary airflow based on computed tomography (CT) data that can be validated on real lungs. Airways were segmented and made into surface files in Avizo. Surface models were meshed into a computational meshes using the unstructured mesh generation utility, snappyHexMesh. CFD simulations were run using a custom PIMPLE-based dynamic solver in OpenFOAM. Varanid lungs consist of an intrapulmonary bronchus (IPB) that ends in a caudal bronchus, branches cranially into a hilar-cranial bronchus (HCB), and opens throughout into secondary bronchi that interconnect via perforations. Smaller species have fewer but larger caudal chambers and relatively thicker IPBs. Flow in *V. exanthematicus* is net-unidirectional: the IPB moves air net caudally, the secondary bronchi move air net cranially, and the HCB is tidal. In *V. spenceri*, which has a has a thin IPB, the dorsal aspects of secondary chambers carry net caudal flow and the ventral aspects carry net cranial flow. These results show that pulmonary airflow patterns in varanids vary with life-history traits and varanid lungs contain a mix of unidirectional and tidal lung traits.

130-1 CIRINO, LA*; LENGA, SH; MILLER, CW; University of Florida; *lacirino@ufl.edu*

Males with damaged weapons produce more offspring in non-competitive environments

Some males engage in fierce competitions using elaborate weapons to gain access to females and reproduction. Yet, not all males in these species have large or robust weapons. Weapons can become damaged and this phenomenon is surprisingly common. When weapons are compromised, males are less likely to win male-male competitions or may avoid them altogether. Thus, males in species that use weapons to secure females are likely to have evolved alternative routes to achieve reproductive success. One way may be to boost sperm production, so males can provide more ejaculate to females in the rare cases that they are encountered. In this study, we examined whether males with weapons damaged during development have increased offspring production. We induced developmental hind leg weapon damage in *Narnia femorata* (Hemiptera: Coreidae), a species that exhibits resource defense polygyny and is known to increase testes size when a weapon is lost during development. We then mated intact and weapon damaged males with four virgin females successively. Weapon damaged males produced more offspring with large females. We also noted behavioral differences between male groups. Large males with intact weapons mated with more females than weapon damaged males. Together, these results suggest that damaged males have a larger ejaculate and may be strategically investing that ejaculate in fewer females, leading to the increase in overall reproductive success. When weapon damage limits male access to females, they are able to employ an alternative reproductive strategy to counteract their diminished opportunities to mate. This strategy may help maintain variation in a population and relax the strength of sexual selection on these weapons.

P3-34 CLAPP, N*; REICHERT, M; CLAPP, Nicole; Oklahoma State University ; *nicole.clapp@okstate.edu*

The Effect of Arginine Vasotocin on Competitive Behavior in Hyla chrysoscelis

Hormones play an important role in animal social behavior, including competitive behaviors. Previous studies demonstrate that the hormone Arginine Vasotocin (AVT) modulates the calling behavior of different frog species. Male frogs produce acoustic advertisement calls to attract females and compete with one another by increasing their call rate and call duration. Previously, AVT has been shown to correlate with increased call rate and call duration; however, how competition influences this relationship remains unknown. We investigated how the effects of AVT would be impacted by different competitive environments in the gray treefrog *Hyla chrysoscelis*. We predicted that increased competition would further amplify the effects of AVT on call rate and call duration. Frogs were caught and injected with either a saline control (n=37) or AVT (n=39) and then sequentially exposed to noncompetitive, moderately competitive, and highly competitive environments via playbacks of synthetic calls with differing call rates and durations. Preliminary data suggest that there is not a significant difference in the likelihood to resume calling after injection between the two treatment groups. We also analyzed the data for changes in calling characteristics to demonstrate the role that competitive environments play in modulating social behaviors influenced by AVT. This has important implications for the overall competitiveness of the individual and the individual's subsequent reproductive success.

P3-242 CLARDY, TR*; THOMAS, BK; DAS, PB; AL-NUWAIRAH, MA; HEINLE, MJ; HIKMAWAN, TI; PRIHARTATO, PK; ABDULKADER, KA; QURBAN, MA; King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia, Environmental Protection Department, Saudi Aramco , Environmental Protection Department, Saudi Aramco; *clardytodd@gmail.com*

Optimal temperatures for common copepods in the Western Arabian Gulf

The Arabian Gulf (Gulf) is a shallow marine basin located in one of the hottest, most arid environments in the world. Water temperatures of the Gulf range annually from 15-35 °C. Under these variable conditions, the species composition of the copepod community changes markedly between winter and summer. The community change is likely driven by different optimal temperatures for the dominant copepod species. In this study, the optimal temperature, and temperature ranges, for 15 of the most common copepod species in the Gulf were estimated, using a reciprocal quadratic yield-density model. Abundance data for the model were compiled from 360 plankton tows collected from Saudi Arabian waters of the Gulf between May 2016 and October 2018, across a range of temperatures from 14-37 °C. There were differences in the optimal temperatures among the 15 species, suggesting that different species prefer different thermal conditions in the Gulf. Differences in thermal preference among species may explain the high seasonal turnover of copepods in the Gulf.

S6-1 CLARK, CJ; University of California, Riverside; *cclark@ucr.edu*

Introduction to the Symposium on Bioinspiration of silent flight of owls and other flying animals

Owls are well known for their nearly soundless flight, in comparison to the wing sounds of other birds. Owls have evolved wing and tail features, including a comb-like structure on the leading edge of the wing, a 'velvet' in between adjacent wing feathers and tail feathers, and fringed feather margins that are associated with sound reduction. Recent studies have used techniques such as beamforming and computational fluid dynamics models to understand how these wing structures suppress sound in flight. The stated intent of these studies is to discover whether any evolved features of owl wings may have a design basis with technological application to noisy human devices such as drones, windmills or trains. Neurobiologists have extensively studied owl hearing as a model for sound localization. The purpose of this symposium is to bring together biologists and engineers to discuss ongoing research in 'animal aeroacoustics', the study of how animal flight produces an acoustic signature, and its biological context.

S6-9 CLARK, CJ*; LE PIANE, K; CLARK, Christopher; University of California, Riverside; *CCLARK@UCR.EDU*

Evolutionary and ecological correlates of silent flight in owls, nightbirds and hawks: Does silent flight evolve for stealth, or to reduce self-masking?

Owls, Nightbirds (nocturnal members of Caprimulgiformes) and certain hawks have all evolved feather features that reduce the sound they produce in flight. These features are: a leading edge comb (owls) which reduces sound primarily below 10 kHz; vane fringes (owls and nightbirds), which may reduce low or high-frequency sound; and a velvet on the dorsal surface of their wing and tail feathers (all three groups) which ameliorates broadband rubbing sound that includes substantial ultrasound (sound as high as 50 kHz). Two non-mutually exclusive hypotheses make predictions about why silent flight has evolved. The self-masking ("owl ear") hypothesis states that wing sounds reduce the predator's ability to hear prey sounds, thus silent flight enables the predator to better locate prey. The stealth ("mouse ear") hypothesis states that wing sounds reduce the ability of prey to hear the predator approach, limiting the prey's ability to take evasive action in response to an attack. For owls, which hunt by ear, most available lines of evidence better support the self-masking hypothesis, such as: increases in background sound reduce owl hunting success. For nightbirds, the data better support the stealth hypothesis, as nightbirds do not use sound to hunt and their wing features reduce ultrasound not audible to them but audible to their insect prey. For hawks the answer is unclear; while all hawks use visual cues to hunt, some hawks also use acoustic cues, and not enough is known about either the use of sound nor the distribution of silencing features within Accipitriformes to draw firm conclusions about their function.

P3-153 CLARK, AE*; MEREDITH, TL; PORTER, ME; Florida Atlantic University ; *clarka2014@fau.edu*

Comparing Olfactory Rosette Morphology Among Elasmobranchs

Elasmobranch (sharks, rays, and skates) olfactory morphology is similar to teleost fishes, but the effects of ontogeny and phylogeny are unclear. Olfactory rosettes are composed of a central raphe that supports repeating lamellae, which are lined with the sensory epithelia. Previous research has shown that lamellar number varies among species, but does not indicate sensitivity to odorants. Habitat has also been correlated with the number of lamellae. The goal of this study was to investigate the relationships among ontogeny, species, and rosette morphology using fineness ratio (2D measure of shape), lamellar count, raphe width, interlamellar distance, and lamellar thickness measurements. The shapes of the rosettes are expected to vary among species due to cranium structure; however the shape should remain constant throughout development. Morphological measurements were collected from five elasmobranch species (N=29 specimens; families Alopiidae, Lamnidae, Carcharhinidae, and Sphyrnidae) with a known body size, measured by fork length (FL). Data was analyzed using mixed model ANOVAs with species, body size (FL), and species * body size (FL) interaction term as effects. We found that olfactory organ fineness ratio, lamellar counts, and raphe width among species was significant. Body size (FL) was not a significant effect for any of the tested variables. The species * body size (FL) interaction term was a significant effect for fineness ratio. Interlamellar distance and lamellar thickness were not significant over a range of sizes and among species. We hypothesize that phylogeny is a key component of olfactory rosette variability. Further research will examine the data using a phylogenetic principal component analysis (pPCA) to examine these relationships.

90-1 CLARK, EG*; HUTCHINSON, JR; BISHOP, PJ; BRIGGS, DEG; Yale University, Royal Veterinary College; *elizabeth.g.clark@yale.edu*

Investigating the Locomotion of an Early Deuterostome through 3D Imaging and Digital Modeling

Living echinoderms utilize a variety of unique locomotion strategies to leverage radial symmetry for omnidirectional locomotion. Fossil echinoderms exhibit a much greater disparity of body plan, making it difficult to determine the origins of five-fold symmetry and track its functional and ecological consequences, including the evolution of locomotion. Most early fossil echinoderms were sessile; stylophorans represent an important exception. These fossil echinoderms have a relatively flat body and a single segmented arm (aulacophore) which has been interpreted as locomotory. Many fundamental aspects of stylophoran biology, from their phylogenetic position to their dorsoventral orientation, remain unclear. Determining whether or not stylophorans were capable of locomotion has been considered critical to addressing these issues. We calculated the range of motion of the aulacophore in an Ordovician stylophoran by constructing a digital model using morphological data from a micro-CT scan to evaluate the feasibility of previously hypothesized locomotion strategies. Our results suggest that the aulacophore was used for both feeding and positioning the organism.

P1-205 CLARK, A*; CARUSO, A; GIGNAC, P; UYENO, T; College of Charleston , Oklahoma State University Center for Health Sciences, Valdosta State University; *clarkaj@cofc.edu*

Three-dimensional reconstruction of the hagfish feeding apparatus using diceCT

Hagfishes are jawless fishes that grasp and swallow food items with protractible dental plates. A dental plate (DP) is composed of keratinous teeth mounted on a thin wing-like cartilaginous plate housed within the anterior half of the hagfish feeding apparatus (HFA). Cyclic protraction-retraction of the DP is supported ventrally by relatively thick cartilaginous basal plates (BP). As the DP protracts from the mouth, it unfolds like an opening book revealing the teeth, then during retraction, the DP folds medially like a closing book as it pulls food into the mouth. Protraction is mostly powered by a quartet of strap-shaped muscle rami that originate from the ventral surface of the BP and insert onto the anterior margin of the DP. Retraction is powered by a muscular hydrostat in the posterior half of the HFA. The cylindrical hydrostat contains a three-dimensionally complex arrangement of longitudinal, semicircular, and transverse muscle fibers. Visualizing and reconstructing this morphology is challenging because the HFA is almost entirely composed of soft tissues. We used diffusible iodine-based contrast-enhanced micro-CT scans to successfully visualize and reconstruct the 3D morphology of the HFA from a Pacific hagfish. In Avizo, we segmented the dentition and cartilages and inspected the 3D arrangement of muscle fascicles and connective tissues in the HFA. Dice-CT scans clearly illustrate the 3D complexity of the muscular hydrostat and corroborate recently published histologically based anatomical reconstructions. These data also show that the cartilages and teeth are either poorly interconnected or completely decoupled, suggesting that the anterior HFA can be readily deformed to accommodate various food items.

32-3 CLARK, RM*; FOX, TP; HARRISON, JF; FEWELL, JH; Siena College, Loudonville, NY, Arizona State University, Tempe, AZ; *rclark@siena.edu*

Energetic Savings of Grouping During Nest Initiation in Harvester Ants

Queens of the seed-harvester ant *Pogonomyrmex californicus* vary geographically in their propensity to cooperate with each other when starting a new colony, leading to questions about the mechanisms that facilitate such grouping and cooperation. Given recent studies that show that ant colony mass-specific metabolic costs decline with group size, we tested the hypothesis that cooperation provides a metabolic advantage for queen pairs during colony founding. We determined that the most energetically intense period of nest initiation extends from the postmating period, through nest excavation, until the onset of brood-rearing. Correspondingly, both queens with an evolutionary history of cooperative nest-founding and queens that lack this history showed reduced mass-specific metabolic rates when paired together during the most energetically intense period. This effect occurred independently of any metabolic costs associated with locomotion. Collectively, our findings suggest that the simple act of grouping somehow provides a direct energetic benefit to queens during the energetically demanding life stage of colony founding, regardless of whether or not queens have actually evolved to cooperate during this period. This research was partially supported by NSF IOS 1558127.

S6-12 CLARK, CJ; CLARK, Christopher; UC Riverside; *cclark@ucr.edu*

Final roundtable discussion on bioinspiration of silent flight

We conclude our symposium on bio-inspiration of silent flight of owls and other flying animals, by discussing open questions within this area, with an eye towards identifying areas of research that are not currently being addressed. Open engineering questions include: what is the role of wing flapping in the acoustics of bird flight? Does flapping fundamentally alter the airflow over a wing (such as through the leading edge comb of an owl's wing), and its acoustic signature? On the biological side: What types of sound are owls and other silent flyers selected to reduce? What is the relationship between the adaptations to reduce flights sounds, and the hearing of the predator and prey? The final goal of this discussion is to explore bio-inspiration of silent flight. What types of biological data are most important for inspiring new directions of 'bio-inspiration'? And what are the potential engineering applications of discoveries that may yet be made on how animals make sound as they fly?

78-2 CLAVEL, J*; MORLON, H; The Natural History Museum, École Normale Supérieure; *j.clavel@nhm.ac.uk*

Phylogenetic Signal and Linear Model for High-Dimensional Multivariate Comparative Data: a case study with the MANOVA

Phylogenetic linear models (e.g., regressions, ANOVA, or ANCOVA) provide a statistically rigorous framework for comparative studies of phenotypic traits across taxa. However, the development of their multivariate counterparts is still lagging behind because of the computational challenges encountered with multidimensional datasets. In particular, when the number of traits *p* approach or exceed the number of taxa *n*, the conventional statistical machinery is limited, and we have to rely on alternative methods that are approximate and restricted to the Brownian motion model of trait evolution. Here we developed more flexible multivariate phylogenetic linear models (e.g., multivariate regressions, MANOVA, MANCOVA) to deal with the high-dimensionality of modern high-throughput comparative datasets. We used intensive simulations to assess the performances of the proposed approaches to various level of phylogenetic signal, of correlations between the traits, and distributions of phenotypic changes in the multivariate space. We show that the proposed approaches outperform conventional ones when *p*, and current alternative when $p>n$. We further show that current available approaches to deal with high-dimensional datasets lack the power to detects differences in multivariate datasets and may have high type I error rates. Finally, we provide an empirical test of our phylogenetic MANOVA on a geometric-morphometric dataset describing the mandible morphology in phyllostomid bats along with data on their diet preferences. Overall our results show significant differences between ecological groups while accounting for the mild phylogenetic signal of these ecomorphological data. We provide some guidance on the use of multivariate statistics for comparative analysis and discuss some recent concerns about the use of phylogenetic comparative methods.

P1-131 CLAY, TA*; HESS, AJ; BONETT, RM; Nicholls State University, University of Tulsa; *tim.clay@nicholls.edu*

Biogeography of the Ouachita Dusky Salamander, Desmognathus brimleyorum

The Ouachita dusky salamander, *Desmognathus brimleyorum*, is a semi-aquatic salamander restricted to the Interior Highlands of Arkansas and Oklahoma. We conducted surveys during their active season to determine their distributional extent and to collect genetic samples for phylogeographic studies. Using MAXENT, distributional data were combined with fine scale temperature data, geographical data, and macroenvironmental parameters to identify the relative importance of environmental variables in the distribution of *D. brimleyorum*. Out of 26 environmental variables, the top 5 variables contributed to nearly 90% of the species distribution model. The top predictor variable, land cover, accounted for approximately 33% of the distribution model. Extrapolating the model over the entirety of the Interior Highlands of Arkansas and Oklahoma predicts a distribution largely confined to the Ouachita Mountains, and absent from the Ozarks and Coastal Plain, consistent with historical observations. The MAXENT model highlights the importance of conservation and land cover on the distribution and continued persistence of salamander populations of the Interior Highlands.

18-2 CLEMENTS, KN*; HEAGY, FK; BLAIN, E; WARD, J; ISSA, FA; East Carolina University, Greenville, NC; *clementsk10@students.ecu.edu*

Repeated Social Defeat Affects Dopaminergic Modulation of Spinal Motor Circuits

Social submission negatively impacts behavior and physiology of many social animals, yet the effects of repeated social defeat (RSD) on nervous system function underlying locomotion remain poorly understood. We investigated how RSD affects dopaminergic modulation of swimming and startle escape in zebrafish. Paired zebrafish form dominance relationships where subordinates are repeatedly defeated by their opponents. We showed that subordinates swim less and increase startle escape compared to dominants. Dopamine (DA) is involved in regulating locomotion by directly modulating spinal circuits. We studied whether DA signaling underlies this shift in locomotor activity. Western blot results showed that RSD decreases expression of dopamine 1 receptor (D1R). Pharmacological blockage of D1R caused dominants to swim less and escape more, resembling subordinate behavior. We also tested these behaviors in D1R knockout fish and found that they exhibited subordinate-like locomotive patterns. This suggests that RSD affects DA modulation of motor circuits by regulating the expression of D1R on postsynaptic targets. To test whether RSD also induces morphological changes within the presynaptic DA system, we counted the number of DA neurons in the hypothalamic A11 DA nuclei with Tg(dat:EGFP) zebrafish. The A11 nucleus is known to project into the spinal cord and modulate swim and escape circuits. Preliminary results of confocal images showed that RSD decreases total number of DA neurons in the A11. This suggests A11 is influenced by chronic defeat and allows exploration of if these neurons modulate the escape and swim circuits in the context of RSD. Our results highlight how RSD impacts CNS function and how this modifies adaptive motor behavior.

135-2 CLIFTON, IT*; CHAMBERLAIN, JD; GIFFORD, ME; University of Toledo, Southern Arkansas University, University of Central Arkansas; *Ian.Clifton@rockets.utoledo.edu*

The Role of Phenotypic Plasticity in Morphological Differentiation Between Watersnake Populations

An individual's morphology is shaped by the environmental pressures it experiences, and the resulting morphological response is the culmination of both genetic factors and environmental (non-genetic) conditions experienced early in its life (i.e., phenotypic plasticity). The role phenotypic plasticity plays in shaping phenotypes is important, but evidence for its influence is often mixed. We exposed female neonate diamond-backed watersnakes (*Nerodia rhombifer*) from populations experiencing different prey-size regimes to different feeding treatments to test the influence of phenotypic plasticity in shaping trophic morphology. We found that snakes in a large-prey treatment from a population frequently encountering large prey exhibited a higher growth rate in body size (SVL) and in head length than individuals in a small-prey treatment from the same population. This pattern was not observed in snakes from a population that regularly encounters small prey. We also found that regardless of treatment, snakes from the small-prey population were smaller at birth than snakes from the large-prey population and remained so throughout the study. These results suggest that the ability to plastically respond to environmental pressures may be population-specific. These results also indicate a genetic predisposition towards larger body sizes in a population where large prey items are more common.

P2-162 CLIFTON, IT*; REFSNIDER, JM; University of Toledo; *ian.clifton@rockets.utoledo.edu*

Characterizing the Thermal Ecology of a Montane Lizard Community

Elevational clines have long been recognized for their consistent patterns of climatic variation. Specifically, daily temperatures at lower elevations are generally warmer and less variable than daily temperatures at higher elevations. Thus, organisms at either extreme of the elevational range are likely experiencing markedly different climates. The consistent thermal differences that occur with elevation are likely to drive local adaptation to the thermal regimes frequently experienced. Here, we compared the thermal physiology of three sympatric phrynosomatid lizard species (*Sceloporus tristichus, S. graciosus*, and *Uta stansburiana*) across an elevational gradient in San Juan County, Utah. Because climate varies with elevation, we predicted lower thermal tolerance would decrease as elevation increased, and that critical thermal breadth would increase with elevation as daily temperatures become more variable with increasing elevation. We also expected lizards at lower elevations to exhibit greater thermal specialization at lower elevations (i.e., higher maximal performance across a narrower range of body temperatures). Contrary to predictions, we found no evidence of consistent patterns of variation in thermal physiology across elevation in any of the three lizard species we measured. Although lizards were captured across their entire elevational range for the area, the gradient (~500m for each species) may not have provided a large enough thermal gradient to drive adaptive processes. Alternatively, the seeming ubiquity of each of these species along the elevation gradient and lack of discernible patterns in thermal physiology may suggest a relatively large degree of gene flow along the gradient, potentially washing out any local adaptation at the extremes.

139-1 CLIFTON, GT*; HOLWAY, D; GRAVISH, N; Univ. of California, San Diego, UCSD; *glclifton@eng.ucsd.edu*

The influence of uneven terrain and vision on ant walking

Visual feedback substantially informs vertebrate walking coordination and control, but the ability of some ant species to forage at night and through dark tunnels suggests that vision may be less essential for certain insects. To understand how vision influences walking performance under naturally rugged conditions, we recorded 3900 high-speed videos of Argentine ants (*Linepithema humile*) walking on 3D-printed substrates both in light and dark conditions. Ants walking on flat ground showed a small, but significant shift to slower speeds in the dark. On a checkerboard substrate, ants walked 50% slower but, surprisingly, lighting did not influence speed. Pathway sinuosity increased on the checkerboard array but did not change between light and dark conditions. Since many walking perturbation studies focus on a discrete step, we also included a step substrate. When confronted with a step up, ants decelerated on average ~2.8 mm before the step, a distance corresponding to when the antennae first contact the step. For stepping down, ants slowed down <1 mm from the step approximately when the forelimbs would reach the step edge, regaining original speeds only 2.5-3 mm after the step. Together these findings support that vision does not critically impact walking for the Argentine ant, especially on uneven terrain. Instead, ants could either walk without sensory feedback or by relying on tactile and proprioceptive cues from the antennae and limbs. The reduced influence of vision in this ant species could stem from slow visual perception relative to movement speeds and from the ability to generate large body accelerations using specialized tarsal structures. These results have the potential to inform insect neuromechanics, inspire new robotic control strategies, and explain ecological patterns in life history.

P2-18 CLINE, NW*; BROTHERS, CJ; MORROW, CD; CURTIS, MD; ANDERSON, SM; AMSLER, CD; SHILLING, AJ; MCCLINTOCK, JB; Walla Walla University, University of Alabama at Birmingham, University of Alabama at Birmingham, University of South Florida; *noah.cline@wallawalla.edu*

Characterizing the Digestive Microbiome of Antarctic Sea Stars

Sea stars (Phylum Echinodermata; Class Asteroidea) are some of the most abundant macroinvertebrates in shallow waters surrounding Antarctica and are well-adapted to a benthic environment with limited food availability. Antarctic sea stars display opportunistic feeding behaviors including scavenging, necrophagy, and detrital feeding. However, the types of micro-organisms associated with the digestive organs of Antarctic sea stars and the importance of these microbes is not well understood. Four species of sea stars (*Diplasterias* sp., *Lysasterias* sp., *Ondontaster meridionalis*, and *Ondontaster validus*), sediment, and seawater samples (n=6, respectively) were collected from the Western Antarctic Peninsula. Digestive organs (stomachs and pyloric caeca) were dissected from the sea stars and the metacommunity 16S rRNA genes (V4 region) were sequenced using the Illumina MiSeq^{TM} platform. The microbial community structure of the samples was determined using bioinformatics tools. Microbial diversity of the digestive organs was lower than that of the surrounding environment (seawater and sediment), with the lowest diversity observed in the digestive organs of *Diplasterias* sp. The microbial community composition also varied depending on the type of sample. The changes in microbial diversity and community composition between the environment and four sea star species suggest the feeding strategies and physiological requirements of each species may play a selective role in determining the digestive microbiome of Antarctic sea stars.

P3-30 CLOSS, LE*; BAKER, DM; FONTAINE, R; WELTZIEN, FA; University of Mary Washington, Fredericksburg, VA, Norwegian University of Life Sciences, Oslo, Norway, Norwegian University of Life Sciences, Oslo, Norway; *lcloss@umw.edu*

Investigating Reproductive Success and Endocrine Regulation of Mating Strategies in Male Medaka

Mate guarding, when two males compete for one female, is a reproductive strategy seen across a variety of vertebrate species. This often leads to hierarchical relationships, in which one male exerts dominance over other, subordinate males. However, the physiological mechanisms that promote dominance or subordinance in males remain largely unexplored. In this study, we investigated the reproductive success and endocrine signals of the two reproductive strategies in Japanese medaka (*Oryzias latipes*). To identify dominant and subordinate males, triads consisting of two males of different genotypes and one female were observed repeatedly for 5 days. Male reproductive success was determined by genotyping 20-21 embryos from each female. We found that the number of eggs fertilized by dominant and subordinate males did not differ (p=0.29), indicating that dominant behavior does not guarantee reproductive success and that subordinate males may successfully fertilize eggs using sneaker male tactics. We hypothesize that these behaviors are linked to activity in the reproductive endocrine axis. To test this hypothesis, we quantified pituitary levels of luteinizing hormone (Lh) and follicle stimulating hormone (Fsh) in dominant and subordinate males using an ELISA. While Fsh did not differ between the groups, Lh was unexpectedly higher in subordinate males (p=0.047). This indicates that either Lh production is stimulated or its pituitary release is inhibited in subordinates. To investigate these opposing explanations, we are measuring mRNA levels of Lh, Fsh, and GnRH receptors in the pituitary, and GnRH and AVT in the brain of dominant and subordinate males using qPCR.

P2-73 CLOWSER, D*; WILSON, C; PETERSEN, A; POSTLETHWAIT, J; Oregon State University- Cascades, Bend, University of Oregon, Eugene; *clowserd@oregonstate.edu*

Is it an Androgen, Estrogen, Obesogen, or all of the above? Perchlorate Exposure Causes Different Pathologies in Different Fishes

Perchlorate (P) is a contaminant found in surface water around the globe and is known to cause health issues in vertebrates. P reduces production of thyroid hormone and masculinizes germ cell growth and adult phenotypes in threespine stickleback fish (*Gasterosteus aculeatus*); this effect on germ cells is not fully explained through known thyroid-hormone pathways. Our study aims to quantify P's effects on fish development. We exposed zebrafish (*Danio rerio*) to 100ppm P from fertilization to 45 days post fertilization (dpf). Experiments were conducted using Nadia stock to allow for sex genotyping. We collected fish at 17, 25, and 45 dpf and analyzed histology from control and P treated (PT) groups to assess pathologies correlated with endocrine disruption. These endpoints are density of liver adipocytes, primary germ cell count, thyroid follicle count and size, and density of spleen melanomacrophages. Thyroid follicle counts were significantly higher in PT fish at 25 and 45dpf. Melanomacrophage density increased with PT at 45dpf; this effect appeared earlier in female fish. Primary germ cell counts were significantly higher in 25dpf PT females, but adipocyte density did not increase in PT fish. High germ cell number is a female trait in zebrafish, and failure to find changes in adipocyte density means that P is not an obesogen in zebrafish. We found no effect of P on sex ratio during development. Our findings differ from previous published data involving stickleback, where P caused masculinization and adipogenesis. Overall, our findings provide new insight into mechanisms and action pathways of P, but also raises questions about the species-specific response to the contaminant.

P2-26 COBB, BA*; GIBSON, JD; BOTNARU, L; Georgia Southern University, Statesboro, GA; *bc05764@georgiasouthern.edu*

Exploring the lethality of genetic incompatibility in jewel wasp hybrids

The parasitoid wasp genus *Nasonia* serves as an emerging model for mitochondrial disease due to an incompatibility between nuclear and mitochondrial genomes between sister taxa. Male hybrids of *Nasonia vitripennis* and *Nasonia giraulti* experience mortality during the larval stage of development as compared to parent strains. Previous research has shown that 98% of F2 males with an incompatible allele on chromosome 5 combined with *N. giraulti* maternity die. This region of interest on chromosome 5 encodes a gene suspected to be involved in the NADH pathway, possibly explaining the energetic shortfall preventing the organism from reaching adulthood. The goal of this research is to further explore what genetic basis underlies the mortality seen in *N. vitripennis* and *N. giraulti* hybrids and the energetic effects of a given genotype. To better understand how this mitochondrial incompatibility affects individuals, progeny counts will be taken of each life stage to determine fecundity of backcrossed F2 females and parent crosses. Larvae and pupae will be collected at arrested stages to determine genotype, as diapause can be an indicator of lesser metabolic capability. Offspring and parents of each cross will be genotyped to determine allele ratios. Rate of oxygen consumption will be measured in backcrossed F2 female mitochondria to test energy metabolism and deduce what energetic consequence each genotype has across strains. Once we can describe the relationships between genotype and metabolic phenotype in *Nasonia*, we can begin to explore what other combinations of factors lead to lethality during hybrid development.

134-4 COBOS, AJ*; HIGHAM, TE; University of California, Riverside; *acobo002@ucr.edu*

Get a grip: the effect of asperity size on gecko adhesion

Geckos have garnered much attention over the years due to their remarkable ability to adhere to smooth surfaces, resulting in detailed assessments of their unique morphological adaptations and adhesive capabilities. Their adhesive structures operate at many different length scales, each of which contributes to overall adhesion of the gecko as they interact with various types of surfaces in their natural environment. That said, we have a cursory understanding of how surfaces of different roughness impact adhesive contact and overall force as few studies have considered these interactions, particularly on the micro scale. Here we tested adhesive performance of tokay geckos, *Gekko gecko*, on 7 different sandpaper grits with asperity sizes ranging from ~3 – 200 µm to determine the effect of surface roughness on maximum shear adhesive force. We recorded the interactions with a high-speed video camera in order to account for slipping (timing and velocity). For each surface, we visualized the three-dimensional topography using a combination of scanning electron microscopy and confocal imaging to get area roughness (S_q). We found that shear adhesive force was reduced up to 91% when asperity size approached ~100 µm, the average setal length of tokay geckos. Similar to the findings of other studies on adhesion, when surface structure dimensions parallel those of the adhesive structure, adhesion is greatly reduced as attachment opportunities are limited. In this case setae are likely unable to conform to the surface thus reducing overall spatulae contact. Connecting measures of whole-animal performance with information about ecologically-relevant surfaces can further our understanding of the origin and evolution of adhesion, but also improve biomimetic applications.

P2-159 COCHRAN, J K*; ORR, S E; BUCHWALTER, D B; North Carolina State University; *jkcochra@ncsu.edu*

Assessing the concept and thermal sensitivity of the Pcrit in the mayfly N. triangulifer

Climate change and various human activities decrease the dissolved oxygen (DO) content of freshwater ecosystems. Historically, scientists have used the concept of the Pcrit (the DO level below which an animal can no longer oxyregulate) to infer hypoxia tolerance across species, primarily fish. The Pcrit concept has been recently challenged on several fronts and requires critical evaluation. Using cutting edge respirometry equipment, we tested the hypothesis that the Pcrit is positively correlated with temperature in the mayfly *N. triangulifer*. Pcrit estimates were taken from 96 individual larvae across 5 temperatures spanning 10°C. We found a modest ($r = 0.45$), but highly significant ($p < 0.0001$) association between temperature and Pcrit despite relatively large inter-individual variability (CV=25.9% ±8.35%). We next tested the concept that the Pcrit represents the tipping point between aerobic and anaerobic metabolism by quantifying the expression of hypoxia-responsive genes along a DO gradient at three different temperatures. Neither EGL-9 (an oxygen sensing gene and modulator of HIF-1a activity) nor LDH (a hypoxia indicator) were upregulated at oxygen levels above the temperature-specific Pcrit estimates. However, at or below the Pcrit estimates, expression of both genes was stimulated (e.g. 19.66- and 3.01-fold change for EGL-9 and LDH, respectively at 22°C). Our data provide modest support for the notion that the Pcrit represents a physiologically meaningful shift from aerobic to anaerobic metabolism in *N. triangulifer*. However, a high degree of inter-individual variation precludes the use of a single value to describe a species response to DO. Further, because hypoxia tolerance likely involves a complex suite of physiological attributes, the Pcrit alone may not be a suitable predictor of hypoxia tolerance.

48-5 COELHO, JC*; POOLE, AZ; Berry College, Berry College ; *Jenny.Coelho@vikings.berry.edu*

The Evolution and Role of GTPases of Immunity Associated Proteins (GIMAPs) in Cnidarians

Corals, which are members of Phylum Cnidaria, play a critical role in coral reefs, one of the world's most productive and diverse ecosystems. Coral reef health depends on a mutualistic symbiotic relationship between cnidarians and photosynthetic dinoflagellates of the family Symbiodiniaceae. However, a variety of stressors to reefs such as elevated temperatures and coral disease contribute to breakdown of this symbiotic relationship which can lead to coral death and collapse of the reef ecosystem. To better understand coral disease and symbiosis, we looked at a group of potential immune proteins in cnidarians called GTPases of immunity associated proteins (GIMAPs). In vertebrates these proteins regulate the fate of developing lymphocytes and a previous study revealed their presence and potential immune function in cnidarians. To better understand the evolution of GIMAPs within this phylum, bioinformatic searches were conducted in a diversity of publicly available genomes and transcriptomes. Additionally, to better understand the role of GIMAPs in cnidarian immunity and symbiosis, both symbiotic and aposymbiotic *Exaiptasia pallida* were exposed to the immune stimulant lipopolysaccharide (LPS) and gene expression of four GIMAP-like sequences called *Ep_GIMAPs* was measured using qPCR. The bioinformatic searches revealed two types of GIMAP-like sequences termed long and short, with patchy distribution, including cnidarians that contain one, both, or neither GIMAP type. The gene expression work showed two of the *Ep_GIMAPs* had greater expression in symbiotic than aposymbiotic *E. pallida*, implying a function in regulating symbiosis. However, *Ep_GIMAPs* did not show significant expression differences in response to LPS treatment, suggesting a role other than immunity. Overall, this work provides a greater understanding of the cnidarian immune system and the evolution of GIMAPs.

54-3 COFFIN, JL*; KELLEY, JL; TOBLER, M; Kansas State University, Washington State University; *jlcoffin3@gmail.com*

Adaptation to Life in Acid Mine Drainage: Transcriptomics and Molecular Evolution in Western Mosquitofish

The world has seen an unprecedented increase in anthropogenic inputs of numerous elements since the onset of the industrial revolution, often leading to perturbed or destroyed ecosystems. Heavy metals sourced from the byproducts of mining activities are common contaminants in the biosphere and can have detrimental effects at all levels of biological organization. The Tri-State Mining District of Kansas, Missouri, and Oklahoma has long been characterized by elevated heavy metal concentrations in animals and humans from improper waste management, leading to the designation of the Tar Creek Superfund Site. The surviving ichthyofaunal community of Tar Creek is dominated by Western mosquitofish (*Gambusia affinis*), which also inhabit neighboring, unpolluted watersheds, facilitating comparative analyses of physiological and evolutionary responses to heavy metal pollution. We coupled molecular evolutionary analyses in related fishes inhabiting extreme environments with RNA-sequencing of gill, liver, and brain tissues of *G. affinis* to address basic questions regarding evolutionary responses to heavy metal stress: 1) which genes are experiencing positive selection in populations of *G. affinis* inhabiting polluted habitats?, and 2) what genes are differentially expressed between populations of *G. affinis*? We hypothesized that genes involved with metal homeostasis would be under positive selection and be upregulated in the Tar Creek population of *G. affinis*. These analyses 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 heavy metal contaminated extreme environments.

129-1 COHEN, HE*; KANE, EA; Georgia Southern University; *hc02684@georgiasouthern.edu*
When the Expected Doesn't Happen: A Lack of Local Adaptation in Trinidadian Guppies
When populations occupy different environments, divergent selection pressures can result in phenotypic differentiation in traits that provide a local fitness advantage. Trinidadian guppy (*Poecilia reticulata*) populations are separated by physical barriers which result in repeated shifts in selective pressures from predator avoidance in high predation environments towards resource competition in low predation environments. Previous studies have shown that these changes result in a range of locally adapted morphological and behavioral traits, including color, length of gestation, and shoaling behavior. Regarding prey capture, although consumption rates and head morphology may differ, suction-feeding behaviors do not, and the role of local adaptation on feeding is unclear. We analyzed morphological differences such as body size, eye area, jaw positioning and body depth to validate known differences between populations. Since biting is a more relevant behavior for guppies, we then filmed adult females from replicate high/low predation pairs while they used biting behaviors to feed on an agar substrate. We did not find divergence in either morphological or kinematic traits, suggesting a general lack of local adaptation, contrary to previous findings. A lack of divergence could be due to less pronounced morphological divergence in females, perhaps as a constraint of bearing young, and the absence of divergent selection on prey capture performance. In female guppies, morphology and performance are not locally adapted, and divergence may exist primarily in behavioral traits (consumption rates) as a result of competition in low predation environments.

S3-3 COHEN, K.E*; WELLER, H.I; SUMMERS, A.P; University of Washington , Brown University , University of Washington; *kecohen@uw.edu*
What is homodonty?
Homodonty and heterodonty attempt to capture tooth battery morphology as it relates to prey processing. Homodont teeth are similar in shape or size and assumed to perform a uniform task. Heterodont teeth have shape regionalization and are associated with regionalized functions. These categories have poorly defined boundaries: how much morphological variation is permitted in a homodont dentition before it should be classified as heterodont? Development, replacement, and damage directly alter the shape and size of teeth along the jaw further complicating homodonty. Incipient, transient, or phylogenetic homodonty attempt to provide a more rigorous definition by incorporating additional contingencies, but instead serve to highlight the difficulties in categorizing dentitions. For instance, conical teeth are a simple shape with a simple job of puncture. Yet they vary in length, curvature, and sharpness as a result of additional selective pressures aside from puncture. By constraining homodonty to static shape, we miss aspects of how teeth are being used. Instead we propose to use function to tease apart not just how teeth look, but how they are used. We present a functional lens on homodonty by looking at stress, orientation, and curvature. These functional parameters allow us to analyse how large and small teeth work together to transmit forces to a prey item. Our results show that the placement of teeth affects their function and that there is a functional advantage to having several smaller teeth surrounding a singular large tooth. Our statistical models present a new tool for determining 'functional homodonty' and a series of dentitions that demonstrate the complexities of this problem. We show that teeth that look alike don't always act alike; morphologically heterodont teeth are functionally homodont.

P2-47 COLLAR, DC*; DIPAOLO, E; MEHTA, RS; Christopher Newport University, University of Rhode Island, University of California Santa Cruz; *david.collar@cnu.edu*
Evolutionary transformation along orthogonal anatomical axes in blennioid fishes
Extreme body elongation has occurred repeatedly in the evolutionary history of ray-finned fishes. Transitions from disc-shaped or fusiform to highly elongated (eel-like) forms can involve evolutionary changes in head dimensions as well as vertebral number and shape, but it is unknown whether some anatomical characteristics evolve more readily during body shape transformation. In this study, we examine body elongation in blennioid fishes (including combtooth, labrisomid, and tube blennies) and identify two independent origins of extreme body elongation that have occurred through orthogonal anatomical evolutionary trajectories. Within Blenniidae (combtooth blennies), species in the genus *Xiphasia* have dramatically elongated the caudal region of the body, with increased number of caudal vertebrae and aspect ratio of vertebral centra, but this lineage has experienced little change in head dimensions or abdominal vertebral morphology. In contrast, within Chaenopsidae (tube-blennies), a clade that includes species from the genera *Chaenopsis* and *Lucayablennius* has elongated the head and abdominal vertebral region but not the caudal region. These non-overlapping sets of anatomical modifications reveal that elongation can result from divergent evolutionary trajectories, which may reflect differences in the selective factors that shaped diversification. Elongation of the head and abdominal region in the *Chaenopsis* / *Lucayablennius* lineage likely enhanced the capture of large prey by ambush predation, whereas the elongation of the caudal region in *Xiphasia* presumably provided additional body flexibility for crevice-dwelling.

P3-57 COLLUM, A*; WHITMAN, S; HODGES, A; State University of New York ; *collan18@oneonta.edu*
Does Mating with a Novel Male Affect Female Fecundity in Bean Beetles?
The bean beetle, Callosobruchus maculatus, is both a crop pest and a model organism for understanding sexual conflict. Mating is costly for female bean beetles because the males have barbed copulatory organs, used to remove other males' sperm from the females' reproductive tracts. However, females may also benefit from multiple mating due to the water in the male ejaculate and due to increased genetic variability in their offspring. We compared fecundity between females mated twice to the same male and females mated to two different males. We predict that female fecundity will decline more slowly in the novel male group than the same male group.

35-7 COLOMBERO, CR*; WAINWRIGHT, DK; LAUDER, GV; Harvard University, Yale University; *crcolombero@college.harvard.edu*

Shark Dermal Denticles: Loss and Regeneration Patterns Vary with Body Position and Ecotype

Dermal denticles – the characteristic scale-type of sharks – are tooth-like structures embedded in the skin. Observation of denticles in a diversity of shark species and body locations reveals "gaps" in the denticle surface pattern where denticles are missing. These missing denticles may be lost as a result of natural replacement cycles or through injury, although little is known about the extent of these gaps in the shark skin surface and how (or if) denticles are replaced. In order to quantify the extent of missing denticles and describe the pattern of denticle replacement, we used four imaging techniques: (1) High-resolution µCT scanning to generate volumetric models, (2) surface profilometry to scan the surface for missing denticles, (3) Scanning Electron Microscopy (SEM), and (4) histology for visualization beneath the skin surface. The percent surface area of missing denticles was calculated for 10 shark species with benthic, coastal mid-water, and pelagic ecologies, and we observed replacement denticles forming and emerging from the dermis and epidermis in the gap regions. Our findings indicate that dermal denticles replace themselves and that this process begins after a scale has been lost. Replacement denticles develop crown-first and are weakly ossified early-on, with a large open pulp cavity and lacking a true root. Thus far, the tails of highly pelagic species including the thresher and mako sharks (*Alopias vulpinus* and *Isurus oxyrinchus*, respectively) have the highest percentage of missing denticles of the species surveyed, although even benthic sharks show gaps in the denticle surface and generation of emerging replacement denticles.

111-4 COMBES, SA*; GAGLIARDI, SF; WARGIN, AH; U.C. Davis; *sacombes@ucdavis.edu*

Wing damage isn't all bad for bumblebees: Asymmetric damage impairs maneuverability, but symmetric damage improves stability

Bumblebees fly through cluttered environments while foraging for resources, and collisions with vegetation cause irreversible wing damage that accumulates with age. Wing damage has been linked to increased mortality in bees, but the mechanism behind this finding remains unclear. We examined the effects of wing damage on two major aspects of flight performance, stability and maneuverability. We filmed 25 *Bombus impatiens* flying with a 2.5 m/s headwind in three conditions: in unsteady, structured flow generated by an upstream cylinder, while maneuvering to track a laterally oscillating flower, and while maneuvering to track a flower in the presence of unsteady flow. Bees flew in all three conditions with intact wings, with asymmetric damage (~20% area clipped from one wing), and with symmetric damage (~20% area clipped from both wings). To quantify stability and maneuverability, we calculated translational and rotational body orientation, and evaluated flower tracking performance. Neither type of damage led to significant changes in stability during flight in unsteady flow, but maneuverability during tracking was reduced by asymmetric (but not symmetric) wing damage. When unsteady flow was combined with the challenge of tracking a flower, we did find an effect of wing damage on stability; however, in this case symmetric wing damage actually improved stability over intact wings, whereas asymmetric damage had no effect. These results suggest that reduced maneuverability caused by natural wing damage, which is typically asymmetric, could underlie the increased mortality found in previous studies. However, bees' overall flight performance is impressively robust to wing damage, and symmetric damage can even provide stability benefits that may help compensate for the loss of force-producing wing area.

P1-68 COMERFORD, MS*; CARROLL, SP; EGAN, SP; Rice University, Houston, TX, University of California, Davis, CA, Rice University; *mattheauc@gmail.com*

Spatial sorting drives rapid ecological adaptation of the soapberry bug

Spatial sorting describes a mechanisms of evolutionary change where differential dispersal ability spatially structures mate choice, leading to rapid evolution favoring increased future dispersal capacity along an expanding range edge. We test the role of spatial sorting in the red-shouldered bug (*Jadera haematoloma*) as they recolonize areas that went locally extinct. These seed feeding insects are a model system for rapid ecological adaptation, as their beak lengths have been shown to quickly evolve to match the seedpod physiology of their different host plant associations. In addition, these insects express a discrete wing polymorphism that renders a proportion of the population flightless. These two traits are associated, in that, flighted individuals have longer beaks than their flightless counterparts. Serendipitously, this trait association creates both a differential in dispersal ability to fulfill the requirement of spatial sorting, and an ecologically relevant trait which we can observe in the face of natural selection. Through continuous monitoring of these traits before and after local extinction due to a catastrophic weather event, we test spatial sorting's evolutionary capacity as locally extinct metapopulations are re-colonized. Our study shows that flighted individuals are capable of recolonizing extinct patches, and that these re-colonizers bring with them longer beaks than the previous inhabitants. These longer beaks not only persist over multiple generations but also tend to grow longer as mate choice in recolonized patches remains limited to only long beaked flighted individuals. Interestingly, this increase in beak length occurs in habitats where it is adaptive and maladaptive, demonstrating that spatial sorting is a powerful evolutionary mechanism that can promote rapid morphological change.

P3-40 COMITO, D*; BENTLEY, GE; University of California, Berkeley; *dcomito@berkeley.edu*

Gonadotropin-Inhibitory Hormone and its Receptor in Zebra Finch Spinal Cord: A Novel Pathway for Neuropeptide Action?

Gonadotropin-inhibitory hormone (GnIH) is a neuropeptide that typically acts in the hypothalamic-pituitary-gonadal (HPG) axis to inhibit reproductive activity and sociosexual behaviors. GnIH is synthesized in the brain and in the gonads, where it can act via its cognate receptor. However, immunohistological evidence in songbirds also shows GnIH projections towards the brainstem. We investigated the possibility that this neuropeptide might act directly within the spinal cord of zebra finches (*Taeniopygia guttata*). Using immunohistochemistry, we determined that GnIH-immunoreactive fibers are present throughout the length of spinal cord gray matter, with the majority of the peptide located in the cervical region. Using PCR, we also found mRNA expression of GnIH precursor peptide and GnIH receptor (GnIH-R) throughout the spinal cord. These data raise questions about the potential mechanisms of action and roles of GnIH in zebra finch spinal cord. Our results provide evidence for potentially novel modes of action of GnIH that have implications for physiology and behavior. Current research is exploring modulation of GnIH and GnIH-R in the central nervous system in response to fasting and sickness.

P1-88 CONGDON, ER*; EVANS, MB; Bethune-Cookman University, TheraPet Inc.; *congdone@cookman.edu*
Using Therapeutic Play to Alleviate Stress in Shelter Dogs
One challenge of having dogs adopted from shelters is the excitement they show when being visited that may not be representative of their personality, but rather a symptom of being kenneled for the majority of their time. Occupational therapy interventions with children use sensory-motor strategies of heavy work (proprioceptive input) and movement (vestibular input) for improved behavior responses and emotional regulation. Through neural plasticity, nervous system pathways are strengthened and recruited for a more developed and mature nervous system. Based on these concepts, an object (toy) was designed for dogs that matches their high threshold for stimuli required to elicit a neuronal response. Shelter dogs are likely to be anxious or stressed due to their lack of interaction, presenting behaviors such as pacing, barking, or jumping. However, if they receive sufficient neural stimuli through interaction with this object – therapeutic play – they should develop a calmer, perhaps more approachable, demeanor and hopefully have a greater likelihood of being adopted. To test this strategy, behavioral observations were conducted for baseline classification of play-interest levels in shelter dogs in the Daytona Beach area. The dogs were then presented with either a control object or the test object for therapeutic play at regular intervals. Finally, behavioral observations were conducted for an additional two weeks to determine any lasting effects. Throughout the entire study, regular fecal sampling of cortisol levels provided insight into the stress that may have been alleviated by the therapeutic play. We are hoping to design a program that will allow as many dogs as possible to have and take home with them their own toy.

118-5 CONITH, AJ*; HOPE, S; LIU, M; ALBERTSON, RC; UMass Amherst; *ajconith@bio.umass.edu*
The Developmental and Functional Origins of a Key Feeding Innovation in the Cichlid Pharyngeal Jaw
The perciform group Labroidei (cichlids, labrids, damselfish, and surfperches), have independently evolved pharyngognathy, a highly derived set of upper and lower pharyngeal jaws (U-LPJ). The muscle that retracts the UPJ, the retractor dorsalis (RD), connects the UPJ to the anterior vertebrae and functions to process prey. Cichlids are unique in having developed a ventrally projected pair of processes at the posterior connection between the RD and vertebrae, typically on the third vertebrae. It is not uncommon to find these projections shifted anteriorly, which shortens the RD muscle and has consequences for UPJ performance. Here we characterize the shape and development of the vertebral projections using morphometric and genetic methods. We sought to answer two questions: 1, how functionally integrated is the UPJ musculoskeletal system, and 2, can we take a candidate gene approach to find regions of the genome responsible for vertebral projection development? We µCT scanned 640 individuals from a hybrid cross between two Malawi cichlids and used 3D morphometrics to characterize neurocranium and vertebral shape. We then extracted shape scores from our vertebral data, which reflected projection positioning, and performed quantitative trait loci (QTL) mapping. We found a strong association between the vertebral and neurocranium shapes, suggesting an anterior shift of the projections produces a change to the mechanics of UPJ retraction. We also gain two significant QTL peaks in our map, which reveal a possible role for the SIK pathway in regulating the development of these projections. Taken together, this suggests a small developmental change in the pathway regulating projection positioning can produce large-scale changes the mechanics of UPJ performance.

48-1 CONKLING, ME*; HESP, K; MUNROE, S; SANDOVAL, K; MARTENS, DE; SIPKEMA, D; WIJFFELS, RH; POMPONI, SA; Florida Atlantic University, Fort Pierce, FL, Wageningen University, Wageningen, NL; *mconkli2@fau.edu*
Breakthrough in Marine Invertebrate Cell Culture: Sponge Cells Divide Rapidly in Improved Nutrient Medium
Sponges (Phylum Porifera) are among the oldest Metazoa and considered critical to understanding animal evolution and development. They are also the most prolific marine source of chemicals with pharmaceutical relevance. Cell lines are important tools for research in many disciplines, and have been established for many organisms, including freshwater and terrestrial invertebrates. Despite many efforts over multiple decades, there are still no cell lines for marine invertebrates. In this study, we report a breakthrough: we demonstrate that an amino acid-optimized nutrient medium stimulates rapid cell division in 9 sponge species. The fastest dividing cells doubled in less than 1 hour. Cultures of 3 species were subcultured from 3 to 5 times, with an average of 5.99 population doublings after subculturing, and a lifespan from 21 to 35 days. Our results form the basis for developing marine invertebrate cell models to better understand early animal evolution, determine the role of secondary metabolites and predict the impact of climate change to coral reef community ecology. Furthermore, sponge cell lines can be used to scale-up production of sponge-derived chemicals for clinical trials and develop new drugs to combat cancer and other diseases.

P1-146 CONNOR, C*; ZINN, D; WILLIAMS, DA; WATSON, CM; Midwestern State University, Texas Christian University; *chelseaacconnor@gmail.com*
Dietary Niche Overlap of Native and Invasive Anoles on Dominica
Invasive species can negatively affect a community by taking resources otherwise used by native species. Among the most direct forms of competition between such organisms is food. On the island of Dominica exist a native species of Anole (*Anolis oculatus*) and a relatively recent invader (*Anolis cristatellus*). In the ~20 years since *Anolis cristatellus* first invaded Dominica, it has established breeding populations in all regions of the island except the most mountainous. This presumably puts them in direct competition with the native *Anolis oculatus* for prey. However, the extent of their dietary niche overlap remains undocumented. Some populations of the endemic native anole appear to be affected by the presence of the invasive more than others. This study uses molecular techniques and fecal samples to determine major groups of arthropods consumed by members of each species in multiple populations across the island. By documenting the extent of their dietary niche overlap, we can better understand competitive dynamics between species within communities and among populations.

101-2 CONRAD, H*; WITTMAN, T; POLLOCK, N; JOHN-ALDER, H; Rutgers University, University of Texas, University of Virginia; *hmc87@scarletmail.rutgers.edu*

Tolerance of ectoparasitism in Eastern Fence Lizards, Sceloporus undulatus

Eastern fence lizards (*Sceloporus undulatus*) are heavily parasitized by chigger mites (*Eutrombicula alfreddugesi*), with mite counts >500 on some individuals. Among growing yearlings, mite counts vary by an order of magnitude, and the week-to-week rank ordering of mite counts is highly concordant. In yearlings, males are more heavily parasitized than females, even as mite populations change across the summer activity season. Thus, any potential costs of ectoparasitism may vary consistently among individuals and between males and females. Furthermore, exposure of lizards to mites may be increasing with climate change, potentially leading to higher ecological costs. We investigated growth costs of chigger mites in field-active yearling *S. undulatus* in three independent studies conducted in 2014-15, 2016, and 2019, and we attempted to manipulate ectoparasitism experimentally by administering Ivermectin in 2019. We found no evidence of a negative correlation between mite count and growth rate in either sex. Furthermore, Ivermectin had no effect on mite counts or growth rates. Yearling males had consistently lower growth rates than females, consistent with findings that testosterone inhibits growth in *S. undulatus*, but the inhibitory effect of testosterone on growth in males does not appear to be mediated through increased mite parasitism. Average mite intensities increased progressively across years, suggesting that exposure to mites may be increasing as the climate warms. Given these conditions, selection may favor the evolution of tolerance as opposed to resistance to mites. If so, further increases in mite populations due to climate change may have little effect on *S. undulatus*. Supported by NSF 1754934 and Hatch Multistate project no. NJ17240.

116-6 CONVERSE, A*; THOMAS, P; University of Texas Marine Science Institute; *aubreykoch@utexas.edu*

Female ZIP9-Knockout Zebrafish Exhibit Abnormal Egg Activation and Reduced Fecundity

Our research group recently cloned and characterized a putative membrane androgen receptor from teleost ovarian tissue that is homologous to the zinc transporter protein ZIP9 (Slc39a9). Since the discovery of its androgen receptor activity, ZIP9 has been found to mediate androgen actions in a number of cell culture models from various tissues. However, ZIP9 has not been examined in an *in vivo* model so the precise physiological functions of this receptor remain unclear. A ZIP9-mutant strain of zebrafish was developed using a CRISPR-Cas9 system to examine the role of the protein in teleost reproduction. Mutant females have reduced fecundity and spawn significantly fewer eggs than wild-type fish. ZIP9-mutant females also produce a high proportion of eggs that do not undergo chorion elevation, a characteristic of normal egg activation. Eggs that show this phenotype have low fertilization rates and produce larvae that exhibit a high incidence of pericardial/yolk sac edema and reduced growth compared to larvae hatched from wild-type eggs. Zinc detection using fluorescent probes indicated that in wild-type eggs, zinc is localized to intracellular vesicles prior to activation, but once activation occurs the number of zinc containing vesicles decreases and a rise in extracellular zinc is detected. This suggests that zinc is released during activation in fish eggs similar to observed in mammalian eggs. ZIP9-mutant eggs that show the abnormal activation phenotype also show abnormal zinc vesicle morphology in that the vesicles are significantly smaller than those of wild-type eggs. Thus, the potential disruption of zinc regulation during egg activation and/or maturation in ZIP9-mutant fish may account for the abnormal activation phenotype and the reduction in viable offspring produced by mutant fish.

P2-57 COOK, TO; FARGEVIEILLE, A*; WARNER, DA; Auburn University, Auburn, AL, Auburn University, Auburn AL; *akf0020@auburn.edu*

Dorsal pattern polymorphism in female Brown Anoles: testing the "male-mimicry hypothesis"

To understand the evolution of polymorphisms in females, many scientists have been interested in the "male mimicry hypothesis". The evolutionary explanation for male mimicry by females often involves a reduction in sexual harassment, at the cost of higher testosterone levels and lower reproductive success in "male-like" females. Three primary dorsal patterns have been described in female brown anoles (*Anolis sagrei*), but some populations also include a "male-like" pattern. A recent study on female polymorphism in *A. sagrei* proposed that the presence of the male-like dorsal pattern could be maintained as a consequence of relaxed sexual harassment. We tested this hypothesis using two sets of analyses. First, we aimed to determine if female dorsal pattern was truly similar to male dorsal pattern using two different methods: 1) unbiased human vision with no or low previous knowledge of the existing classification, and 2) computer classification of dorsal patterns. Second, we then related the female dorsal patterns to body condition, dewlap size and coloration to support or discount the idea of "male-like" females being viewed as males in the wild. We also related female dorsal patterns to egg production as a metric of reproductive success. In accord with the "male-mimicry hypothesis" we predict male-like females to have larger and more colored dewlaps and lower fecundity than the other female morphs.

P2-213 COOK, A*; ILTON, M; Harvey Mudd College; *acook@hmc.edu*

Computational Modeling of Latch-Spring Systems

Latch mediated, spring actuated (LaMSA) systems occur in nature as a way to drastically amplify the kinematic performance of a mechanical system. LaMSA systems exhibit remarkable diversity in mechanisms and materials, which makes it challenging to generalize insights about the underlying mechanics. We present developments to a mathematical and computational "toy model" of latch-spring systems based in Newtonian mechanics that allows us to assess system performance for arbitrary latch geometry and unlatching kinematics. We also expand our model to include a lever arm with some mechanical advantage, a feature found in many biomechanical systems. In particular, we use our model to identify couplings between the latch, spring, and lever that give rise to optima in performance metrics. We find that these optima are created by couplings related to the loading of the spring, size scaling, and non-ideal properties of the spring and lever. We can then use these couplings to form hypotheses about trade-offs observed in nature. As a proof of concept, we deploy our model in the context of trap-jaw ant morphology and materials properties from the literature. Using our model, we identify a four-dimensional normalized parameter space and explore the utility of the model to raise interesting questions about the comparative placement and performance of different species in this space.

138-1 COOMES, CM*; DERRYBERRY, EP; University of Tennessee Knoxville; *cmcoomes@gmail.com*

It's too darn hot: Effects of ambient temperature on singing behavior in male song birds

Due increasing heat waves, animals are facing more challenges induced by increasing temperatures. Birds are particularly vulnerable to high temperatures as they are diurnal and have limited access to cooler microclimates. Exposure to high temperatures has been shown lead to changes in critical behaviors. For example, song birds have been shown to sing less when temperatures are higher. Song is crucial for communicating territory boundaries and advertising mate quality. Here, we experimentally tested how temperatures affect song production in male zebra finches. We used a repeated measures design and recorded all songs produced in three temperature treatments: 27°C, 35°C, and °C, or below, within, and above the zebra finch thermal neutral zone (TNZ) respectively. We found that song production was highest at temperatures within the TNZ and was lowest above the TNZ. We discuss our results in terms of the effects of high temperatures on wild birds, as zebra finches experience heatwaves in the wild. These results may also inform future experiments, as zebra finches are often tested at room temperature, which is below the zebra finch TNZ, where we show potential effects on song production.

P1-166 COOMES, CM*; DERRYBERRY, EP; University of Tennessee Knoxville; *cmcoomes@gmail.com*

Some like it hot: Do female songbirds discriminate between songs produced under hot and cold temperatures?

Heat waves are increasing in number, length, and intensity around the globe, causing more animals to undergo heat stress. Heat stress, like other kinds of stress, can cause behavioral changes. Small songbirds are particularly vulnerable to high temperatures as they are active during the day and produce a high amount of metabolic heat. One songbird behavior that has been shown to be impacted by high temperatures is song production. Often, male songbirds sing a species-specific song, which serves as a signal of quality to a potential mate. While it has been shown that male songbirds sing less when temperatures are higher, we do not know if the information contained within these songs changes. As an observer, it can be difficult to visually identify changes in birdsong, even when other birds can tell the difference. Therefore, the first step to test whether heat stress influences song salience is to ask the signal receivers: female songbirds. Here we tested whether 17 female zebra finches (*Taeniopygia guttata*) could discriminate between songs produced by males under heat stressed (43°C) and thermal neutral conditions (35°C). While females exhibited a range of individual variation for songs produced under different temperature treatments, we found no evidence that our population preferred songs produced by males under thermal neutral or control temperatures.

66-1 COOPER, C*; KEELING, E; LIWANAG, H; California Polytechnic State University; *Ccoope05@calpoly.edu*

Feeling out your Food: A histological analysis of the vibrissal system in pinnipeds

The vibrissal (whisker) system is present in nearly all mammals and is especially important in deep-diving mammals. Pinnipeds (seals, sea lions, walrus) have highly innervated whiskers, indicating they serve as important sensory structures. Vibrissae are needed for foraging and thus it is vital to maintain their functionality under all environmental conditions. In pinnipeds studied thus far, each vibrissal unit includes a follicle sinus complex characterized by a three-part blood sinus system: the upper cavernous sinus (UCS), ring sinus (RS), and lower cavernous sinus (LCS). The UCS is unique to pinnipeds and lacks innervation. Based on this, we hypothesize that the UCS plays a thermoregulatory role, insulating temperature-dependent mechanoreceptors. Our objectives were (1) to measure and compare the relative lengths of the three sinuses (UCS, RS, and LCS) among three pinniped species and (2) to examine the UCS as a thermoregulatory structure. To do this, we measured and compared the relative lengths of the UCS in deep-diving polar Weddell seals (*Leptonychotes weddellii*, n=6), deep-diving temperate northern elephant seals (*Mirounga angustirostris*, n=4) , and shallow-diving temperate harbor seals (*Phoca vitulina*, n=2). Individual vibrissal follicles were collected and histologically processed from animals that died in the wild or during rehabilitation efforts. We predicted that the species faced with the coldest environment both at depth and in air (i.e., Weddell seals) would have the longest UCS. Our preliminary results suggest a positive correlation between the total sinus length and the average UCS length. This represents the first study to characterize the microstructures of the vibrissal system in Weddell seals and the first study to investigate the UCS as a thermoregulatory structure.

73-5 COOPER, WJ*; KNIAHNITSKAYA, K; NIXON, A; DEVERS, M; RINGO, D; BARBER, E; Washington State University; *jim.cooper@wsu.edu*

Using genetically modified zebrafish to investigate the evolution and development of feeding in other minnows

The zebrafish (*Danio rerio) is a model organism that is widely used to understand developmental processes. The relevance of zebrafish studies to other organisms is proportionate to the closeness of their evolutionary relationship. Genetically modified zebrafish were used to investigate the development of the functional morphology of feeding among its closest relatives: minnows of the subfamily Danioninae (Cyprinidae). Alterations to thyroid hormone levels caused zebrafish bite mechanics to converge with that of several other danionine species. Hyperthyroid mutant zebrafish developed elongated lower jaws and upturned mouth openings. These aspects of cranial shape were convergent with those of the giant danio (Devario aequipnnatus). Both giant danio and hyperthyroid zebrafish show a preference for feeding from below. Hypothyroid transgenic zebrafish retain many of their larval feeding characteristics. The functional morphology of their upper jaws is convergent with both paedomorphic minnows in the tribe Danionini and members of the sister tribe Rasborini. Wild-type zebrafish, hyperthyroid zebrafish, hypothyroid zebrafish and giant danio have nearly identical feeding mechanisms until metamorphosis. Taken together, these findings suggest that modulation of thyroid hormone signaling has played a role in the evolution of danionine feeding mechanics. RNA-Seq was used to investigate whether patterns of gene transcription in the developing jaws of genetically modified zebrafish with altered thyroid hormone levels converged with those in other minnow species.*

P3-32 COOPER , D *; KOVACS, J ; Spelman College ;
dcoope16@scmail.spelman.edu
Evidence of Horizontal Gene Transfer in the Pea Aphid Acyrthosiphon pisum

The purpose of this study is to understand the role of horizontal gene transfer (HGT) in eukaryote evolution. HGT is known to be widespread in prokaryotes and allows for the rapid acquisition of traits for mutation and gene duplication. HGT can explain how genes are independently transferred to multiple unrelated species. More recently, it has been found that HGT has allowed for the independent acquisition of traits in multiple distantly unrelated species in a variety of multicellular eukaryotes. In this study, HGTs will be studied to see if a gene is transferred among niche-sharing eukaryotic species. An ecological niche is a role a species has in its environment regarding how it survives, how it gains nutrition, and how it reproduces. A species' niche includes all of its interactions with biotic and abiotic factors in its environment. The study aims to discover if HGTs are shared by related niche-sharing species and absent from more closely related, but non-niche sharing species or if HGTs provide ecologically relevant traits to their host species. In this study we used a newly designed bioinformatic pipeline to identify shared HGTs in the genome of the pea aphid Acyrthosiphon pisum and other phloem feeding arthropods. This will test the prediction that shared HGTs are more likely to be found in distantly related, niche sharing species than in closely related, non-niche sharing species. This research will aid in discovering the unique relationship between in niche-sharing species and their genetic makeup.

75-2 COOPER, AN*; MARTIN, JC; MCDERMOTT, WJ; DULANEY, SO; CARRIER, DR; University of Utah, The Orthopedic Specialty Hospital, Murray, UT;
amanda.cooper@utah.edu
The Role of Muscle Fascicle Length in the Power versus Economy Performance Trade-off

The ability of the locomotor muscles to effect both economical transport and powerful bursts of activity is necessary for survival in many species. However, specialization in either of these performance traits is expected to negatively impact the other due to functional constraints in muscle design, resulting in a performance trade-off. The muscular power *versus* economy trade-off has traditionally been explained by muscle fiber type composition. Although fiber type plays an undeniable role in performance specialization, differences in muscle architecture may also determine the economy and power of a muscle. Muscles with longer fascicles, composed of more in-series sarcomeres, are capable of faster shortening velocity, allowing for increased power production. However, long fascicles are expected to reduce economy because, for a given force production, more energy-consuming contractile units must be activated. We hypothesized that longer muscle fascicle length is positively correlated with both power production and increased locomotor cost. In a set of 11 power- and 13 endurance-trained athletes, we measured 1) gastrocnemius lateralis (GL), gastrocnemius medialis (GM), and vastus lateralis (VL) muscle fascicle length via ultrasound, 2) maximal power production during cycling and countermovement jumps, and 3) running cost of transport. We found that longer fascicles in GL and GM are positively correlated with both cycling and jumping power, and that longer GL fascicle length is directly correlated with increased cost of transport. These results are consistent with the hypothesis that, at least for certain muscles, fascicle length plays a significant role in the performance trade-off between power and economy.

137-2 CORBIN, CE*; ROPER, VG; Bloomsburg University;
ccorbin@bloomu.edu
Linking Effects of Acid Mine Drainage to Ecology and Morphology of Riparian Birds

Acid mine drainage (AMD) constrains within-stream trophic linkages and has negative effects on freshwater ecosystems. The extent to which AMD affects higher trophic levels in riparian ecosystems is not well known. Additionally, it is unknown how AMD affects the ecomorphological relationships between stream and riparian ecosystems. Some terrestrial organisms that normally acquire nutrients from stream may either avoid or be excluded from polluted areas. If true, then AMD potentially constrains cross-ecosystem energy transfer, and may influence the emergent properties of biological organization such as population densities, community membership, and functional ecomorphological relationships. Our goals were to 1) explore the similarities and differences between AMD and non-AMD bird community membership, 2) test for numerical responses in aerial insectivores along those tributaries and 3) determine if there is a morphological, and hence functional loss these AMD affected streams. We conducted bird and nest surveys along tributaries of the Susquehanna River with varying degrees of AMD pollution. We characterized and compared the morphological space of bird communities of AMD and non-AMD streams. Analysis of variance, Monte-Carlo null-community analysis, and non-parametric statistical tests indicate there are fewer species, particularly piscivores and insectivores in AMD stream reaches. Aerial insectivore nesting was less dense and the morphological diversity of AMD streams was negatively affected. The latter result suggests pollutants such as AMD may preclude the capacity for ecomorphological relationships to form along these streams. Acid mine drainage affects the emergent properties of bird communities (e.g. species richness), and potentially more important, negatively affects functional cross-ecosystem dynamics and watershed quality.

P1-35 CORDER, KR*; SCHWEIZER, RM; CHEVIRON , ZA; University of Montana, University of Montana ;
keely.corder@umontana.edu
The Role of Mitonuclear Coevolution in High Altitude Adaptation

Metabolic function in eukaryotes relies on coordinated interactions between gene products from the nuclear and mitochondrial genomes. Because of these functional interactions, it is proposed that coevolution should occur between the nuclear and mitochondrial genomes to maintain optimal metabolic capacities and facilitate local adaptation, especially in environments where aerobic performance is tied to survival. Using an genome-scan approach, we show that deer mice (*Peromyscus maniculatus*) from high- and low-elevations in western North America are members of distinct mitochondrial haplogroups, and that several genes that influence mitochondrial function have experienced a history of natural selection in highland populations. We then tested for evidence of adaptive mitonuclear coevolution by conducting a geographical cline analysis across an elevational transect that includes the contact zone between high- and low-altitude mtDNA clades and testing for genotypic associations between mitochondrial and nuclear alleles in the contact zone. We also compare the shapes of allele frequency clines for mtDNA and nuclear-encoded genes with mitochondrial function to determine if mitonuclear associations are maintained by natural selection. Together these analyses provide new insights into whether mitonuclear coevolution may play an important role in adaptation to high altitude.

P1-23 CORDOVA, KC*; FARR, D; DETHIER, MN; DOBKOWSKI, KA; California Polytechnic State University, San Luis Obispo, University of Southern California, Friday Harbor Laboratories, University of Washington, Bates College; *klcordov@calpoly.edu*

Mismatched: Do Northern Kelp crabs (Pugettia producta) eat where they live?

Nearshore kelp forests and seagrass meadows create complex 3-D habitats that house high species diversity within the Salish Sea. Bull kelp (*Nereocystis luetkeana*) is one of the main annual canopy-forming kelp in these coastal waters. Eelgrass (*Zostera marina*) is a native seagrass that forms underwater meadows and provides habitat for many fish and invertebrates. Wireweed (*Sargassum muticum*) is an invasive perennial species from the Western Pacific Ocean that is potentially detrimental to the growth and distribution of native kelp and seagrass species. One native species of kelp crab (*Pugettia producta*, the Northern Kelp crab) has a voracious appetite for bull kelp, and may exert some level of top-down control of the habitat. Less is known about the diet by another local species of kelp crab, *Pugettia gracilis* (graceful kelp crab). We analyzed fresh foregut contents of *P. producta* and *P. gracilis* collected near San Juan Island, WA using SCUBA and snorkeling. We hoped to gain insight into whether kelp crabs are eating the kelp and seagrass on which they are found. We visually quantified the percentage of each food type found in a crab's foregut and used a chi-square contingency table to test whether the crabs were eating the kelp or seagrass they were found on. *P. gracilis* had a non-significant interaction ($X^2 = 2.213$, $p = 0.136$) indicating that they are not preferentially eating or avoiding the seaweed species on which they were found. *P. producta* did have a significant interaction ($X^2 = 10.693$, $p = 0.005$) indicating that they are preferentially eating (*S. muticum* and eelgrass) or avoiding (bull kelp) the species they were found on. These results indicate that kelp crabs exhibit a wide variety of diet preferences and move around a fair amount to access the different food types.

55-5 CORDOVA, KL*; BERSIN, TV; SAENGER, EK; JOURNEY, ML; BECKMAN, BR; LEMA, SC; Cal Poly, San Luis Obispo, Northwest Fisheries Science Center; *klcordov@calpoly.edu*

Opposing influences of fasting stress and Igf1 on skeletal muscle gene pathways for Igf-signaling and myofibrillar protein degradation in gopher rockfish

Insulin-like growth factor-1 (Igf1) regulates skeletal muscle growth in fishes by increasing protein synthesis and promoting muscle hypertrophy. In the wild, fish can experience periods of insufficient food intake that can lead to slower muscle growth or muscle wasting, and those changes are linked in part to nutritional modulation of Igf1 signaling. Here, we examined how food deprivation (fasting) affects Igf1 regulation of skeletal muscle gene expression in gopher rockfish (*Sebastes carnatus*) to understanding how food limitation affects Igf-mediated muscle growth. Juvenile rockfish were either fasted or fed (9% mass feed ration per d per g wet fish mass) for 14 d, after which a subset of fish from each group was injected with recombinant Igf1 (1 µg per g body mass) from sea bream (*Sparus aurata*). Fasted fish lost body mass and had a lower body condition factor (k), lower hepatosomatic index, reduced plasma Igf1 concentrations, and lower relative mRNA levels for *igf1* in skeletal muscle. Fasted fish also showed elevated mRNA levels for Igf1 receptors A (*igf1rA*) and B (*igf1rB*) in skeletal muscle, and >4-fold higher gene transcript abundance for muscle-specific F-box protein 32 (*fbxo32*, also called *atrogin-1*), a ubiquitin ligase involved in myofibrillar protein degradation and muscle atrophy. Injection with recombinant sea bream Igf1 increased plasma Igf1 concentrations in both fasted and fed rockfish, and strongly down-regulated gene transcript abundance for *fbxo32*, suggesting that elevated muscle protein degradation during food restriction is mediated in part by a reduced availability of Igf1.

10-2 CORN, KA*; MARTINEZ, CM; BURRESS, ED; WAINWRIGHT, PC; Univ. of California, Davis; *kacorn@ucdavis.edu*

High rates of evolution of cranial mobility are characteristic of suction feeding

Suction feeding is used by every group of aquatic vertebrates and is the primary mechanism of prey capture for most ray-finned fishes. Cranial mobility, or the process of rapidly expanding a mobile skull, is a crucial component of suction feeding. We studied evolution of cranial mobility in suction feeding fishes and compared to fishes that rely on biting. We recorded videos of prey capture by suction in 44 species, including 13 that normally feed by biting prey attached to the substrate. Kinematics of cranial motion were quantified by tracking the change in position of 18 landmarks on the head and body, which were used to generate variables describing components of motion, such as mandible rotation, upper jaw protrusion, and cranial rotation. We analyzed this dataset using a new multivariate, variable rate, state-dependent Brownian motion model of continuous character evolution to estimate rates of kinematic evolution. The diversity of cranial mobility among suction feeders was 10.2 times that of native biters, in association with a 2.4-fold higher rate of evolution of kinematics. Surprisingly, this difference in the rate of feeding motion diversification is not a simple consequence of variation in morphology, as we found that suction feeders have just 1.5 times the disparity in interspecific cranial morphology than biters. With lower rates of kinematic evolution, biters have convergently decreased cranial mobility and each of its components, indicating substantial anatomical and functional constraints on fishes that evolve biting feeding modes. We conclude that diversity in cranial mobility and high rates of kinematic evolution are characteristic of suction feeding and provide a link between feeding mode and the exceptional diversity of suction feeding vertebrates.

P2-181 CORNELIUS, JM*; CAMERON, R; BRADLEY, D; Oregon State University, Eastern Michigan University; *cornelja@oregonstate.edu*

Activity drives investment in hematocrit recovery versus fat storage in food-restricted captive red crossbills Loxia curvirostra

Hematocrit - or the percent volume of red blood cells in whole blood - is thought to fluctuate adaptively in response to changing oxygen demands that occur during different life activities and in different environments. Because red blood cells are made from materials that can be limiting, however, it is thought that hematocrit may also reflect general body condition and access to resources. We tested the effect of hydration state, resource restriction (i.e., time available to forage) and activity (i.e., different cage sizes) on hematocrit in captive red crossbills (Loxia curvirostra). We found no evidence that a mild dehydration protocol impacts hematocrit and only weak support that mild food restriction impacts hematocrit. However, birds housed in flight aviaries had higher hematocrit than those housed in small cages and those in aviaries that were also food limited invested in recovering hematocrit at the cost of fat stores following successive bleeds. In contrast, food-restricted birds housed in small cages lost additional hematocrit in an apparent attempt to conserve fat stores following successive bleeds. Together these results suggest a physiological trade-off between investing in fat storage or red blood cell development and reveals a potential prioritization based on activity demands when faced with a reduction of resources. Our results also demonstrate the need for scientists to carefully record hematocrit data and the time course across which multiple tubes of blood are collected to avoid confounding real patterns with variation generated by sampling protocol.

P3-41 CORNELIUS RUHS, E*; MARTIN, LB; DOWNS, CJ; Global and Planetary Health, University of South Florida, FL, Department of Env & Forest Biol, SUNY-ESF, NY; *ecruhs@usf.edu*
The impacts of body mass on immune cell concentrations in birds
The impacts of body mass on the immune system are fairly unknown. Recent research on mammals found that neutrophil concentration scaled hypermetrically with body mass (that is, larger mammals had disproportionately higher concentrations), a surprising result not predicted by any scaling framework for immunity. Although we can predict the form of relationships between leukocyte cell concentrations and body mass in birds based on previous mammalian slopes, fundamental physiological differences (e.g. cell differentiation/storage, anatomical structures to accommodate flight, etc.) and evolutionary histories between taxa might have produced differences in their form. Here, we examined whether existing scaling hypotheses accurately predicted form of relationships of lymphocytes, eosinophil, and heterophils, the avian functional equivalent of neutrophils. We also examined the predictive ability of body mass, life-history variation and phylogenetic relationships for variation in the three cell types (i.e., an omnibus model). An intercept-only model best explained lymphocyte and eosinophil concentrations, supporting hypotheses with a slope of zero. The omnibus model that included body mass and life history variables best-explained variation in heterophils, however. In this model, body mass explained over 30% of the variation in heterophils with life-history traits providing comparatively little explanatory power (~8%). No a priori hypothesis predicted the hypermetric scaling we observed for heterophils (b=0.19 +/- 0.05). These results reveal surprising effects of body size on avian heterophil concentrations, consistent with observations in mammals, and imply that large organisms, generally, might require larger reserve pools of broadly protective immune cells.

56-3 CORREA, AMS*; GRUPSTRA, CGB; HOWE-KERR, LI; VEGLIA, AJ; BRYANT, RL; CONETTA, D; Rice University, Houston, University of Rhode Island, Kingston; *ac53@rice.edu*
Viral Reefscapes: Microbial Interactions with Threatened Coral Hosts and Reef Ecosystems
Coral-associated microbes (e.g., dinoflagellates in the family Symbiodiniaceae, bacteria) contribute to the health and function of their host colonies. Yet, during acute periods of environmental stress, microbial partners can shift or dissociate entirely from hosts, causing colony disease/bleaching and mortality. Shifts in coral-associated viruses are also likely to correlate with differences in coral and reef health, yet relatively few studies target this group. We are exploring the diversity of coral- and dinoflagellate-associated viruses in a range of Pacific and Caribbean host species, in healthy and diseased/bleached coral tissues, and in laboratory cultures of Symbiodiniaceae. We recently examined actively transcribing viruses from the coral, *Pocillopora verrucosa*, and recovered OTUs that aligned with 108 distinct viral groups at several taxonomic levels in a single host colony using RNA-Seq. Viral reads processed to date were dominated by phage (~94%) but also included similarities to members of the Megaviridae, Pandoraviridae, and Alvernaviridae, all of which likely infect Symbiodiniaceae. We characterized lineage-specific diversity in a positive single-stranded RNA virus (Alvernaviridae) in five *P. verrucosa* genets exposed to control and thermal stress treatments using nested degenerate primers and amplicon sequencing, and identified ~2,400 ASVs (N = 55 coral fragments total), and found that the community composition of these viruses is more strongly correlated with coral genet than thermal stress. There have been challenges in confirming the roles of coral-associated viruses, due to the techniques applied and difficulties in culturing these viruses. We discuss the importance of developing a cnidarian-dinoflagellate-virus model system in order to advance our understanding of the roles of viruses in corals and other hosts.

129-5 CORYELL, RL*; NISHIGUCHI, MK; New Mexico State University; *nish@nmsu.edu*
Temperature Adaptation Influences Environmental and Symbiotic Fitness in the Squid-Vibrio Mutualism
Sepiolid squids (Cephalopoda: Sepiolidae) are found in mutualistic partnerships with members of the Vibrionaceae throughout the world. Beneficial microbes that are environmentally transferred between generations of their hosts are exposed to abiotic factors that can eventually influence their symbiotic competence. Therefore, we examined the influence of temperature adaptation on the free-living stage of *Vibrio fischeri* from various hosts and their native temperature regimes. Using *in vitro* experimental evolution, we adapted five strains of symbiotic *V. fischeri* from temperate, tropical, and semi- temperate native ranges. These strains were adapted to five temperatures for 2000 generations to assess the impact of temperature adaptation on symbiotic fitness. Physiological assays of growth, luminescence, biofilm activity, and motility were performed comparing evolved *V. fischeri* lines to their ancestor. Colonization experiments using naïve juvenile squid were performed singly and in competition with their ancestors. Lines evolved at elevated temperature lost their ability to luminesce, especially those from temperate ranges, however, this did not seem to influence colonization efficiency. Evolved lines, regardless of physiological response, gained fitness compared to their ancestors when colonizing a host after 1000 generations while, in some cases, lost this advantage after 2000 generations. Our results indicate that evolved *V. fischeri* are able to compensate for their altered physiology, influencing colonization fitness. These findings will help determine whether changes in environmental conditions such as temperature will be detrimental to the establishment of symbiotic associations, and therefore have a much greater impact on beneficial microbes that contribute to the overall health of metazoan life.

59-6 COSTA, D.P*; KIENLE, S.S; TRUMBLE, S.S; KANATOUS, S.; GOEBEL, M.E; BORRAS, R; CROCKER, D.E; University of California at Santa Cruz, Baylor University, Colorado State University, National Marine Fisheries Service-NOAA, Chilean Antarctic Program, Sonoma State University; *costa@ucsc.edu*
Foraging Behavior and Movement Patterns of the Leopard Seal in the Antarctic Peninsula
The Antarctic Peninsula is one of the most rapidly changing habitats in the world. 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 deployed 12 satellite-linked tracking devices on 3 adult males, 8 adult females, and one juvenile female leopard seal on Cape Shirreff Livingston Island, Antarctica during April-May 2018. The animals ranged from 147 to 540 kg with a mean mass of 389 ± 95 kg. Three of the twelve leopard seals remained within the South Shetland Islands, while two female seals transited well to the northeast, with one stopping at South Georgia Island. On average leopard seals made short shallow dives with a mean depth of 28 ± 7 sd meters and a duration of 3.8 ± 0.5 sd min. However, they occasionally made deep dives, with the single deepest dive being to 428 m and lasting 10.1 minutes. Their physiological parameters were consistent with a shallow aerobic diver, with a blood volume of 134 ± 5.2 sd ml/kg. Their hematocrit ranged from 44 – 56 with a mean of 51 ± 4 sd. We determined myoglobin concentrations in the locomotor muscles 6 of the animals and those ranged between 44.9 ± 1.4 se mg/gr for Longissimus dorsi and 32.9 ± 0.8 se for pectoralis muscle. Information on their habitat requirements can be used to predict how their habitat might shift as the climate changes.

81-2 COSTA, D.P*; HUCKSTADT, L.A; University of California at Santa Cruz; *costa@ucsc.edu*

Incorporating the movement of Marine Megafauna is critical to developing appropriate marine protected areas

Movement patterns of marine megafauna vary broadly, from species that are highly resident moving no more than tens of kilometers over their lifetime, to species that migrate over tens of thousands of kilometers each year. Marine Protected Areas have been proposed as a conservation tool for protection. However, while the characteristics of MPAs appropriate for marine invertebrate species has been considered, the issues surrounding the development of MPAs for highly migratory species is only just being considered The potential risk (sensitivity and exposure) to individuals within a population will vary in response to how they move in space and time. Some species move throughout their species range whereas others cover only a very small proportion of the species range. Some highly migratory species have foraging areas that are spatially distinct from their breeding areas, which are then connected by migration. Movement patterns are therefore critical to provide insight into the proportion of the population that would be protected within a specific MPA and which activity (i.e., feeding, migrating, and breeding) would be protected.

2-6 COSTELLO, RA*; COOK, PA; FORMICA, VA; BRODIE III, ED; University of Virginia, Swarthmore College; *rac2zb@virginia.edu*

Habitat Structure Influences Sex-Specific Patterns of Multilevel Selection in Experimental Populations of Forked Fungus Beetles

Multilevel selection occurs when a group phenotype influences individual fitness above and beyond the effects of individual traits. Patterns of multilevel selection are largely unexplored, yet understanding what drives multilevel selection is critical for revealing when group traits may evolve. Social networks provide a unique opportunity to study multilevel selection, as social networks quantify complex social interactions at both the individual and group levels. In this study, we used experimental populations of forked fungus beetles (*Bolitotherus cornutus*) to measure the effects of both individual position within a social network and emergent group-level social network characteristics on individual fitness. We found that male beetles that hold positions of high strength in social networks by interacting more often and with more conspecifics had higher mating success. However, the emergent group-level social network connectedness did not influence male mating success. Conversely, we found that individual strength had no effect on female reproductive success but that females in experimental populations with many social interactions and high network connectedness had lower reproductive success. We additionally manipulated the distribution of fungal resources in the experimental populations to explore how habitat structure influences patterns of multilevel selection. We found that females in more connected networks laid fewer eggs only when fungal resources were distributed in discrete clumps. Our results suggest that patterns of multilevel selection differ across the sexes and across habitat structures.

P3-125 COUGHLIN, DJ*; CHROSTEK, JD; ELLERBY, DJ; Widener University, Chester, PA, Wellesley College, MA; *djcoughlin@widener.edu*

Intermittent Propulsion in Largemouth Bass

Locomotion dominates energy budgets of animals, and selection should favor behaviors that minimize transportation costs. Recent field work has altered our understanding of the preferred modes of locomotion in fishes. For instance, bluegill employ an intermittent swimming form with 2-3 tailbeats alternating with short glides. Volitional swimming studies in the laboratory with bluegill suggest that the propulsive phase reflects a fixed-gear constraint on body-caudal-fin activity. Anecdotal observations of another centrarchid, the largemouth bass (*Micropterus salmoides*), suggests they also routinely employ intermittent propulsion in nature. We examined swimming by bass in a static tank in the laboratory to quantify the parameters of volitional locomotion including tailbeat frequency and glide duration across a range of swimming speeds. We found that tailbeat frequency was not related to swimming speed at low swimming speeds. Instead, swimming speed was a function of glide duration between propulsive events, with increasing swimming speed associated with decreasing glide duration. Analysis of the Strouhal number of bass locomotion in the static tank suggests they operate outside of the Strouhal range of peak efficiency. The results offer support for a new perspective on fish locomotion – intermittent swimming is key to understanding minimization of cost of transport.

33-4 COUGHLIN, DJ; Widener University, Chester, PA; *djcoughlin@widener.edu*

Thermal Acclimation Studies in Cold-Water Fishes: Do They Reveal the Potential Impact of Climate Change?

As climate change alters the thermal environment of the planet, interest has grown in how animals may mitigate the impact of a changing environment on physiological function. My students and I have been examining how thermal acclimation alters swimming performance, muscle contractile properties and the gene expression and protein content of myotomal muscle in several cold-water fishes. Thermal acclimation to a warm environment may, for instance, blunt the impact of a warming environment on metabolism by allowing a fish to shift to slower isoforms of metabolically significant proteins such as myosin heavy chain. Our studies of rainbow smelt (*Osmerus mordax*) and three salmonids – Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*) – reveal a range of responses to thermal acclimation that suggest that the impact of climate change will be highly variable, even amongst related species. Smelt show a substantial thermal acclimation response, with significant shifts in swimming performance, muscle contractile properties and gene expression with changes in environmental temperature. Alternatively, young salmon displayed very little thermal acclimation response, suggesting they may be more substantially impacted by climate change. Brook trout and rainbow trout show intermediate thermal acclimation responses compared with smelt and salmon, with modest changes in muscle function with changes in thermal environment. How variations in thermal acclimation capacity will relate to species survival in the face of climate change remains an open question.

S1-7 COUNTWAY, PD*; MATRAI, PA; Bigelow Laboratory for Ocean Sciences, East Boothbay, Maine; *pcountway@bigelow.org*

Antarctic Microbial Interactions Revealed by Continuous Flow Incubation and Variable Rates of DMSP Supply

Interactions between bacteria and protists drive ecosystem processes and contribute to the overall diversity, structure, and function of marine plankton communities. These interactions occur through direct cell-to-cell contact or via cell metabolites that provide biochemical and ecological linkages among diverse groups of organisms. One metabolite, the phytoplankton-derived compatible solute dimethylsulfoniopropionate (DMSP), may play a key role in structuring Antarctic microbial assemblages. A series of experiments were performed to investigate microbial interactions related to DMSP cycling during the austral summer (2017) and fall (2018) at Palmer Station (Anvers Island, Antarctica). The diversity, structure, and function of Antarctic plankton communities were investigated through seawater incubation experiments conducted in both continuous and batch modes. Incubation bottles containing natural microbial assemblages were supplied with nutrient- and DMSP-amended filtered seawater with two different supply rates. Batch treatments served as controls for the continuous cultivation. Overall, the supply of DMSP was depleted very quickly, likely via bacterial DMSP demethylation and lyase pathways, with evidence for a wide variety of DMSP genes in coastal Antarctic waters. The summer microbial assemblage was characterized by relatively low levels of bacterial diversity while substantially higher levels of bacterial diversity were detected during the fall. Evidence suggests that the supply rate of DMSP influenced the structure of microbial assemblages for both bacteria and protists. This experimental design opens the door to quantify additional protist-bacteria interactions in aquatic environments.

P1-248 COUTTS, VM*; BEATTY, A; SCHWARTZ, T; COOPER, C; HURLEY, L; GRIFFITH, S; WADA, H; Auburn University, Auburn, AL, Macquarie University, Sydney, NSW, AUS; *vzc0035@auburn.edu*

Changes in Gene Expression in Response to Ambient Temperature Fluctuations in the Zebra Finch

Thermal physiology contributes to limits on heat tolerance and species' geographical distribution. Small birds living in the desert is particularly at risk of heat stress because of waves of extreme temperature, diurnality, and limited access to food and water. Using zebra finches (*Taeniopygia guttata*) as a model system, we tested whether temperatures at the upper limit of the thermoneutral zone would elicit anti-damage regulators, such as heat shock proteins and a DNA repair mechanism, to minimize cellular damage caused by heat. To test this, birds were placed in two treatments: 1) 30°C for 8 hours and 18°C for the rest of the day, and 2) 40°C for 8 hours and 28°C for the rest of the day. These treatments occurred for 2 weeks, then all birds went through a period of the cooler temperatures (18°C or 28°C) for 2 weeks. After that, they were exposed to the higher temperatures (30°C or 40°C) for 8 hours. Whole blood was collected from these individuals after the last heat exposure. Currently, we are quantifying differential gene expression of heat shock protein 60 (HSP), HSP90, and APTX (mitochondrial DNA repair gene) with the prediction that these genes will be elevated in the zebra finches exposed to 40°C.

101-5 COX, CL*; ROSSO, AA; NICHOLSON, DJ; MCMILLAN, WO; LOGAN, ML; Florida International University, Georgia Southern University, Queen Mary University London, Smithsonian Tropical Research Institute, University of Nevada-Reno; *clcox@georgiasouthern.edu*

Sex-biased Parasitism and the Expression of a Sexual Signal in a Tropical Forest Lizard

Sexual signals are usually strongly linked to reproductive success and fitness. Because these signals are often but not always expressed more highly in one sex than the other, they can impose a sex-specific cost of reproduction. One mechanism whereby sexual signal expression can inflict a cost of reproduction is parasitism, which can reduce performance, survival, and reproduction. We tested the relationship between expression of a sexual signal (the dewlap) and ecological, morphological, and energetic factors mediating ectoparasite (mite) load in the Panamanian slender anole (*Anolis apletophallus*), using a combination of field and laboratory studies. We found that males were more highly parasitized than females, and that this relationship was driven by the preponderance of ectoparasites on the larger dewlap of males. Indeed, ectoparasite infection increased with both body size and dewlaps size in males but not females. We found no relationship between ectoparasite load and either habitat use or field-active body temperature. Energetics was related to parasite infection in a sex-specific fashion, as male anoles with smaller fat stores had higher mite loads, whereas there was no relationship between mite infection and fat body mass in females. In contrast, we found that the size of the gonads was positively associated with the number of mites in females, but not in males. Our results suggest that the expression of the sexual signal could incur a sex-specific fitness cost that is distinct from testosterone-based immunosuppression and may play a role in structuring life-history tradeoffs.

104-3 COX, RM*; WITTMAN, T; ROBINSON, CD; COX, CL; JOHN-ALDER, HB; University of Virginia, Georgia Southern University, Rutgers University; *rmc3u@virginia.edu*

Sex steroids as mediators of phenotypic integration, genetic correlations, and evolutionary transitions

Comparative endocrinologists have increasingly adopted evolutionary approaches not only to characterize the evolution of the endocrine system itself, but also to leverage it as a framework for exploring basic evolutionary principles. For example, by virtue of their massively pleiotropic effects on the expression of genes and phenotypes, sex steroids and their receptors are predicted to (1) structure the patterns of phenotypic variance and covariance that are available to natural selection, (2) alter the underlying genetic correlations that determine a population's evolutionary response to selection, and (3) facilitate evolutionary transitions in fitness-related phenotypes via subtle regulatory shifts in underlying tissues and genes. We present experimental support for each of these predictions by focusing on the specific case of androgen-mediated gene expression and sexual dimorphism in growth and ornamentation of *Anolis* and *Sceloporus* lizards. A central theme to emerge from these studies is that the rapidly increasing availability of genomic and transcriptomic data from non-model organisms places evolutionary endocrinologist in an excellent position to address the hormonal regulation of the key evolutionary interface between genes and phenotypes.

P2-209 COX, SM*; DEBOEF, A.; SALZANO, MQ; KATUGAM, K; PIAZZA, SJ; RUBENSON, J; Penn State, Georgia Tech; *zanne@psu.edu*

Elastic System Shows No Plasticity to Different Functional Demands During Growth

Elastic elements can help improve muscle function by reducing metabolic cost and amplifying power output. While increasing evidence suggests that elastic elements may only provide these benefits when tightly tuned to both muscle properties and the inertia of the system, we don't yet know how changes in elastic systems influence their capacity to play different functional roles. For instance, are elastic systems that best improve energy conservation different from those that increase power? To explore these questions, we raised helmeted guinea fowl, a species that multi-tasks their elastic systems for both functions, in conditions that eliminated the functional demand for power production during their entire growth period. We hypothesized that elastic systems that improve energy conservation differ from those that aid power production. Thus, we predicted that birds with less demands for high power production would adapt elastic system to improve running economy. We found, instead, that there were no differences in metabolic energy costs between our restricted birds and controls at adulthood. Yet, restricted birds showed deficits in jump performance, producing lower peak forces and power during jump tests as adults. Further, these functional differences did not correspond to systematic changes in the morphology (max isometric force, optimal fiber length) of two muscles that power ankle extension (medial and lateral gastrocnemius) or of their common tendon (cross sectional area, stiffness, or slack length). From this we conclude 1) that plasticity in elastic systems during growth may be minimal and 2) differences in functional performance of elastic systems may be significantly influenced by behavioral or neurological changes.

52-7 COY, CO*; MOORE, PA; BELANGER, RM; NEWCOMB, TJ; Bowling Green State University and University of Michigan Biological Station, University of Detroit-Mercy, Michigan Department of Natural Resources; *coyc@bgsu.edu*

Perfluoroalkyl Substances in Bluegill (Lepomis macrochirus) and Their Relationship to Histology and Swimming Performance

Per- and poly-fluorinated alkyl substances (PFAS) can be found in many household, industrial, and personal care products, including furniture, aqueous film forming foam, and sunscreen. PFAS enters the environment through wastewater treatment plant effluent, leaching of fire-fighting foam into groundwater at application sites, and landfill leachate. Many recent studies have shown PFAS in surface waters and aquatic organisms around the world. PFAS levels are higher near contamination sources, such as Wurtsmith Air Force Base in Oscoda, Michigan, USA. Unexpectedly, PFAS levels have not biomagnified in Clark's Marsh near Wurtsmith Air Force Base. Bluegill (*Lepomis macrochirus*) in Clark's Marsh have higher PFAS levels than their predators, however, the reasons and effects of these high levels are unknown. To investigate these effects, Bluegill were sampled in various inland lakes and rivers in Michigan with differing PFAS concentrations. Bluegill were individually tested for critical swimming speed, liver PFAS concentrations, and liver and gill histology. The data collected was analyzed spatially and quantitatively to determine differences between PFAS effects at different sites and with different levels of PFAS. We hypothesize that higher PFAS levels will relate to higher amounts of vacuoles in liver tissue and a slower critical swimming speed. This research will help to determine how PFAS affects fish physiologically and behaviorally in environmentally relevant concentrations. Ultimately, this information will investigate how PFAS effects fish within an individual and potentially, an entire population.

16-8 COYLE, J.A*; LOLAVAR, A.A; MEREDITH, T.L; Florida Atlantic University; *jashcra1@fau.edu*

Developing a multidisciplinary, undergraduate research training program for dual enrolled students

Florida Atlantic University High School (FAUHS) is a public, dual enrollment high school on the campus of Florida Atlantic University. FAUHS students begin college full time at FAU following a rigorous 9th grade year and typically accumulate 3-years' worth of college credit by the time they graduate high school. To ensure the students are prepared and qualified to enter graduate programs 1 year after high school graduation, we created a program to guide them through undergraduate research experiences at FAU. The FAUHS Research Program supports students in conducting undergraduate research and scholarly inquiry in a variety of disciplines, while helping them navigate aspects related to minors conducting research in a university setting. This support is scaffolded into three levels - exposure, skill-building, and intensive research experience - and consists of a series of research methodology courses, individualized mentoring, and access to the FAUHS Owls Imaging Laboratory (OI Lab). The research program goals include introducing the students to research being conducted at the university; developing basic, commonly-used research skills; finding a faculty research mentor; developing a research project proposal; finding and applying for research funding; performing data analysis; and presenting and publishing research results. The OI Lab is a research space within the high school where students can actively conduct research with or without a university mentor. University researchers use the lab in exchange for mentorship of FAUHS students. This program enables the students to strategically refine their career paths, build transferable skills, effectively compete for future opportunities, and make a real impact in their discipline.

P3-118 CRAIG, KJ*; MERGES, C; PIRTLE, TJ; The College of Idaho; *kathryn.craig@yotes.collegeofidaho.edu*

Exposing Daphnia magna to Ethanol Results in a Decline in Heart Rate by Increasing Nitric Oxide Production

Daphnia magna, known as the common water flea, are small planktonic crustaceans that possess myogenic hearts - similar to those found in vertebrates. Due to this similarity, *Daphnia* are frequently used as model organisms to test different chemicals and their effects on the heart. In this study, we seek to understand the pharmacological effects of nitric oxide (NO) on the cardiovascular system of *Daphnia*. To examine changes in heart activity, *Daphnia* were exposed to different sets of chemicals using a perfusion system and activity was monitored using an inverted microscope. In separate experiments, *Daphnia* were exposed to either a NO donor, Diethylamine NONOate sodium salt hydrate or a mixture of a nitric oxide synthase (NOS) inhibitor, L-NAME hydrochloride and NO deactivator, Carboxy-PTIO, potassium salt. To determine changes in heart rate, videos were taken at regular intervals after a standard acclimatization period and stored for further analysis. We hypothesized that NO would increase *Daphnia* heart rate; however, *Daphnia* exhibited a significant decrease in heart rate when exposed to both NO and ethanol (10%) separately. Combined and simultaneous exposure of *Daphnia* to the NOS inhibitor (L-NAME; 100 µM) and NO deactivator (PTIO; 100 µM) in 10% ethanol mitigated the decrease in *Daphnia* heart rate when compared to those treated with 10% ethanol alone. Thus, our data indicates that ethanol leads to a decrease in *Daphnia* heart rate in part by increasing NO production.

69-1 CRAIN, DD*; USENKO, S; MANSOURI, F; WINFIELD, ZC; ZERBINI, AN; GABRIELE, C; SABIN, R; POTTER, C; TRUMBLE, SJ; Baylor University, Waco, TX, Marine Mammal Laboratory, Seattle, WA, Glacier Bay National Park and Preserve, AK, Natural History Museum, London, Smithsonian Institution, Washington, DC; *dani_crain@baylor.edu*

A Different Kind of Wax Museum: Forecasting Population Trajectories of Baleen Whales Using Reproductive Parameters From Earplugs.

Reliable estimates of baleen whale growth rates are difficult to obtain when sampling populations at low densities and/or in complex habitats. We evaluate baleen whale population dynamics by analyzing progesterone in baleen whale waxy earplugs (N = 11, total lamina = 835, age range = 13 – 63 years). To identify pregnancies, we calculated percent change in progesterone from the previous lamina, ranked these points, then assigned the top 30% of points as pregnancies. From these pregnancies, we estimated age at first pregnancy, pregnancy intervals, and pregnancy rate. Our results matched well with published calving intervals, age at first birth, and birth rate. Next, we compared multiple individuals for age-specific fecundity (aligned by age). Our results demonstrated, for the first time, age-specific fecundity in fin whales (n = 3, total lamina = 117) and reproductive senescence beginning at 25 years, theoretically reaching zero fecundity at 55.5 years. Finally, we modeled the average rate of increase (ROI) of fin whales using a ROI model which includes age-specific fecundity and reproductive senescence. Compared to the standard ROI model, our results suggest a 19.7% reduction in future population size when projecting the ROI from each model forward to the year 2050. Using a model that incorporates age-specific fecundity and reproductive senescence is important to effective management and can be used to assess how exposures to stressors can impact vital rates of baleen whale populations over the long-term.

9-4 CRALL, JD*; EASTON-CALABRIA, A; CRONIN, K; THUMA, J; DEY, B; FORD VERSYPT, A; DE BIVORT, BL; Harvard University, Tufts University, Princeton University, Oklahoma State University; *jcrall@oeb.harvard.edu*

The social scaling of stress-sensitivity: Understanding the impacts of pesticide exposure and temperature stress in bumblebee colonies

Social insects such as ants, bees, and wasps are ecologically and evolutionarily dominant animals that provide critical ecosystem services such as pollination. While both theoretical and empirical studies suggest that the degree of sociality (i.e., colony size or degree of division of labor) plays a critical role in resilience to stressors such as pesticides, the specific behavioral mechanisms underlying these impacts remain unclear. Here, we use a combination of empirical and modeling approaches to explore how colony size affects sensitivity to environmental stressors (particularly pesticides and temperature fluctuations). By developing an agent-based model parameterized on detailed behavioral data, we show that colony size mitigates the impacts of exposure to imidacloprid in *Bombus impatiens* colonies. Next, we describe recent experiments combining automated individual tracking with high-resolution thermal imaging to study how the synergistic effects of temperature fluctuations and pesticide exposure change during colony development in bumblebees (*Bombus impatiens*, *Bombus bimaculatus*, and *Bombus griseocolis*). Finally, we highlight the potential of combining modeling and high-throughput, empirical tracking techniques for exploring central questions in collective resilience of bumblebees and other social insects.

14-2 CRANE, RL*; DENNY, MW; Stanford University, CA; *rlcrane@stanford.edu*

Resistance and Repair of Mechanical Fatigue in Mussel Shells

Like other rigid armors, bivalve shells protect from potentially lethal predatory and environmental threats that range in frequency and magnitude from single powerful predator strikes to repeated insults from ocean waves. Shells' effectiveness at defending from such forces is often quantified with a test of one-time breaking stress (strength): a shell is compressed until it breaks. However, this technique cannot reveal how shells resist mechanical fatigue, a process by which repeated, subcritical stresses weaken and break a material. Furthermore, the long-term threat posed by fatigue hinges on the animal's capacity for repair. We quantified and contextualized fatigue resistance and repair in the California mussel (*Mytilus californianus*) to identify the ecological threat of fatigue. We used two tests of fatigue resistance: applying a subcritical load constantly or cyclically until fracture. Mussel shells broke when fatigued such that lower forces required longer loading periods before fracture. We also measured the ability of live mussels to repair non-lethal fatigue damage (15 cycles at 67% of predicted strength) over one month. Shells were weakened by fatigue but, on average, repaired within one week. Strong predators can fracture shells with a single impact, and low forces (e.g., a shell clamping shut) won't cause damage on ecologically relevant timescales. Fatigue can make intermediate forces a threat, though; weaker predators can fatigue otherwise inaccessible prey, and failed predation attempts and episodic threats (e.g., hurled debris) can weaken shells. However, mussels have the capacity for speedy repair. A mussel would have little recourse during one predator attack, but one week between threats is sufficient for repair. Rapid, repeated forces can break shells, but, if survived, do not cause irrecoverable lifelong damage.

40-5 CRAWFORD, CH*; CERRATO-MORALES, CL; FLAMMANG, BE; New Jersey Institute of Technology; *crawford.callie@gmail.com*

Comparative Kinematics of Terrestrial Walking in Two Balitorid Loaches

Hillstream loaches (Balitoridae) inhabit the fast flowing hillstreams of South and Southeast Asia. These fishes have evolved behavioral and morphological characteristics necessary to survive in these torrential streams, including the evolution of a robust pelvic girdle modified sacral ribs. The modified ribs create a skeletal connection between the vertebral column and the puboischiadic plate. Previous researchers have suggested that this connection likely evolved as a means of facilitating station holding in their rheophilic environment. We expect the tetrapod-like walking behaviors observed in balitorids to be facilitated by this skeletal connection. Within the family there is variation in the amount of modification of the sacral rib which can be divided into three morphotypes: 1, elongated sacral ribs with similar thickness to anteriorly adjacent ribs; 2, enlarged and elongated sacral ribs; and 3, enlarged and elongated sacral ribs with a flared crest. All three morphotypes have the sacral rib inserting at the lateral foramen of the pelvic plate and secured via a ligamentous support. We hypothesize that increased pectoral girdle stability will result in greater terrestrial walking performance. Performance is measured by comparative kinematic variables including timing of fin placement; walking velocity; and fin, head, and tail angle. Here we compare the walking kinematics of two species of hillstream loaches, *Homaloptera parclitella* and *Cryptotora thamicola*, which exhibit morphotypes 1 and 3 respectively.

119-3 CRAWFORD, K*; ALBERTIN, CB; KOENIG, KM; ROSENTHAL, J; St. Mary's College of Maryland, St. Mary's City, MD, Marine Biological Laboratory, Woods Hole, MA, Harvard University, Cambridge, MA ; *kcrawford@smcm.edu*

CRISPR-Cas9 Genome Editing in the Cephalopod Doryteuthis (Loligo) pealeii

Cephalopods exhibit complex behaviors and have the largest nervous systems among the invertebrates. Their large brains and sophisticated neural networks allow them to interact with and respond to their environment with astounding speed and specificity. Cephalopods, most notably the longfin inshore squid, Doryteuthis (Loligo) pealeii, have and continue to play a critical role in our understanding of neural function. Although the mechanisms that direct their development are only now being approached at the molecular level, as genome and transcriptome resources for cephalopods become available, the time is ripe for developing genome editing technologies, such as CRISPR-Cas9, for use in cephalopods. We chose the gene for the enzyme tryptophan dioxygenase (TDO) to target in our experiments. TDO is an enzyme that is necessary for the production of the ommachrome pigments which color the chromatophores and the retina. Successful editing of TDO with CRISPR Cas9 should result in mosaic embryos with regions lacking pigmentation. In this study, in vitro fertilized D. pealeii embryos were injected with Cas9 preincubated with a CRISPR gRNA targeting TDO and cultured to hatching. Injected embryos developed normally and possessed discrete regions of ¼ to ½ albinism. Partial albino embryos were all positive for INDELs in TDO, suggesting that our CRISPR-Cas9 mutagenesis was successful. This study demonstrates for the first time that genome editing studies and the generation of transgenic animal lines are possible for cephalopods. This work was supported by an MBL Fellowship to KC and an NSF EDGE grant (1827509) to our team.

P3-7 CRILE, KG*; ABDULELAH, SA; ALMOUSELI, A; MANZO, VJ; HADEED, MN; FARD, A; IQBAL, T; BELANGER, RM; University of Detroit Mercy; *crilekg@udmercy.edu*

Ecologically relevant atrazine exposures affect the cells of the hepatopancreas of crayfish (Faxonius virlis)

The hepatopancreas of crayfish is responsible for filtering and detoxifying the body following xenobiotic exposure. The herbicide atrazine is heavily applied in the Midwestern United States and concentrations in streams and rivers surrounding agricultural areas can reach >300 ppb for upwards of three weeks. We exposed crayfish (*Faxonius virlis*) to environmentally relevant concentrations of atrazine (0, 10, 40, 80, 100, and 300 ppb) for seven days and examined the effects of atrazine on the cells of the hepatopancreas. We used hematoxylin and eosin staining in addition to TdT mediated dUTP nick-end labelling (TUNEL) to determine if atrazine exposure causes changes in morphology and DNA damage following exposure. We hypothesize that as atrazine exposure concentrations increase; there is an increase in both DNA damage and vacuolization in cells of the hepatopancreas. We expect to see an increase in TUNEL-positive cells as atrazine exposure concentrations increase. Further, we predict that there will be a disintegration of tubular epithelia, dilation of the tubules, and an increase in the number of vacuoles per lobule. Understanding the effects of atrazine and correlating these with accumulation and recovery from exposure to herbicides like atrazine will allow us to assess the long-term effects of atrazine on aquatic organisms. Because detoxification of xenobiotics is energetically demanding, responses to and recovery from atrazine exposures may subsequently impact growth, development, and reproduction.

S3-5 CROFTS, SB*; SMITH, SM; ANDERSON, PLS; CROFTS, Stephanie; UIUC, Field Museum of Natural History, 1984; *scrofts@illinois.edu*

Crushing and puncturing: biomechanics of tooth shape

The tight relationship between tooth morphology and food material properties is often used to make inferences about an organism's ecology and diet. Certain basic tooth shapes have been tightly tied to trade-offs associated with inducing fracture in different food items. For example, teeth used to puncture tough, deformable tissues can be modeled as relatively tall, narrow cones that balance tip sharpness with avoiding failure via buckling. Crushing teeth, alternatively, can be modeled as low rounded or flattened cones, which fracture brittle shells while resisting failure themselves. Simplified models such as these can be useful, but it is important to remember that teeth are more than simple cones. There are levels of complexity to tooth form and function, and secondary structures can be important to tooth function. The cusps of mammalian teeth are a well studied example of secondary tooth structures, whereas surface complexity and secondary structures occurring in non-mammalian taxa have been generally less studied. Ridges or edges, sharp raised features running from the tip of the tooth along the long axis, are one example of an easy to model secondary structure. Hypothesized purposes for these ridges include: reducing work to fracture, better gripping of food particles, and resisting biting stresses. Teeth used to cut tough materials, like skin and muscle, typically have bladed edges which serve to reduce required work. Similar but more numerous ridges occur in many tetrapods, and may be associated with durophagy and/or herbivory. Here we use biomechanical models to test hypotheses regarding ridge function under different loads, number and arrangement affect function, and how this interacts with overall tooth shape.

95-6 CROSIER, AE; BAPODRA, P; SANTIESTEVAN, J; COMIZZOLI, P; PLACE, NJ*; Smithsonian Conservation Biology Institute, Front Royal, VA, Columbus Zoo and Aquarium, Powell, OH, Cornell University, Ithaca, NY; *njp27@cornell.edu*

Anti-Müllerian hormone as a predictor of responses to ovarian stimulation in cheetahs, Acinonyx jubatus

Serum anti-Müllerian hormone (AMH) concentrations have been shown to predict the ovarian response to exogenous gonadotropin stimulation for assisted reproductive technologies (ARTs) in women and production animals. Our objective was to determine if the same holds true for cheetahs. In anticipation of planned artificial inseminations (AI), six cheetahs underwent ovarian stimulation with a standard eCG/LH protocol. Within one month before eCG, a blood sample was collected for serum AMH determination. A second blood sample was collected approximately 42 hours post LH and before laparoscopic intra-oviductal AI, when the total number of corpora lutea (CL) were enumerated. Pre-eCG AMH concentrations were 1.00-3.09 ng/mL, and the number of CL ranged from one to 17. Females appeared to segregate into high and low AMH groups (N = 3 each), defined by AMH greater than 2.00 ng/mL (range 2.14-3.09 ng/mL) or substantially less than 2.00 ng/mL (range 1.00-1.15 ng/mL). The number of CL (mean ± STD) for the high AMH group was 10.6 ± 6.0, and for the low AMH group was 3.7 ± 3.1. The pre- and post-gonadotropin AMH concentrations were significantly correlated ($r2 = 0.66$, $p = 0.03$), and females with a high pre-AMH concentration uniformly showed a decline in AMH post-eCG/LH. Females with a low pre-AMH concentration did not have consistent changes in AMH following eCG/LH. While additional females are being recruited to this study, the results from the initial cohort suggest AMH is likely to be a good predictor of individual responsiveness to ovarian stimulation in preparation for ARTs in cheetahs.

P2-35 CROWE-RIDDELL, JM*; PIETERMAN, L; SIMOES, BF; NANKIVELL, JH; FORD, M; LUDINGTON, A; ALLEN, L; SANDERS, KL; University of Michigan, Ann Arbor MI, University of Adelaide, Adelaide, Australia , Venom Supplies, South Australia, Australia; *jmcr@umich.edu*

Ontogenetic change in hue and structure of caudal lure reflects dietary shift in Australian death adders (Elapidae)

Death adders (genus *Acanthophis*) are ambush predators that entice prey within striking range by moving their tail tip in hypnotic undulations (caudal luring). This ambush hunting strategy makes death adders unique among Australian venomous snakes (Elapidae) and ecologically convergent with vipers and rattlesnakes (Viperidae). However, unlike viperid snakes that tend to stop caudal luring in adulthood, both juvenile and adult death adders caudal lure despite showing ontogenetic shifts in diet: juveniles tend to eat small frogs and lizards; adults eat large lizards, birds and mammals. To test whether caudal luring is retained in adults to lure new prey types (i.e. endotherms), we examined the hue, texture and shape of caudal lures in captive juvenile and adult *A. antarcticus* from South Australia. We found that once a snake reaches a certain mass, the caudal lure undergoes changes in dermal pigment colouration and epidermal microstructure, resulting in a different caudal lure morphology in adults. These results suggest that caudal luring is under selection to attract specific prey types into adulthood, which has implications for our understanding of how morphology relates to luring behaviour and how predators exploit sensory biases in prey.

66-7 CROWELL, HL*; TAYLOR, EN; University of Michigan, California Polytechnic State University; *hlcrowel@umich.edu*

Comparative Thermal Ecology of Coastal and Inland Populations of Pacific Rattlesnake Crotalus oreganus

Reptiles have become focal organisms for studying the direct effects of changing climates due to their reliance on environmental temperatures for physiological functions. In this study, we compared thermal and behavioral data collected during 2010-2017 from four distinct populations of *Crotalus oreganus* on the central coast of California to examine how climate change will impact closely related populations inhabiting distinctly different climates. Using biophysical temperature models, surgically implanted temperature data loggers, and radiotelemetry, we collected data on the thermal microhabitats available as well as field active body temperatures for 85 individual snakes. Along with lab-derived preferred body temperature range, we determined the thermal accuracy of each snake population. Snakes from hot, inland populations thermoregulated most accurately, despite inhabiting more thermally constrained environments. We then used a climate change model at a 1°C and a 2°C increase to predict changes in habitat thermal quality and theoretical changes in snake standard metabolic rates. In both coastal and inland areas, the availability of annual thermally favorable temperatures is predicted to increase with increasing ambient temperatures. Additionally, a theoretical increase in body temperature of 1 and 2 °C would have a minute impact on the overall energetic needs of snakes, still allowing them to meet baseline energetic requirements with only one large meal a year. Small increases in ambient temperature will most likely have little impact on rattlesnake thermal ecology, as our findings suggest that these animals are fairly precise thermoregulators, maintaining relatively constant body temperatures regardless of extreme thermal variation in their surrounding habitats.

P1-204 CROWNOVER, LA*; ANDERSON, CV; Univ South Dakota, Vermillion; *Lucas.Crownover@coyotes.usd.edu*

Diversification patterns and evolutionary drivers in the chameleon axial skeleton

With over 200 taxa in twelve genera, chameleons exhibit an incredible amount of diversity in their morphology, ecology and behavior. While much of their anatomical diversity is evident from their extreme body size variation and diverse external ornamentations, many of the internal structural differences that contribute to their variation has been less well examined. Among the most variable skeletal features in chameleons is the number of presacral and caudal vertebrae, as well as the number of sternal and parasternal ribs. Our previous work has expanded the known variation of these axial skeletal elements and suggested that both phylogenetic and ecological differences may help drive some of this variation. Here, we performed phylogenetic comparative methods on rib and vertebral counts from micro-CT scans of chameleon specimens to provide further insight into the chameleon axial skeleton. We tested for effects of arboreality and body size, along with other ecological factors, on the observed variation in axial skeletal element counts. Further, we performed ancestral state reconstructions to assess where in the phylogeny specific changes in morphology occurred. In total, vertebral and rib counts from more than 60% of the described species diversity and all twelve genera were included in our analysis. From these analyses, we show that arboreality is a significant predictor of the number of certain axial skeleton elements. We also find a previously unknown synapomorphy for one of the twelve chameleon genera, which show a reduction in cervical vertebrae and ribs relative to all other genera. These results suggest that both ecological and phylogenetic factors have played important roles in shaping patterns of axial skeleton variation in the Chamaeleonidae. More broadly, these results also provide insight into the morphological evolution of the axial skeleton across disparate ecologies and environments.

P2-169 CUEVAS-SANCHEZ, A.Y*; MOESER, E; BUHL, K; DINH, K.V; DOWD, W.W; Washington State University, University of California, Los Angeles, Washington State Univ, Washington State Univ; *a.cuevas-sanchez@wsu.edu*

Interactive effects of oxygen and temperature on physiology and behavior of the splash pool copepod Tigriopus californicus

Splash pools along rocky coastlines experience daily fluctuations of environmental parameters such as temperature, dissolved oxygen, pH and salinity, often reaching levels beyond the physiological tolerance of most organisms. Yet, along the Pacific coast the copepod *T. californicus* can be found in high abundance, making it a useful model to study how multivariate environmental fluctuations influence physiology and behavior. We examined the interactive effects of temperature and oxygen levels on thermal tolerance and preference behavior of *T. californicus*. Given the temporal correspondence between high temperatures and high oxygen levels in the field, we first set out to test the Oxygen Capacity Limited Thermal Tolerance hypothesis (OCLTT) by exposing egg-mass bearing females (n=384) to one of four acute levels of oxygen ranging from hypoxic to hyperoxic, coinciding with a heat ramp with peak temperatures ranging from 34.1°C to 38°C. Female survival was monitored for one week following exposure. The results indicate a higher survival rate in females exposed to high oxygen while simultaneously exposed to high temperature, supporting the OCLTT hypothesis. However, the effect size is small in magnitude. A second set of females were used to determine preference when exposed simultaneously to gradients of temperatures (12-29°C) and oxygen saturation (15-210%). Results to date indicate a trend of thermal preference being modulated by dissolved oxygen levels; distribution appeared unaffected by oxygen levels at low temperatures, but females avoided hypoxia at high temperature. Addressing how organisms respond to realistic combinations of environmental conditions can help us better predict the outcomes of future changes.

99-7 CUFF, AR; BISHOP, PJ; MICHEL, KB; GAIGNET, R; HUTCHINSON, JR*; Structure & Motion Lab, Royal Veterinary College, United Kingdom; *jrhutch@rvc.ac.uk*

Anatomically Grounded Estimation of Limb Muscle Sizes in Archosauria

It is commonly assumed that "muscle scars" on bones correspond to the cross-sectional areas of muscle-tendon units. This issue is vital both for understanding morphology itself (e.g. musculoskeletal integration) and for reconstructing musculoskeletal form in extinct taxa. Archosaurian reptiles famously evolved disparate skeletal forms with differences in body size, posture, gait and other aspects of locomotion reflected by variations of the muscle attachments. We tested how well hindlimb muscle sizes can be predicted from skeletal evidence in archosaurs. With a high-precision manual digitizer (±0.01mm), we digitized the bony attachment areas (AA) of all major hindlimb muscles in five juvenile Nile crocodiles and five Elegant-crested tinamous. Additional, lower-precision (~±1mm) older digitized data from an adult ostrich, emu, turkey and chicken were added to our avian dataset for comparison. We measured the physiological cross-sectional areas (PCSAs) of the same muscles for all specimens via dissection. Our prediction was that fleshier attachments would give more consistent estimates of muscle PCSA from AA, whereas more tendinous attachments would have more variable PCSA estimates from AA within and across taxa. Examining how well homologous muscles in Crocodylia and Aves preserve consistent PCSA:AA ratios, we found that only a few muscles do. Finally, we show examples how these ratios can be analysed in a phylogenetic context across Archosauria, applying them to fossil specimens; vs. other methods from the literature.

22-3 CULUMBER, ZW; University of Alabama in Huntsville; *zwc0001@uah.edu*

Variation in Animal Personality Across a Major Environmental Gradient

Theory indicates that animal personality should arise in association with predictable life history trade-offs. Environmental gradients are common in the wild and generate predictable trade-offs, yet we have limited knowledge of how animal personality varies at broad spatial scales. Here, I examined variation in a suite of behaviors in 18 populations of a livebearing fish across latitude, one of Earth's major environmental gradients. Consistent with environmental variation across latitude, and with observed variation in life history traits, personality changed across latitude. Individuals from high latitudes tended to be less social, more bold, and more active than counterparts from lower latitudes, potentially associated with the need to grow and reproduce quickly in regions with shorter seasons and more extreme winters. Overall, these results indicate that animal personality changes in a predictable manner along a major environmental gradient, with potential implications for broader evolutionary patterns.

P1-16 CUMMING, M*; SMITH, FW; University of North Florida; *n01403244@unf.edu*

Genomic and developmental origins of tardigrade legs

Tardigrada consists of two lineages—Heterotardigrada and Eutardigrada. All tardigrades are microscopic animals with tiny legs. To understand the evolution of tardigrade legs, we have analyzed the leg gap genes, *Distal-less*, *dachshund*, and *homothorax*/*extradenticle*, which specify distal, intermediate, and proximal appendage domains in arthropods. In *Hypsibius exemplaris*, a representative of Eutardigrada, *Distal-less* is broadly expressed across the appendage bud during development. *Homothorax*/*extradenticle* do not specify proximodistal appendage domains in this species. *Dachshund* is not found in the genomes of *H. exemplaris* or a second representative of Eutardigrada, *Ramazzottius varieornatus*. These results indicate that tardigrade legs evolved by the loss of proximal and intermediate regions. To further characterize the evolution of the proximodistal axis of tardigrades, we recently sequenced the genome of *Batillipes pennaki*, a representative of Heterotardigrada. Consistent with our earlier study of eutardigrade genomes, orthologs of *Distal-less*, *homothorax*, and *extradenticle* are present in the genome of *B. pennaki*, and an ortholog of *dachshund* is not present in the genome. In order to further characterize the role of *Distal-less* in tardigrade leg development, we have identified orthologs of genes that are either upstream or downstream of *Distal-less* during leg development in arthropods. We have identified orthologs of *BarH1*, *clawless*, *decapentaplegic*, *rotund*, and *zfh2* in both eutardigrade and heterotardigrade genomes. Additionally, we have identified orthologs of *apterous*, *aristaless*, *Lim1*, *nubbin*, and *spineless* in eutardigrade genomes. Results of preliminary analyses of the developmental roles of candidate appendage patterning genes in *H. exemplaris* will be shown.

P1-140 CUPP, PV; Eastern Kentucky University; *paul.cupp@eku.edu*

Interspecific Cooperation of Philomycus Slugs and Green Salamanders, Aneides aeneus, May Enhance Water Economy

Philomycus slugs and green salamanders, *Aneides aeneus*, are commonly found in the same rock crevices in sandstone rock cliffs. Previous studies suggested that any interactions of *A. aeneus* with slugs in crevices likely were not beneficial for either species. Also, the presence of slugs in *A. aeneus* breeding crevices may be harmful to the eggs. However, I have observed twelve instances in which *A. aeneus* (adults and young) were in direct contact with single *Philomycus* slugs in rock crevices with no apparent ill effects. This water-conserving posture may reduce the surface area exposed by the two animals such that water loss would be minimized and may allow survival over short dry periods until humidity or moisture levels increase. In some cases, additional water conserving measures were observed, including pressing of the tail against the side of the body and coiling it over the head. Both species have a moist integument and thus are readily subject to evaporative water loss. While opportunistic, this aggregative behavior by both species may be adaptive and beneficial. One possible negative effect was in the case of a large slug present in a small *A. aeneus* brooding crevice which may have prevented deposition of her eggs. The aggregative behavior observed here indicates that interspecific cooperation or mutualistic symbiosis with regard to water economy may be important for some individual slugs and salamanders.

P1-98 CURREA, JP*; FRAZER, R; THEOBALD, JC; WASSERMAN, S; CURREA, Joh; Florida International University, Wellesley College; *jcurr001@fiu.edu*

Using Microscope or MicroCT Images to Measure Compound Eye Optics

Eye structure directly limits what an animal can see. By studying the natural range of eye designs we can learn a great deal about visual ecology, visual development, and the selective pressures placed on eye development that drive the evolution of vision. The compound eye found among arthropods contains an impressive range of designs and sizes and is a prime subject in the study of vision. Compound eyes are composed of many units called ommatidia, each equipped with a lens that focuses light upon photoreceptors below. In contrast to camera-type eyes, many of the structures limiting compound eye performance are externally visible. For spherical eyes, many visual parameters like spatial resolution, optical sensitivity, and field of view can be measured externally using microscope images. For non-spherical eyes, which often have skewed ommatidial axes, internal structures must be accounted for. MicroCT, a burgeoning imaging technique, generates a 3d image of the specimen where voxel values represent physical densities. In particular, MicroCT can reliably image insect brain structures, like the visual neuropils, and eye structures, like the the crystalline cones of the ommatidia. We propose two methods, one for microscope and another for microCT images, and offer an open source Python program to semi-automatically approximate parameters like spatial acuity, optical sensitivity, and field of view across different regions of the eye. We demonstrate the reliability of these methods on the eyes of a number of insect species (fruit fly, moth, bee, ant), finding that both succeed in characterizing the optical performance of compound eyes accurately and reliably while minimizing labor.

P3-178 CURTIS, N*; MACKIEWICZ, A; PUTLAND, R; MENSINGER, A; University of Minnesota Duluth, Marine Biological Laboratory; *curti448@d.umn.edu*

Seasonal changes in male Oyster Toadfish's response to boatwhistle playbacks

During the mating season, male Oyster Toadfish (Opsanus tau) establish nesting sites and produce courtship calls called boatwhistles to attract females. The boatwhistle consists of a broadband grant followed by a longer tonal segment that male fish will produce from mid-May to mid-August. The fundamental frequency of the tonal portion of the call is correlated with water temperature; it is thought that females are attracted to this portion of the call. Females must localize the call to find the nest and deposit the eggs which the male guard throughout development. Males also will produce short grunts to jam the tonal portion of rival males' calls. The toadfish population in Eel Pond was monitored acoustically throughout the mating season using a linear hydrophone array. Pure tones and boatwhistle calls were broadcast using an underwater speaker at four different frequencies (150 Hz, 175 Hz, 200 Hz, and 225 Hz) to determine the effect of extraneous sound on the number and timing of toadfish calls. Toadfish were more responsive to lower frequency sounds (150 Hz) early in the season when the water was 19°C. However, as the water temperature increased to 22°C, they shifted their responses to higher frequencies (200 Hz and 225 Hz). The results show that boatwhistle production will increase in response to both pure tone and boatwhistle playback. Additionally, as the fundamental frequency of their own calls increase with rising water temperature, so does their response to higher frequency calls.

P2-17 CURTIS, MD*; MCCLINTOCK, JB; University of Alabama at Birmingham; *curtismi@uab.edu*

Potential impacts of near-future climate-induced ocean warming on the stomach microbiome of the common soft-bottom sea star Luidia clathrata

Studies have demonstrated that near-future ocean warming is likely to negatively impact aspects of larval development, immune function, and behavior in sea urchins. Moreover, a recent study reported the gut microbiome of a sea urchin was altered in response to predicted near-future warming. Sea stars, similar to sea urchins, play pivotal roles in marine communities as keystone species. *Luidia clathrata* is an extremely abundant, soft-bottom, predatory sea star that occurs in shallow inlets and bays in the northern Gulf of Mexico (GOM). These regions are projected to experience disproportionately higher temperatures due to climate change. An understanding of the capacity of *L. clathrata* to adapt to warming conditions is crucial since the northern GOM offers no option of northern migration as warming occurs. *Luidia clathrata* were collected from the northern GOM and held individually under controlled experimental conditions at ambient (28°C), mid-century (30°C), and end-of-century (32°C) temperatures. After four weeks, stomach, sediment, and seawater for each individual were collected and their microbial communities determined by sequencing the V4 region of the 16S rRNA gene using the Illumina MiSeq™ platform. Microbial community composition was analyzed using bioinformatics tools. Microbial diversity differed by sample type. The composition of the microbial community of the stomach shifted between the 28°C and 30°C treatments. As different microbes contribute to the performance of a variety of key metabolic functions, understanding how ocean warming might alter the microbiome will be critical to our understanding of how sea stars will adapt to future ocean conditions.

P2-175 D'ALESSANDRO, MN*; HOWEY, CAF; The University of Scranton; *Michelle.dalessandro@scranton.edu*

Metabolic Rates of City Anoles

Organisms living in urban areas are exposed to ambient light at night (ALAN) and these conditions are known to affect the natural rhythmicity of hormones produced by the body (e.g., glucocorticoids and melatonin). Disruptions with these physiological processes may also have cascading effects on the metabolism of an organism. The objective of this study was to determine if anoles exposed to ALAN would increase metabolism due to the disruption of sleep patterns and increased activity, or if the chronic stressor, ALAN, may lead to downstream pathological effects and a decrease in metabolism. To answer this question, 24 green anoles (*Anolis carolinensis*) were divided randomly into two groups: the Experimental Group with a 24-hour light cycle and a Control Group with a 12:12 light:dark cycle. Both groups were maintained at similar temperatures, humidity, and UV light conditions. We measured metabolic rates of anoles at the beginning of the study, week 3, and week 6 using stop-flow respirometry. Metabolic rates were measured at both midday and midnight. By measuring the changes in CO_2 production and O_2 consumption, the respiratory quotient (RQ) was determined and used to compare if treatment groups were metabolizing different sources (lipids, proteins, or carbohydrates). This study can help biologists further understand how populations are affected by anthropogenic disturbances and the effect of a chronic stressor on the metabolic rate of an organism.

92-5 DA SILVA, DP*; GOMES, FR; University of Sao Paulo; *diego.pnds@gmail.com*

Interplay between personality, physiology, and temperature in American bullfrogs

Personality has been identified in several different ecological contexts. However, the physiological mechanisms underlying different animal personalities are still poorly understood. Different personalities have been correlated with different patterns of activity and reactivity of the hypothalamus-pituitary-adrenal axis and the resulting plasma corticosteroid levels. Amphibian studies in personality literature are scant. The objective of this study was to broaden the literature on amphibian personality and understand how it correlates with plasma levels of corticosterone (CORT) and testosterone (T), as well as to identify how a chronic high temperature stress might affect behaviour and physiology. Thirty male American bullfrogs were brought from a local farm into laboratory conditions - summer photoperiod (13:11 LD), 28±1°C. Blood was sampled after 15 days of habituation to assess each individual's basal plasma levels of CORT and T. Animals were then submitted to behavioral tests and we assessed activity, bold, and exploratory behavior. After this initial phase (42 days), animals were divided into two groups: control (28±1°C (n = 15)) and experimental (34±1°C (n = 15)). Blood was sampled again from both groups 12 hours, 25 days, and 46 days after animals from the experimental group were transferred to the high temperature treatment. Furthermore, all 30 animals were resubmitted to the behavioural tests 1 month after the temperature treatment began, in order to verify if personality traits remained the same through time and through the experimental treatment. All tests were video recorded and will be analyzed in a tracking software. We will test for the existence of behavioural syndromes, for the association between personality and physiology, and how increment temperature modulates these associations.

66-5 DAHLHOFF, VC*; LARKIN, B; WOODS, HA; DAHLHOFF, Vic; University of Montana, MPG; *victoria.dahlhoff@umontana.edu*

Capturing behavioral thermoregulation in the western tent caterpillar Malacosoma californicum pluviale using thermal imaging

Several traits characterize colonial living in animals, but an especially important one is modification of environmental temperature. Colonial insects are some of the most common animals known to create structures that alter thermal conditions of the group. Because insects are ectotherms and rely on their environmental temperature to regulate body temperature and thus rates of metabolism, the ability to control environmental temperature is especially crucial. Here I describe mechanisms of thermal modification in the Western tent caterpillar, *Malacosoma californicum pluviale*. Tent caterpillars build communal silk tents, which can be heated to temperatures substantially above ambient air temperature. In spring 2019, I quantified how individual caterpillars are experiencing this extra heat. Using IR thermal imaging I captured body temperatures of caterpillars in the following combinations: grouped on the tent, alone on the tent, grouped off the tent, and alone off the tent. I found that caterpillars grouped together off the tent had somewhat elevated body temperatures above solo caterpillars - a result that was replicated using operative temperature models. However, grouped caterpillars on the tent reached much higher temperatures, suggesting that the tent is capturing extra heat. My data suggest that the tent plays an important role in maintaining a more buffered thermal environment for caterpillars over and above its function as a platform for behavioral thermoregulation.

S10-4 DAKIN, R*; SEGRE, PS; BERBERI, I; ALTSHULER, DL; Carleton University, Stanford University, University of British Columbia; *roslyn.dakin@gmail.com*

Multilevel analysis of maneuvering performance and morphology in hummingbirds

The ability of a flying animal to maneuver can be critical for survival. How do morphological traits determine agility? To address this question, we developed an approach to analyze thousands of rotations, accelerations, and turns, as the geometrical building blocks of complex flight. To relate morphology to maneuverability, we recorded flight performance from over 200 individuals in 25 hummingbird species. We used multilevel regression models to analyze variation both within and among species, accounting for phylogenetic nonindependence. The advantage of the comparative approach is that evolution repeatedly explores new variants, making it possible to determine the contribution of several morphological and biomechanical traits. We found that larger hummingbird species have evolved disproportionately larger wings and muscle capacity, which allows them to outmaneuver smaller species (overcoming their size-based disadvantage). This demonstrates how multilevel models can be used to reveal compensatory evolution. Our current work investigates whether species differ in the predictability of flight maneuvers. We will address whether predictability and the level of performance are associated with different morphologies, representing a potential tradeoff.

P3-42 DALLAS, JW*; DEUTSCH, M; WARNE, RW; Southern Illinois University, Carbondale; *jason.dallas@siu.edu*

Thermal Performance of an Exotic Gekkonid and the Effects of n-3 PUFAs on Immunity

Environmental temperature is a driving force in ectothermic physiology and is a limiting resource in temperature habitats. We examined the sprint speed and innate immune ability of *Hemidactylus turcicus* across a thermal gradient to determine this species' thermal optimum and potential thermal plasticity. The effects of dietary n-3 PUFAs on immune performance were also tested, because these essential nutrients are suspected to be a limiting factor in some aspects of immunity. Adult *H. turcicus* were collected from buildings in southern Illinois following the breeding season and maintained in captivity. Sprint speed was recorded across a thermal gradient from 20–36°C in 4°C intervals, which represented both the extremes and optimal temperatures for this species. Innate immune performance was also tested along a thermal gradient from 20–35°C in 5°C intervals, by injecting *H. turcicus* with PHA extracts in their rear foot and measuring the swelling response. Geckos were then orally dosed with n-3 PUFAs or water and the PHA experiments were conducted again at 25 and 35°C. As expected, sprint speed increased with temperature but plateaued at 28–36°C, and the swelling response to PHA exhibited a similar increase with temperature. These results show that *H. turcicus* exhibits high thermal plasticity as they are able to maximize physiological performance across a range of temperatures. N-3 PUFAs supplements induced a significant and complex interaction between innate immunity and temperature; whereby geckos orally dosed with n-3 exhibited an increased swelling response to PHA at 25°C, compared to controls, but a strong reduction in swelling at 35°C. Controls did not change with temperature. While previous studies have shown that n-3 PUFAs are associated with immunomodulatory effects, our results suggest n-3 PUFAs can also have complex, temperature dependent anti-inflammatory affects.

114-4 DANFORTH, SM*; LARSON, JG; DAVIS RABOSKY, AR; MOORE, TY; Univeristy of Michigan, Ann Arbor, MI; *sdanfort@umich.edu*

A Kinematic Analysis of Micrurus Coral Snake Thrash Duration and Curvature Enables Quantitative Characterization of Non-Locomotory Behavioral Motion

Warning signals in chemically defended organisms greatly impact the outcome of predator-prey interactions. These aposematic signals are often composed of high-contrast color patterns combined with complex behavioral movements with little locomotory function. When threatened by a predator, venomous coral snakes (genus *Micrurus*) display a vigorous, non-locomotory thrashing behavior that has been only qualitatively described. This thrashing display is likely a key component of a complex aposematic signal under strong stabilizing selection across species in a mimicry system. We analyzed variation in the presence and expression of the thrashing display across five species of South American coral snakes by experimentally testing snake response across simulated predator cues. We measured the duration of each thrash and the curvature along the body during the resting period after each thrash. These kinematic analyses can be performed with minimal animal handling and can cope with multiple self-occlusions and acute curvatures. We found significant variation in the propensity to perform a display at all, the duration of thrashing, and the curvature of snake bodies. This variation was mediated by predator cue type, snake body size, and species identity. Our results suggest that a high degree of variation persists in thrashing behavior exhibited by *Micrurus* coral snakes despite presumably strong selection to converge on a common signal. This quantitative behavioral characterization presents a new framework for analyzing the ecologically relevant motions displayed by elongate organisms.

P1-99 DANG, A*; BERNARD, GD; OLGUIN, AR; MACIAS-MUNOZ, A; LAWRENCE, JP; HILL, RI; MULLEN, SP; BRISCOE, AD; University of California, Irvine, University of Washington, Seattle, Universidad Nacional Autónoma de México and University of California, Irvine, University of the Pacific, Boston University; *danga5@uci.edu*

Color Vision in Nymphalid Butterfly, Adelpha fessonia

Mimicry is a defensive strategy that helps prey avoid predation by resembling unprofitable species. More is known about the vision and behavior of predators compared to prey species' visual systems. We investigate the visual system of *A. fessonia* using epi-microspectrophotometry (epi-MSP), optophysiology, spectroscopy data, opsin phylogenetics, immunohistochemistry and opsin gene expression among various tissues. Eyeshine of *A. fessonia* suggests an absence of heterogeneously-distributed red filtering pigments found in other nymphalid species. RNA-Seq revealed the presence of three opsin mRNAs encoding long-, blue- and ultraviolet (UV)-sensitive opsins. Epi-MSP showed a 530 nm peak sensitivity in the long wavelength (LW)-sensitive region of light and optophysiology showed an UV-sensitivity to light at 355 nm. We infer the peak sensitivity for the blue rhodopsin at ~431 nm using spectroscopy data and amino acid sequences from other *Adelpha* species. Immunohistochemistry will confirm the presence and abundance of the LW, blue and UV opsins while transcripts per million will determine the expression levels of their mRNAs. Our results reveal characteristics of *A. fessonia* eyes which can be compared to other *Adelpha* and nymphalid species. As *Adelpha* possess expansive mimicry complexes within Nymphalidae, examining visual systems in individual species is vital to understanding how mimetic species discriminate one from another to maintain mimicry complexes while avoiding hybridization.

P2-116 DANG, H*; MARTINEZ ACOSTA, V; Univ. of the Incarnate Word; *hdang@student.uiwtx.edu*

Immunohistochemical Analysis of Synaptic Proteins During Regeneration

The freshwater annelid *Lumbriculus variegatus* regenerates from as little as three body segments (Martinez-Acosta and Zoran, 2015). Recent electrophysiological studies demonstrate recovery of function as early as 24hr post amputation (Lybrand and Zoran, 2012). Using immuhistochemical analysis, we describe the emergence of serotonergic neurons 24hr post amputation which begin formation of the cephalic ganglion in regenerating head blastema. These data suggest that *Lumbriculus* has one of the fastest regenerating nervous systems in the metazoan phyla. To further investigate this rapid recovery of function, we describe changes in expression of synaptic proteins during regeneration. In other species such as lamprey, researchers have found the upregulation of synapsin in the brain after spinal cord injury which plays a big role in neurite outgrowth and synapse formation (Lau et al 2011). Antibodies were tested for cross-reactivity against synaptic proteins like synapsin, synaptic vesicle protein (SV2), syntaxin, and synapse associated protein 47 (DSAP47). Of these DSAP 47 (Developmental Hybridoma Bank) immunoreactivity is found along the ventral nerve cord (VNC), more closely associated with the lateral giant fibers. DSAP47 epitopes were also found in co-lateral extensions that arise from the VNC and are thought to be points of sensory integration from the periphery. In cross-section, SV2 and syntaxin are found at active synapses within the neuropil of the VNC in regenerating fragments. As we move forward, changes in expression of these synaptic proteins will be quantified at different time points of regeneration: 24 hrs, 72 hrs, and 1 wk post-amputation to provide insight for how they may be functioning in this remarkable regenerating system.

P1-12 DANIEL, L*; DUBANSKY, B; BURGGREN, W; University of North Texas; *lindseydaniel2@my.unt.edu*

Differences in Early Embryo Cleavage Rate in Two Populations of Killifish (Fundulus grandis)

The first hours post-fertilization represent critical time points in teleost development, and may be an overlooked source of adult phenotypic variation. This experiment quantifies early cell stages from two killifish populations (*Fundulus grandis*). Killifish from a polluted area in the Houston Ship Channel are highly tolerant to environmental stressors, whereas wildtype populations outside the Houston Ship Channel are more susceptible during development. Accompanying these differences are many biochemical and physiological differences. To test the hypothesis that temperature influences these critical time points and that the responses are population-dependent, fertilized embryos from tolerant and wildtype populations were maintained in one of 22°C, 25°C, and 28°C. Repeated measures of each cleavage tracked development rate over 4 h to the 64 cell stage. Tolerant populations at 22°C in non-polluted water showed a higher ($p<0.01$) cleavage rate of 13.5 cleavages/h compared to the wildtype population's rate of 13.2 cleavages/h in non-polluted water at 22°C, indicating intrinsic differences in cleavage rate associated with each population. Cleavage rate of the tolerant population to 64 cells was less temperature sensitive (Q_{10} = 1.8, $p<0.01$) then in the wildtype population (Q_{10} = 2.8). Alterations in physiological and morphological phenotypes associated with exposure to different temperatures indicate that temperature alters initial developmental trajectory, as expected. Unexpected was that this fundamental biological process of cell division would vary between populations. Experiments are underway to determine underlying mechanism(s) for differences in individual and interindividual cleavage rate.

132-2 DANIELS, J*; OSBORN, K; AOKI, N; HAVASSY, J; MUSHEGIAN, N; KATIJA, K; Monterey Bay Aquarium Research Institute, Moss Landing, CA, Monterey Bay Aquarium Research Institute, Moss Landing, CA and Smithsonian Institution, Washington, DC, Smithsonian Institution, Washington, DC, Smithsonian Institution, Washington, DC; *joost@mbari.org*

A Midwater Polychaete on the Move: Swimming of Tomopteris

Tomopterids are a family of highly-derived, holopelagic, gelatinous polychaetes found throughout the world's oceans. The lack of internal segmentation and chaetae combined with their large paddle-like appendages (parapodia) distinguish tomopterids from other polychaetes. Paddling of the fleshy parapodia and lateral body motion allow these animals to swim with a speed and maneuverability that are visually distinct from other swimming polychaetes, such as nereids. We captured living tomopterids using remotely operated vehicles in California's Monterey Bay and transferred them to filming vessels onboard the ship. Swimming motion (kinematics) of the animals was studied using high-speed video recordings of the animals. We found that active paddling of the parapodia generates forward thrust, augmenting the thrust derived from the forward-directed body wave during straight, forward-directed swimming. In addition, this body wave allows for increased range of motion of the parapodia, resulting in an increased displacement of the body per stroke. The characteristics of the stroke deviate from existing metachronal simplified models for polychaetes and crustaceans alike, and a drag/thrust model is presented based on a simplified *Tomopteris* body plan. These results could have applications in biomimetics and soft robotics.

80-4 DANTZER, B*; VAN KESTEREN, F; PALME, R; BOUTIN, S; MCADAM, AG; LANE, JE; University of Michigan, University of Veterinary Medicine Vienna, University of Alberta, University of Guelph, University of Saskatchewan; *bendantzer@gmail.com*

Disentangling how multiple ecological factors impact glucocorticoids in red squirrels

It is widely appreciated that glucocorticoid levels are impacted by environmental factors such as weather conditions, food availability, the degree of competition over some limited resource, and predation risk. These changes in glucocorticoids can in turn mediate plasticity in behavioral or life history traits that increase the ability of an organism to persist through environmental fluctuations. Although numerous studies have documented the impacts of specific environmental factors on glucocorticoid levels in a wide-variety of organisms, few studies have simultaneously investigated the relative impacts of multiple ecological factors on glucocorticoid levels. Given that free-living animals likely experience environments in which multiple ecological factors are changing in unison, it is important to assess whether their effects are additive, interactive, or mitigating. For example, an increased predation risk may typically be associated with increased glucocorticoid levels in prey but those effects may be mitigated or eliminated by a simultaneous increase in per capita food availability. We assessed the relative effects of weather conditions, food availability, competition, and predation risk on fecal glucocorticoid metabolite levels of North American red squirrels in the Yukon, Canada. We will describe the results from these analyses that use >10 years of fecal glucocorticoid metabolite data collected from free-living red squirrels that experienced natural and experimental variation in weather, food, competition, and predation risk. By doing so, we illustrate the importance of testing multiple hypotheses regarding the ecological causes of variation in glucocorticoid levels of wild animals.

P1-121 DANZIGER, A*; FREDERICH, M; University of New England, Biddeford, ME; *mfrederich@une.edu*

Design and use of species-specific Carcinus maenas eDNA primers to analyze shedding and degradation rates of eDNA

The emergence of environmental DNA (eDNA) detection provides a powerful tool to detect and monitor biodiversity, including invasive species. The European green crab, *Carcinus maenas*, is an invasive species world-wide and monitoring its populations is important. To use eDNA, species-specific primers are required. We tested primers developed for *C. maenas* in Australia and published by Bott et al. (2010) on green crabs and other native species in the Gulf of Maine, USA. We found the primers to also detect *H. sanguinaeus*, *C. irroratus*, *H. americanus*, and other species. Therefore, new primers and probes were designed using the COI gene of *C. maenas* and tested on multiple native species, as well as green crabs from Newfoundland, Iceland, and Nova Scotia. These were found to be species specific and detect crabs from all 4 populations. We further investigated the dose dependent quantity of eDNA as well as the degradation rate to test whether the eDNA approach can be used to quantify the abundance of crabs in the environment. Crabs were incubated for 7 days in 4 gallons of aerated artificial seawater. Concentrations of eDNA of *C. maenas* under these conditions was dose-dependent. Degradation of varying amounts of eDNA in water samples showed detectability up to 2 days with a near logistic decay. Therefore, the identified absolute amounts of eDNA in a water sample is dependent on number of animals present and the timing of the collection of samples, making eDNA concentrations as a tool for quantification not usable. Our work shows that species specific eDNA primers need to be verified with the respective local species, and should not be used for quantification. Funded by NSF grant# IUSE-1431955 to M.F.

P1-9 DAO, TK*; LAMBERT, JD; University of Rochester; *tdao@ur.rochester.edu*

The possible roles of retinoic acid pathway in the shell and the embryonic development of the mollusc Tritia.

Retinoic acid (RA) is a potent morphogen that patterns the anterior - posterior axis during embryonic development in vertebrates. Although key enzymatic components of the pathway are present in at least some non-vertebrate genomes, the developmental functions of retinoic acid pathway in these animals is largely unknown. We have been investigating the developmental roles of RA in our animal system, the mollusc *Tritia (Ilyanassa)*. Our data suggest that the *Tritia* genome encodes copies of the RA synthesizing enzyme, RALDH, and the RA receptors, RAR and RXR, suggesting that it could have a functional RA pathway. We also recover a CYP26-like protein (Cyp26), which is predicted to degrade active RA. The morpholino (MO) knockdown of Cyp26 causes specific defects in the shell, digestive gland and the stomach. Excitingly, this is extremely similar to the effects adding RA during early shell development, indicating that it is a specific effect of excess RA in the embryo. In both treatments, the shell defect is characterized by too little shell extension, and too much shell expansion, consistent with a role for the pathway in modulating shell morphogenesis. We also knock down the predicted retinol dehydrogenase (RDH10) and find that it generally affects the same set of organs as the RA treatment and Cyp26 knockdown, further supporting a specific role for RA signaling in normal development of this embryo. Together, this is among the clearest cases known so far of developmental roles for RA signaling outside of chordates.

78-4 DARCY, HE*; ANDERSON, PSL; University of Illinois Urbana-Champaign; *hdarcy2@illinois.edu*

Do aquatic paedomorphs converge in both morphology and performance across phylogeny in Spelerpini Salamanders?

The lungless salamander tribe Spelerpini (Caudata:Plethodontidae) presents an opportunity to study the evolution of aquatic species that arose from terrestrial lineages in a phylogenetic context. Two of five genera (*Eurycea* and *Gyrinophilus*) include both aquatic and terrestrial species, the remainder are terrestrial. Additionally, five of the 16 aquatic *Eurycea* have troglodytic morphology characterized by reduced eyes and elongate skulls relative to surface-dwelling paeodomorphs. Here, we examine if the morphological changes associated with habitat shifts are convergent. We expect species to show convergence due to shared demands, informed by our understanding of hydrodynamics. Relative to terrestrial species, aquatics must deal with different fluid dynamics during locomotion and feeding as well as support gill arches. However, convergence may be in functional ability and not towards a single morphology, as in herbivorous lizards. To explore if salamanders follow the same pattern, we examined species of the tribe Spelerpini, capturing terrestrial and both aquatic morphologies. We gathered 3D microCT scan data from online repositories and by scanning specimens from the Field Museum of Natural History and the Illinois Natural History Survey. A geometric morphometric analysis of the overall head shape of adults from all three habitats captures gross morphological disparity We create a phylomorphospace to show differences between aquatic and terrestrial species and how phylogeny influences the evolution of aquatic groups. These results allow us to test whether aquatic taxa group are closer together in morphospace than their terrestrial sister groups or show parallel trajectories similar to what's been found in herbivorous lizards.

81-1 DAVID, K T*; FAN, Z; HALANYCH, C N; HALANYCH, K M; Auburn University; *kzd0038@auburn.edu*

Are Two Genomes Better Than One? Ploidy Correlates Species' Distributions in South American Frogs

Polyploids are organisms with more than two sets of homologous chromosomes. Polyploids may experience fitness advantages over their diploid counterparts due to increased benefits from effects such as heterosis (hybrid vigor) and gene redundancy. However, as polyploid individuals are formed spontaneously, matings between them are statistically unlikely. Additionally, if matings occur between polyploids and diploids the resulting offspring will be unviable, and as a result it is unlikely to see diploids and polyploids occurring sympatrically. To explore these ideas, we collected 5,660 observations from 75 species across the 5 South American frog genera with verified polyploid members. We recovered a negative correlation between polyploid and diploid occurrences as well as close spatial associations in polyploids across genera. Where diploids are distributed throughout South America, polyploid species are clustered by the Southeastern coast between 40-10oS. This region covers much of the Atlantic forest and shares considerable overlap with the South American dry diagonal. These biomes are hypothesized to have played important roles in maintaining biodiversity over evolutionary time, in addition to being modern day biodiversity "hot-spots”. We also recover some evidence to suggest the observed trend may be the result of more recent anthropogenic influences. Polyploids are positively correlated with areas of high pollution from agricultural runoff, whereas diploids are negatively correlated. Similarly, polyploids are more likely than diploids to occur in areas of high human impact such as croplands, pastures, and urbanized environments. Exploring genomic data from these genera may further elucidate evolutionary dynamics between diploids and polyploids and unlock the secrets of polyploid genomes.

P3-51 DAVIS, AC*; RYAN, MJ; University of Texas, Austin; *acdavis@utexas.edu*

Mirror mirror on the wall: Using mirror image scrutiny to probe phenotypic variation in an asexual-sexual fish system

Sex is a conundrum: the practice is costly – performing mating displays, increased parasite or disease exposure, producing males who do not reproduce – but common. All-female asexual populations escape these costs and thus their population increases exponentially compared to their sexual counterparts. This advantage is often short-lived as the lack of recombination leads to the rapid accumulation of deleterious mutations and a hastened extinction through genomic decay – a phenomenon referred to as Muller's rachet. Therefore, the primary theories as to the advantage of sexual reproduction stem from genetic recombination, which promotes genetic variation and facilitates new, beneficial phenotypic adaptations. However, these theories have long been countered by the fact that there are several asexual species who defy their mutation-predicted demise. This requires further investigation into the assumption that sexual species contain more phenotypic variation than asexual species. Gynogenetic asexual species – those who require sperm for stimulation of embryogenesis but do not integrate genetic information – provide a unique opportunity to study this question. Here we use the amazon molly, a gynogenetic fish originating from a hybridization event between a sailfin molly and Atlantic molly in Tampico, Mexico over 100,000 years ago. We used mirror image scrutiny to examine one aspect of variance in the cognitive phenotype of amazon and sailfin mollies. Other poeciliid fish show heritability of visual lateralization, implying a genetic component to this phenotype. No significant lateralization of eye use and no difference in overall variance occurred in sailfin and amazon mollies. This aspect of phenotypic variation is not predicted by the quantity of genetic variation in these species.

122-6 DAVIS, AL*; NIJHOUT, HF; JOHNSEN, S; Duke University; *al.davis@duke.edu*

Convergent evolution of ultra-black butterfly scales

Understanding animal coloration is important for investigating sexual selection, speciation, and animal signaling. Despite a growing number of papers investigating structural colors, the role of nanostructures in creating black color patches has largely been ignored. Recently, it has been shown that certain animals have evolved micro- or nano-structures responsible for creating matte-black surfaces with reflectances approaching the darkest synthetic materials. It has been shown that certain papilionid butterflies reflect as little as 0.2% of incident light, and this phenomenon is mediated by a honeycomb scale structure with melanin bound to the cuticle. It is unknown, however, if other ultra-black butterflies use this mechanism and whether we can derive general principles about the design of ultra-black materials from butterfly scales. We examined butterflies from four subfamilies and demonstrate that ultra-black color can be achieved through various scale geometries from honeycombs to rectangular holes. Using scanning electron microscopy, we found considerable interspecific variation in the geometry of the holes that does not mirror differences in reflectance. Furthermore, we verified with finite-difference time-domain modeling that the two structural features found consistently in ultra-black scales – steep ridges and expanded trabeculae – each reduce reflectance by up to 16-fold compared to scales lacking these features. Our results demonstrate that butterflies have convergently evolved ultra-black scales by creating a material with high internal surface area that minimizes surface reflection and increases the opportunity for absorption. We hypothesize that butterflies use these ultra-black wing patches to increase the perceived brightness of color signals for use in intra- and interspecific signals

109-3 DAVIS, RL*; CRISTOL, DA; HEIDINGER, BJ; KITTILSON, J; SWADDLE, JP; William & Mary, North Dakota State University , North Dakota State University ; *rldavis@email.wm.edu*

Does lifetime methylmercury exposure impact telomere length in various organs within the zebra finch?

Methylmercury (MeHg) is a highly toxic global pollutant that affects human, wildlife, and ecosystem health. This heavy metal compound can successfully cross the blood brain barrier and is capable of inducing oxidative stress in the formation of free radicals. Organs such as the liver and kidney, which play large roles in the excretory system, may be overwhelmed by the cellular damage caused by exposure to MeHg due to their functional role. Further understanding of how MeHg exposure alters organ performance at a cellular level is critical to understanding physiological effects this toxin can have on both humans and wildlife impacted by environmental contamination. Telomere length is a recently popularized biomarker of biological aging and cellular damage, influenced by both genetics and environment. To assess the impact of MeHg on eukaryotic organisms, we studied how lifetime exposure to dietary MeHg impacts telomere length in various tissues of the zebra finch (*Taeniopygia guttata*) at four time points after hatching from eggs. Using qPCR, we measured relative telomere lengths of brain, liver, kidney, heart, and red blood cells. We predicted that telomere length would decrease with the age of birds, and individuals exposed to an environmentally relevant level of dietary MeHg would have reduced telomere lengths compared to controls. Although blood telomere length clearly declined with age as predicted, we found that mercury-exposed birds had consistently longer telomere lengths in virtually all tissues and time points relative to controls. This latter result suggests the potential selection for longer telomeres within embryos (before egg hatching) and/or disruption of the telomerase pathway by MeHg.

P1-174 DAVIS, TJ*; WYNEKEN, J; Florida Atlantic University; *trevordavis2014@fau.edu*

Diving Behavior of Captive Reared Leatherback Turtles

Understanding diving behavior in marine organisms can shed light on important aspects of their biology such as ontogeny, foraging methods and migration. Studying diving behavior in pelagic species is particularly challenging because the animals are difficult to access. The leatherback turtle (*Dermochelys coriacea*) is a highly migratory species known for deep diving as adults. Juveniles are rarely seen outside of sporadic strandings and oceanic fisheries bycatch. Major data gaps persist about the nature and locations of juvenile nursery habitat, foraging behavior, and migratory movements in this vulnerable species. They are known as hatchlings, and as mature turtles with very little information about them, juveniles. This study measured diving behavior in the field by captive reared juveniles at different age and size points to assess potential habitat use. Husbandry can influence behavior, consequently we created a diet based upon analysis of pyrosomes, their natural food, raised turtles under conditions that mimic pelagic waters, then released small juvenile turtles at different ages and sizes at sea with time-depth recorders to assess diving behavior. Our results are consistent with the sole previous study of juvenile leatherback diving. The captive rearing techniques we developed for this pelagic species are important steps in filling long-standing data gaps. Captive animals are accessible and provide an avenue to gain initial understanding of where wild conspecifics may occur. Establishing baselines for how juvenile leatherbacks behave, particularly how their diving behavior changes with size, may lead us to locate wild turtle nursery habitats.

127-4 DAVIS-BERG, EC*; WILSON, BA; ARNOLD, C; ALMARIO-KOPP, D; Columbia College Chicago, Chicago, IL, Liberty Public Schools, Liberty, KS, Prairie State College, Chicago Heights, IL; *edavisberg@colum.edu*

Molluscs of Anderson County Prairies, a native tallgrass prairie in Eastern Kansas

Tallgrass prairies are plant and animal communities which once covered much of the United States. Anderson County Prairies (1450 acres) are located near Welda, KS; have very deep soils and higher rainfall than other prairies found further west in the state. The goal for this preserve is to maintain and enhance native biodiversity within an imperiled tallgrass prairie ecosystem. It has populations of the threatened plant, Mead's Milkweed and is owned by the Nature Conservancy. Here we present results of our periodic surveys since 2004 at Anderson County Prairies. These preserves consist of native tallgrass prairie with some plots which have been and are currently used for cattle pasture. We have found differences in gastropod diversity by land use with higher counts and different species at the non-pastured versus the pastured land. We combined soil analyses with the gastropod data to determine the source of these patterns.

P2-62 DE BRUIJN, R; KHOSHABA, E; LOPES, PC*; Chapman Univ.; *lopes@chapman.edu*

HPA-axis Functioning and Parental Care in Japanese Quail

Glucocorticoids (GCs) are thought to impact reproductive success, and ultimately fitness. In this study we focus specifically on the relationship between GCs and parental care. Captive bred Japanese quail do not show spontaneous parental care behavior, however previous research has shown that repeated or prolonged exposure to chicks can induce parental care in this species. Our aim was to investigate how the stress responsiveness of Japanese quail relates to parental care in control and induced birds of both sexes. Each bird underwent a hypothalamic-pituitary-adrenal (HPA) axis function test prior to any exposure to chicks. This test consists of obtaining baseline corticosterone levels, the response to a standardized stressor, and assessment of negative feedback efficacy through dexamethasone injection. Next, birds were randomly assigned to a control or treatment group. Treatment birds were exposed to chicks overnight in a small enclosure, while control birds were enclosed but not exposed to chicks. The following morning, all birds were exposed to a fresh set of chicks for 20-minutes to assess the success of induction, through measures of aggression and parental care behaviors. A final GC sample was obtained at the end of the 20 minutes to assess if exposure to novel chicks was perceived as stressful. Stress responsiveness was not correlated to parental care induction success, aggression, or parental care behavior. Additionally, exposure to novel chicks was not associated with an increase in GCs, suggesting exposure to chicks may not be perceived as stressful. Overall it appears that glucocorticoids are not causally related to parental care in captive bred Japanese quail. Our results provide further insights into the role GCs play in avian reproductive success.

P3-123 DE LA CRUZ, D; PERGOLA, D; SVENSSON, K; GELLMAN, E; ELLERBY, DJ*; Wellesley College; *dellerby@wellesley.edu*

Scaling of preferred swimming kinematics in bluegill sunfish (Lepomis macrochirus)

Organisms span a wide range of body sizes through ontogeny and across phylogeny. Size-related changes in performance and their implications for fitness have been the focus of considerable theoretical and empirical attention. Hill's isometric scaling model predicts that geometrically similar animals should run or swim at the same velocity with a propulsive frequency (*f*) that is proportional to mass $M^{-1/3}$. In contrast, a constructal theory developed by Bejar and Marden predicts that optimization for energy economy should lead to speed scaling with $M^{1/6}$ and *f* with $M^{-1/6}$. Fish are ideal for testing such models as many species span a wide range of sizes. Most previous fish swimming data were obtained at imposed velocities. This complicates the analysis of performance scaling as a benchmark for comparing propulsive kinematics across a range of sizes must be chosen e.g. maximum speed or a gait transition. Rather than imposing a velocity we allowed bluegill sunfish (*Lepomis macrochirus*) to swim in a static water volume. This enabled us to examine how preferred propulsive kinematics and speed scaled to size. Data were obtained from bluegill sunfish with masses ranging from 0.0003 to 0.192kg. Reynolds number for the smallest fish was >2600, placing all the data within the inertial range. The preferred swimming mode was body caudal fin propulsion. Tail beat frequency scaled with $M^{-0.315\pm0.031}$ (±95% confidence interval), not detectably different from Hill's predictions, but speed was not invariant and scaled with $M^{0.131\pm0.049}$ congruent with constructal theory. Deviations from model predictions likely arise from shifts in body shape and propulsive kinematics with size that violate assumptions of isometry, or underlying constraints based on the scaling of propulsive muscle properties.

S9-9 DE MEYER, J.*; VERHELST, P.; ADRIAENS, D.; University of Ghent; *jendmeye.demeyer@ugent.be*

The role of understanding the eel's morphology in stopping its decline

The European eel (*Anguilla anguilla*) is a critically endangered species, whose recruitment stocks have declined to nearly 1% compared to the late 70's. An amalgam of factors are responsible for this, amongst them climate change, migration barriers and habitat loss, pollution, non-native parasites and overfishing. While most studies related to eel conservation focus on these aspects, little attention is given to the eel's morphology in function of management measures. Worryingly, however, less than 50% of the currently installed management plans reach their goals, strongly indicating that more information is needed about the eel's morphology, ecology and behavior. In a series of studies, we evaluated how the eel's morphology is related to several ecological and behavioral factors, which provides new insights to install proper management plans. First, we showed that the eel's head shape is related to diet, with broader-headed eels being on a higher trophic level than narrow-headed eels. This difference in trophic position subsequently results in pollutant uptake variability: The higher an eel's position in the food chain, the more pollutants it will accumulate. This link between morphology, ecology and pollution highlights that pollution can affect eels differently. In another study, we evaluated whether broad- and narrow-headed eels differ in migration behavior. Finally, we evaluated burrowing behavior of the European eel and substrate preference. This latter study showed that eels may also suffer from hypoxia and sediment pollution and provides novel insights in how anthropogenic actions such as dredging and extraction of sand and gravel can impact the eel's behavior. The link between an eel's morphology, behavior and ecology therefore plays a pivotal role in maintaining the European eel population.

P2-61 DEAN, CR*; MENDONçA, MT; NAVARA, KJ; University of Georgia, Auburn University; *Crd72388@uga.edu*

Influences of chronic testosterone treatment on follicle growth rates in laying hens

Testosterone is a potent physiological modulator that is not only present in female birds, but plays a critical role in the process of ovulation and exerts programming influences on offspring when deposited into the egg yolk. Female birds respond to social triggers by changing concentrations of testosterone circulating in plasma, and these changing concentrations reach the developing oocyte, as concentrations of testosterone in egg yolk also change in response to the same triggers. Previous correlational studies have indicated that testosterone may also act to stimulate growth rates of ovarian follicles during rapid yolk deposition, an effect that could influence the deposition of other key yolk components (such as carotenoids, for example) as well as influence offspring sex. Yet whether testosterone can exert this effect has never been directly tested in an experimental context. We chronically elevated testosterone concentrations in laying hens using a once-daily application of 2.5% testosterone propionate cream (dissolved in Eucerin hand cream) to the comb. We collected eggs from the hens for 2 weeks, stained the yolk growth rings to quantify growth rates, and tested whether testosterone treatment influenced the rate of yolk growth. The testosterone cream significantly elevated testosterone concentrations for at least a 3h period each day, and hens receiving testosterone treatment laid fewer eggs over the two week period compared to hens treated with control cream. The influence of testosterone treatment on follicle growth rates will be discussed.

110-5 DEAN, MN*; BLUMER, M; GUALDA, E; CHAUMEL, J; SEIDEL, R; MARSAL, M; OMELON, S; MPIKG; *mason.dean@mpikg.mpg.de*

Cartilage canals in ray skeletons: Morphology, homology and putative role in mineralization

Although cartilage is typically described as avascular, this is not always true. In developing mammal/bird skeletons, particularly regions of endochondral ossification, hyaline cartilage is invested by a dense network of tubules called cartilage canals. These canals carry vasculature and undifferentiated mesenchymal cells, are lined by Type I collagen, nourish cartilage, and develop ossification centers. The canals and their vascular network are typically obliterated as animals age. We use a range of tissue characterization/visualization techniques to show that cartilaginous fishes (rays and relatives) possess cartilage canals which persist throughout life. Elasmobranch skeletons are comprised largely of a hyaline-like cartilage sheathed in mineralized geometric tiles (tesserae). Cartilage canals were observed in species from disparate groups, starting in the outer fibrous perichondrium, perforating the tesserae layer in large circular pores, and penetrating the uncalcified cartilage. As in other vertebrates, canals carried vasculature, were either unbranched or bifurcated blunt tubules, but never extended completely through skeletal elements. We demonstrate that Type I collagen lines canals, the same lining canals and forming the perichondrium in mammals/birds. Fluorescence microscopy of DAPI-stained samples suggests canals contain polyphosphates, stable apatite nucleation precursors for controlled distribution to mineralization sites. The morphology and tissue composition of elasmobranch cartilage canals argues for homology with mammal/bird canals and an ancient invasion of bone-like collagen (Type I) into cartilage (Type II collagen). However, anatomical location —heading from mineralized tissue not toward it— and the lack of endochondral ossification in elasmobranch cartilage points to alternative roles for these canals in more basal vertebrate skeletal types.

1-5 DEANGELIS, R/S*; RHODES, J/S; University of Texas, University of Illinois; *Ross.DeAngelis@gmail.com*

Nonapeptides Mediate Trade-Offs in Parental Care Strategy

Parental care represents a suite of distinct behaviors performed by parents to maximize fitness. Dynamic shifts in parental care strategies, such as between nest defense and direct provisioning of the offspring, are required in response to environmental variation. However, the neural mechanisms that mediate strategic parental decisions remain unknown. The anemonefish, Amphiprion ocellaris represents a burgeoning model in social neuroscience which is conducive to manipulating the environment while simultaneously measuring nest defense and direct egg provisioning. The goal of this study was to determine the extent to which arginine vasotocin (AVT) and isotocin (IT) signaling mediate decisions in parental care strategy. Specifically, we tested the hypotheses that AVT signaling is critical for aggressive egg defense and that IT signaling is critical for direct egg attendance. Blockade of IT, using an IT receptor antagonist, significantly reduced direct egg attendance, and increased levels of aggressive egg defense. Conversely, blockade of AVT reduced aggression and tended to increase egg care. Results demonstrate that male anemonefish alter their parental strategy with increased predation risk, and that IT and AVT signaling pathways are important neural substrates underlying decisional trade-offs, weighing heightened aggression against reduced egg attendance.

41-1 DEARBORN, DC*; WARREN, S; HAILER, F; Bates College, Lewiston, Maine and Cardiff University, Cardiff, UK, Bates College, Lewiston, Maine, Cardiff University, Cardiff, UK; *ddearbor@bates.edu*

Meta-analysis of Diversity and Selection at MHC Class II A Genes: the Neglected Half of the Vertebrate Immune System's Heterodimer

Genes of the vertebrate Major Histocompatibility Complex (MHC) defend against disease by making cell-surface proteins that display pathogen peptides to the immune system. Class II MHC proteins are heterodimers encoded by two different genes, but most studies of natural selection or sexual selection have focused only on the II B genes which encode the beta subunit. Here, we characterize MHC Class II A genes in Leach's storm-petrels and then synthesize data across vertebrate species to examine the evolutionary dynamics of these understudied II A genes. Leach's storm-petrels fit the dogma that II A genes are oligomorphic, but our meta-analysis shows that several other species have more than 40 II A alleles within a single population. In many species, allelic polymorphism was similar between II A and II B genes. Less surprisingly, the number of alleles found per species was positively related to sampling effort. However, there was an additional effect of taxonomic group, with fish having more alleles per species than mammals. We found no support for the hypothesis that gene duplication and proliferation of allelic diversity are negatively correlated, that is, that they could be alternative routes to generating a consistently high level of functional diversity in the alpha subunit of the protein. Analyses are in progress to compare signatures of selection at these two groups of genes, to test the hypothesis that II A should show more purifying selection in comparison to the common finding of diversifying selection at II B. Overall results will help determine whether studies of pathogen-mediated selection should continue to neglect the alpha subunit of the protein.

61-5 DEARING, MD; University of Utah, Salt Lake City, Utah ; *denise.dearing@utah.edu*

Mechanisms of detoxification in herbivorous mammals

Herbivores are confronted with potentially toxic diets at every meal, and therefore, must employ physiological, microbial or behavioral processes to circumvent dietary toxicity. This presentation reviews our physiological and behavioral work on this topic with a focus on the results from our studies on herbivorous rodents (and species). With respect to physiological mechanisms related to dietary specialization on toxic diets, we have 1) identified patterns in particular biotransformation ("detoxification") enzymes and quantified the energetic costs of some of these enzymes, 2) correlated gene copy number with dietary specialization, and 3) identified and characterized, at the molecular level, several novel P450s of importance. We are currently undertaking a genome resequencing approach to identify the physiological mechanisms that enable ingestion of toxic diets. On the behavioral front, we have documented unique feeding behaviors used by rodents to circumvent complex toxins in fruits. This work, which had its origins in the research group of Dr. William Karasov, advances our understanding of the mechanisms used by herbivorous mammals to deal with toxic diets.

S5-5 DEBAN, SM*; HOLZMAN, R; MULLER, UK; University of South Florida, Tel Aviv University, California State University Fresno; *umuller@csufresno.edu*

Suction feeding in small animals and carnivorous plants

Suction feeding has evolved independently in two highly disparate systems, aquatic vertebrates and carnivorous bladderworts. Incidentally, bladderworts are the smallest and fastest known suction feeders. Body size has profound effects on aquatic organismal function, including suction feeding. Surprisingly, plant suction feeders appear to have a lower size limit than animal suction feeders. We review how organisms' solutions to functional challenges is affected by their energy budget. Suction feeding at small size takes enormous energy investment, and as a consequence a minority of tiny organisms can afford to suction feed while most cannot. We address two hypotheses that emerge from this core idea: (1) autotrophic organisms (plants) can afford to pay the price that suction feeding requires because they obtain energy through photosynthesis and feed only for nutrients, and (2) heterotrophic organisms (animals) may not be able to suction feed at a comparable scale as plants due to the energetic costs, and furthermore, may be able to feed at the small end of their size range only by employing supplementary mechanisms such as ram and mouth protrusion. Here we review current knowledge of suction feeding to explore energetic and biomechanical performance limits for aquatic feeders based on morphology and kinematics. The performance outcomes of the complex interplay of size, energetics, and biomechanics can be used to produce a causal, predictive framework for suction feeders that is generalizable beyond the focal organisms.

P2-154 DEERY, SW*; HARO, D; GUNDERSON, A; Tulane University; *sdeery@tulane.edu*

Are Introduced Species More Plastic? A Comparison of the Heat-Hardening Capacity of Native and Non-Native Anolis Lizards

An important negative anthropogenic effect on the natural environment is the introduction of invasive species. One hypothesis to explain invasive species' success is that they have high levels of phenotypic plasticity, allowing them to adjust to new environments quickly and outcompete native species. Our study focused on heat hardening, a form of physiological plasticity defined as a short-term increase in heat tolerance as a result of exposure to high temperatures. We tested for differences in heat hardening ability in two species of lizard in the greater New Orleans area: the native *Anolis carolinensis* and the invasive *A. sagrei*, which is native to Cuba. To ascertain the magnitude and timing of heat hardening, we measured an initial critical thermal maximum value (CT_{max}) and then re-tested each lizard after either 2, 4 or 24 hours. We found that the native *A. carolinensis* undergoes significant heat hardening, especially at the 2 and 4 hour intervals. In contrast, the invasive *A. sagrei* does not undergo any heat hardening. Our results do not support the hypothesis that invasive species have greater phenotypic plasticity than sympatric native species. However, the results do suggest that the native species may be better able to adjust to warming than the invasive species in this system.

P1-242 DEHNERT, G/D*; KARASOV, W/H; LINDBORG, A/R; University of Wisconsin; *dehnert2@wisc.edu*

2,4-D impacts on whole-body cortisol response in larval fathead minnows

2,4-dichlorophenoxyacetic acid (2,4-D) is the active ingredient in many systemic herbicides used worldwide for selective weed control and eradication of invasive plants in agriculture and aquatic ecosystems; however, there is limited knowledge of its sublethal toxicity toward non-target organisms. Application practices of 2,4-D herbicides typically coincide with yearly freshwater fish spawning periods and because 2,4-D has been cited as an endocrine disrupting chemical, it is critical to understand how 2,4-D impacts fish offspring throughout their vulnerable development. Therefore, we tested the hypothesis that 2,4-D disrupts the normal functioning of the corticosteroid stress axis. We continuously exposed fathead minnows (*Pimephales promelas*) from fertilization through 8 weeks to environmentally relevant 2,4-D concentrations (0-2ppm) in DMA4®IVM (DMA4), a commercial formulation applied in the field. After 8 weeks of exposure, we did not observe any impacts on whole-body baseline cortisol concentrations for all treatment groups as compared to controls. In all treatment groups following a stress challenge (momentary removal from water), whole-body cortisol levels increased and peaked at 30 min, started a decline by 45 min, and returned to baseline by 180 min. However, fish exposed to 2,4-D had significantly lower whole-body peak cortisol concentrations as compared to controls at 30 min. The effects of 2,4-D exposure followed an inverse dose-response; exposure to 0ppm (control) peaked at 78ng/g, 0.05ppm peaked at 32 ng/g ($p<0.0001$), 0.50ppm peaked at 54ng/g ($p<0.001$) and 2.00ppm peaked at 64ng/g ($p>0.05$). The results indicate that the corticosteroid stress axis is a target for endocrine disruption by ecologically relevant concentrations of DMA4. Work supported by the WI Dept. of Natural Resources.

P2-206 DELAP, SJC*; RIMKUS, B; SHEHAJ, A; KONOW, N; UMass Lowell; *samuel_delap@student.uml.edu*

The effect of stimulation intensity on the range of optimal lengths of mouse hindlimb muscles

In vertebrate skeletal muscle, increases in the intensity of recruitment has been shown to result in a left-shift of the muscle's optimal length (L_o). However, it remains unclear how recruitment influences the width of the force-length relationship (the range of muscle and fiber lengths where near-maximal force can be produced) and thus the scope of its performance. We hypothesized that increased recruitment intensity (from twitch to tetanic stimuli) would result in a widening of the active force-length curve, and that this effect would be relatively insensitive to fiber type composition and architecture. We measured twitch and supramaximal tetanic force-length curves for the mouse tibialis anterior (TA), a fast-fibered, relatively pennate muscle, *in situ* (n=5) and soleus (SOL), a slow-fibered, relatively parallel muscle, *in vitro* (n=5). Near-optimal length range was measured from 90 - 100% P_o on the ascending force-length curve limb. The width of the active force-length curve was significantly ($p<0.01$) greater for tetanic than twitch stimulation for TA (20.8 ± 18.8%; mean ± S.E.M.) and SOL (43.4 ± 20.0%). This broadening of the range of fiber lengths where a muscle can produce near-optimal force is likely important when cadence and joint range-of-motion is increased to produce faster movement.

20-2 DELCLOS, PJ*; MEISEL, RP; University of Houston; *pdelclos@uh.edu*

Genotype-by-temperature effects on thermal preference in the house fly Musca domestica

Environmental temperature strongly affects the physiology of individuals, and so thermoregulation is vital for maximizing an individual's fitness. Ectotherms largely rely on two mechanisms to thermoregulate: while many ectotherms have a limited ability to ameliorate the effects of extreme temperature physiologically, many can behaviorally thermoregulate by moving to more ideal temperatures. As such, habitat use and behavioral patterns can be largely affected by thermal preference functions, and we can expect the development of thermal preferences to be dependent on a variety of genetic and environmental factors. For instance, biogeographical patterns among or within species can be expected to shape individual thermal preferences, allowing for avoidance of extreme temperatures or maximizing time spent at physiologically optimal ones. The house fly *Musca domestica* is an ideal system to examine how genotype and environment interact to shape thermal preferences. In replicated natural systems, we observe a latitudinal cline varying in the male-determining Y chromosome. Specifically, males from cooler, northern populations carry the male-determining gene on the Y chromosome, whereas those from warmer, southern populations carry the gene on the third chromosome. Here, we tested whether chromosomal location of the male-determining gene and rearing temperature affected both mean thermal preference and the breadth of thermal preference, measured as the coefficient of variation of individual-level thermal preference. The results obtained from this study will help elucidate the mechanisms shaping the observed latitudinal cline within *M. domestica*, as well as provide a greater understanding of how genotype and the environment interact to shape the development of physiologically relevant behaviors.

64-7 DeLeo, DM*; Bracken-Grissom, HD; Florida International University, Miami, FL; *dmdeleo14@gmail.com*
The Largest Migration on Earth: Sensory Adaptations of a Bioluminescent Deep-sea Vertical Migrator
Diel vertical migration of deep-sea animals represents the largest migration on our planet. Vertically migrating fauna are subjected to a variety of light fields among other environmental conditions that can have notable impacts on sensory mechanisms, including an organism's visual capabilities. Among deep-sea migrators are oplophorid shrimp, that vertically migrate 100s of meters (m) to feed in shallow waters at night. These species also have bioluminescent light organs called photophores that emit light during shallow-water migrations to aid in a dynamic form of camouflage known as counterillumination. The organs have recently been shown to contain opsins and other genes that infer light sensitivity. Knowledge regarding the impacts of this vertical migratory behavior, and fluctuating environmental conditions, on sensory system (visual/photophore) evolution is unknown. In this study, the oplophorid *Systellaspis debilis* was either collected pre-sunset (Day) from 450-750 m, or pre-dawn (Night) from 150-330 m to ensure sampling across the vertical distributional range. RNA was then extracted and sequenced from the light sensitive tissues (eyes/photophores). *De novo* transcriptomes were assembled discretely for each tissue from *Day* (n=5) and *Night* (n=5) specimens and analyzed to characterize opsin diversity, visual and light interaction genes within a phylogenetic context. Gene expression analyses were also conducted to quantify expression differences associated with the migration. This study sheds light on the visual system of a deep-sea bioluminescent shrimp and provides additional evidence for photophore light sensitivity. Our findings also suggest opsin coexpression and subsequent fluctuations in opsin expression may play an important role in diversifying the visual responses of this deep-sea vertical migrator.

P3-54 DENNIS, AJ*; TAYLOR, LA; PERTUIT, OR; CARSON, IR; SANGER, TJ; JOHNSON, MA; Trinity University, San Antonio, TX, Loyola University, Chicago; *adennis1@trinity.edu*
Oviposition site choice in the brown anole lizard, Anolis sagrei
An organism's embryonic environment can strongly impact its post-hatching phenotype. Therefore, in oviparous species, it is advantageous for females to choose nesting sites with conditions conducive to offspring development. In lizards that bury their eggs, the soil moisture, temperature, and depth of a nesting site can all impact offspring fitness; however, the extent to which each of these factors individually impacts female oviposition site choice is unclear. To quantify female nesting site conditions, we housed 35 wild-caught female brown anole (*Anolis sagrei*) lizards in small groups. In each cage, females had the choice of oviposition in one of two "nesting boxes" containing moist soil: the heated box, which was placed over a heating pad controlled by a thermostat, and the ambient box, which was maintained in ambient conditions. In both boxes, we measured soil moisture and depth for each nesting site, and calculated the temperature at each location where an egg was laid. We predicted that the females would avoid dangerously warm nesting sites near the bottom of the heated box, and that the depth of nesting sites would thus be more variable in the ambient box. Preliminary findings indicate that on average, oviposition sites were deeper and more moist in the ambient boxes than in the heated boxes. Half of the nesting sites were found in the ambient boxes, and half were found in the heated boxes. However, in both boxes, all oviposition sites were warmer than 26 °C and cooler than 33 °C, a range previous research has shown to result in viable anole hatchlings. These preliminary findings suggest that females avoided nesting site conditions likely to result in low fitness offspring.

103-7 DEORA, T*; BRUNTON, BW; AHMED, M; DANIEL, TL; University of Washington, Seattle, WA; *tanvid2@uw.edu*
Tactile active sensing and learning in plant-insect pollination
Sensory systems play a crucial role in the interaction between plants and their insect pollinators. The plants' visual and olfactory cues determine how insects navigate to flowers. As they approach flowers, moths unfurl their proboscis -- straw-like mouthparts that provide mechanosensory feedback as an additional sensory modality to localize and feed from the tiny nectary. Finding the tiny nectary is a challenging task, especially for crepuscular moths that hover over flowers while they feed in low light conditions. Despite the ecological importance of this behavior, few studies have focused on the role of tactile feedback in floral exploration. To examine the role of mechanosensory input, we developed an assay to track naive hawkmoths, *Manduca sexta* , as they fed from 3D-printed artificial flowers with different curvatures. Their geometry varied from naturally occurring trumpet-shaped flowers that are easy to exploit to completely flat flowers that are more challenging. We found that moths became increasingly efficient at locating the nectary over just a few visits, even on flowers that have only slight curvature. Using computer vision and machine learning methods, we tracked the proboscis as moths explored flower surfaces. We found that they repeatedly swept their proboscis across the flower surface in a manner reminiscent of rat whisking. In particular, they whisk along the radial direction of the flower, varying the angle of whisk as they explore the curvature of the flower. The number of whisks decreases as the moths learn to handle floral shapes. However, the number of whisks remains high for flat floral shapes. Our results show that moths use tactile sensing to actively explore flower surfaces and rapidly learn to handle novel flowers, enabling pollination.

93-5 DESIMONE, JG*; TOBALSKE, BW; BREUNER, CW; University of Montana, Missoula; *joely.desimone@umontana.edu*
Prepare or Escape?: The Behavioral, Physiological, and Hormonal Responses of a Facultative Migrant to Declining Food Availability
Migration is an evolved behavior that allows animals to take advantage of resources that are variable in time and/or space, and different migratory strategies depend on the predictability of resource variation. When food varies seasonally, obligate migrants can anticipate and prepare for migration, but it is unknown whether facultative migrants, whose movements are characteristically unpredictable in timing and destination, prepare for migration or rather escape when resources are low. Here we conducted a captive experiment to test two hypotheses about the behavioral and hormonal responses of a facultative migrant (Pine siskin; Spinus pinus) to declining food availability. Prepare Hypothesis: Siskins prepare for departure by increasing fuel stores, and elevations of baseline corticosterone (CORT) support increased locomotor activity. Escape Hypothesis: Siskins don't prepare for departure, body condition declines as food availability declines, and stress-related levels of CORT induce escape behavior. Throughout a 15-day experiment, we measured body composition using a Quantitative Magnetic Resonance machine, continuous locomotor activity using force perches, and baseline CORT levels among birds given ad libitum food or a slow decline, fast decline, or randomly changing amount of food. We found support for the Escape Hypothesis. Siskins' body condition declined as food declined, baseline CORT was elevated in birds with reduced lean mass, and birds showed marked increases in activity only when food availability was low. This work shows that facultative movements are physiologically distinct from seasonal, obligate migration, with food availability likely serving as a proximate cue, and birds showing little to no preparation for flight.

4-1 DIAL, TR*; LAUDER, GV; Harvard University;
trdial@gmail.com
Longer Development Provides First-Feeding Fish with the Jaw Kinematics to Escape Hydrodynamic Constraints
The viscous fluid environment experienced by small, first-feeding fishes resists the ability to produce suction. Compounding the negative effects of small size is the observation that larval fish are inherently immature – first relying on exogenous food sources at as soon as 5 days post fertilization (dpf). Here we compare first-feeding performance, kinematics and hydrodynamics of two species of freshwater fishes (zebrafish and guppy) that produce offspring at 5 ± 0.5 mm in length, but that undergo a 5-fold difference in developmental time (5 vs. 25 dpf, respectively). By manipulating water viscosity, we control the hydrodynamic regime, measured as Reynolds number (Re). Despite first-feeding occurring at similar levels of maturity for both species, capture success is significantly higher in guppies (90% vs. 20%). At any given Re, guppies successfully feed at five-times greater distances to prey (1.0 vs. 0.2 mm). Flow visualization reveals a bow wave is produced ahead of each approaching fish (zebrafish larvae ~ 0.2 mm; guppy offspring ~ 0.4 mm), limiting the predator's proximity to prey. During suction, zebrafish larvae generate flow fields that extend up to, but not beyond, the bow wave. Guppy offspring, likely due to their capacity to protrude the oral jaws, generate a suction field that extends well beyond the horizon of the bow wave, thus leading to successful prey capture from much greater distances. We argue that the difference in observed suction performance, having experimentally controlled for issues of scale, can be best explained by the degree of maturation achieved at the time of first-feeding.

50-8 DIAMOND, KM*; GRINER, JG; LAGARDE, R; PONTON, D; POWDER, KE; SCHOENFUSS, HL; WALKER, JA; BLOB, RW; Clemson Univ., Univ. Perpignan Via Domitia, Univ. La Réunion, St. Cloud State Univ., Univ. Southern Maine;
kmdiamo@g.clemson.edu
Linking morphology, performance, and behavior in the migration of stream goby fishes
Many animals migrate between habitats during their lifetime, encountering challenges to survival along the way. How do performance and body shape of animals help them to overcome the challenges of moving to a new habitat? To study which traits aid in migration, we examined a group of goby fishes that migrate from the ocean where young fish develop, to freshwater streams where fish live as adults. As fish migrate, they must overcome fast stream flows and piscivorous predators. Some species also ascend waterfalls to reach upstream habitats. We measured variation in performance and body shape across six species and two life stages to address two main questions. First, is there a point during migration when the strongest performing fish tend to move upstream? For this study, we collected climbing and escape response data from fishes throughout migrations. Climbing performance peaks 3-5 days after a migration begins, whereas escape performance remains constant throughout a migration. Second, can the predator regime to which fish are exposed influence the performance and/or body shape of fishes that survive to adulthood? We found that fishes living in regimes of consistent predation through their life cycle had low accelerations, but tall bodies, which may gape-limit their predators. Gobies that migrate to habitats with diminished predation showed the highest accelerations, as well as elongated posterior body shapes that may aid in producing higher thrust compared to fishes that live in predator-free habitats. These two analyses show how both morphology and performance relate to migratory behavior in fishes, potentially aiding management decisions for these taxa.

134-1 DIAZ, C*; TANIKAWA, A; LONG, JH; Vassar College, Poughkeepsie, NY, The University of Tokyo, Tokyo, JAPAN;
candido.diaz.jr@gmail.com
Some Spider Glue is Super: Modeling the Fast Spreading Bioadhesive That Defeats the Scale Shedding Defense of Moths
Common orb weaving spiders don't catch many moths. Moths evade capture by shedding the scales on their body and wings when those microstructures contact adhesive on the web. Orb weavers of the genus *Cyrtarachne* have evolved a solution that allows them to be moth-catching specialists: a low-viscosity glue that flows quickly under the moth's scales, gluing the scales and the web attached to them to the underlying cuticle before the scales can be shed. The glue from one species, *Cyrtarachne akirai*, is unremarkable when its properties are measured on glass, the classic substrate for bioadhesion test, but when this glue is tested on biomimetic substrates made from scaled moth wings, its behavior changes dramatically, spreading three times farther and required eight times the force to remove. We hypothesize that this 'hyper-wetting' is caused by the interaction of the glue and the topology of the scales. Using the physics of droplets, capillary forces, and pipe flow, we propose several spreading models. The models are tested and compared using the spreading behavior measured in the experimental situation. We propose that the glue of *Cyrtarachne* is of a particular viscosity that interacts with the scales favorably, creating a porous material, wicking water using capillary action. We tested this by comparing the spreading behavior of (1) variable viscosity liquids brought into contact with scaled surfaces and (2) glue droplets spread on surfaces of various porosities. Furthermore, our model predicts this 'hyper-wetting' leads to a separation of the water soluble components and glycoproteins within the droplet, leading to glue hardening. We used Raman spectroscopy to test this by measuring the distribution of salts and proteins along the radius of droplets spread on glass and moth wings.

60-7 DIAZ, K*; WANG, T; CHONG, B; DING, JL; LU, H; SARTORETTI, G; CHOSET, H; GOLDMAN, DI; Georgia Tech, Carnegie Mellon; *kelimar.diaz@gatech.edu*
Steering Behaviors of C. elegans Locomotion in Heterogeneous Environments
To successfully traverse dissipative environments, slithering animals (e.g., snakes, nematodes) must generate appropriate reaction forces to overcome friction. In yielding substrates (e.g., sand) where there is permanent deformation post interaction, maneuverability is essential in order to overcome heterogeneities. In particular, the mm-long nematode worm *C. elegans* is able to traverse complex environments by using complex steering behaviors without being hindered by heterogeneities. While this worm is the subject of thousands of studies, few have focused on how it performs and controls self-propulsion. To discover principles of nematode control and steering, we conducted experiments in fluid-filled PDMS lattice of posts. We induced escape responses in the lattices via localized thermal stimuli to *C. elegans* with a NIR laser diode (Mohammadi et al, 2013). When stimulated in the head, worms respond by escaping from the thermal source via backing up, self-deforming the body to an omega-like shape for reorientation (known as an omega turn) and moving forward, previously studied in detail in homogeneous environments. This was surprising as we expected omega turns in the lattice to be hindered by obstacles. However, performance was comparable to that on the surface of homogeneous agar plates. A geometric mechanics framework rationalized the observed biological turn dynamics. We posit omega turns are a robust way to turn and maneuver in complex environments. Inspired by the worms capabilities in heterogeneous environments, we developed a robot controller to enable maneuvering in lattices via a scheme which senses joint torques to enable shape-based compliance control.

77-5 DICHIERA, AM*; ESBAUGH, AJ; The University of Texas at Austin, Marine Science Institute; *angelina.dichiera@utexas.edu*
Red blood cell carbonic anhydrase dictates oxygen delivery rate in red drum (Sciaenops ocellatus)
In many teleosts, oxygen (O_2) and carbon dioxide (CO_2) transport are tightly coupled due to the presence of Root effect hemoglobin (Hb), whereby reduced pH dramatically reduces binding affinity and capacity for O_2. Previous work demonstrates that the evolution of Root effect Hb in teleosts coincided with the incorporation of high-activity carbonic anhydrase into the red blood cell (RBC CA). In most vertebrates, the role of RBC CA is thought to be exclusively related to CO_2 transport and excretion, as it is responsible for catalyzing the reversible dehydration/hydration reactions of CO_2. However, RBC CA also dictates the rate of red blood cell acidification during capillary transport, which impacts the relationship between Hb and O_2. Thus, high-activity RBC CA may be an important, previously unknown component of enhanced tissue O_2 delivery in teleosts that contain Root effect Hb. We have developed an *in vitro* assay using lysed red blood cells that allows us to manipulate RBC CA activity while simultaneously measuring O_2 offloading following CO_2 injection. 50% RBC CA inhibition significantly decreased oxygen delivery rate ($p = 0.0196$, Student's t-test) by 50%, demonstrating an almost 1:1 relationship between RBC CA activity and oxygen delivery rate. Additionally, we found that across a ten-fold range in body mass, the allometric scaling of RBC CA activity demonstrates a relationship much like that of standard and maximum metabolic rate. This suggests individuals with higher oxygen demands have higher RBC CA activity. Combined, our data suggest RBC CA dictates O_2 delivery in conjunction with its characteristic role in CO_2 excretion, expanding its function in respiratory gas exchange for the first time in almost 90 years.

18-8 DIEZ, A; MACDOUGALL-SHACKLETON, SA*; University of Western Ontario; *smacdou2@uwo.ca*
Neurogenesis and the development of neural sex differences in vocal control regions of songbirds
The brain regions that control the learning and production in birdsong exhibit some of the larges sex differences in the brain known in vertebrates, and are associated with sex differences in singing behaviour. Song learning takes place through multiple stages: an early sensory phase when song models are memorized, followed by a sensorimotor phase in which auditory feedback is used to modify song output through subsong, plastic song, to adult crystalized song. However, how patterns of neural development in the caudal motor path and anterior forebrain path change through these learning stages, and differ between the sexes, is little explored. We collected brains from 76 young male and female zebra finches *Taeniopygia guttata* over 4 stages of song learning. Using neurogenesis markers for cell division (PCNA), neuron migration (doublecortin), and mature neurons (NeuN) we demonstrate that there are sex-specific changes in neurogenesis over song development that differ between the two pathways of the vocal control circuit. The emergence of neural sex differences in this system thus emerge gradually and with specific trajectories depending on the brain region and its function.

33-7 DIJKSTRA, PD*; FIALKOWSKI, RJ; JANESKI, HM; AUFDEMBERGE, PM; Central Michigan University, Department of Biology, Mt. Pleasant, MI; *dijks1p@cmich.edu*
Sexual Selection Favors Phenotypic Plasticity in Body Coloration in a Polymorphic Cichlid Fish
Sexual selection by female mate choice is a major driving force in speciation. Since sexually selected male traits are often plastic, phenotypic plasticity and sexual selection are thought to jointly facilitate diversification when initially plastic sexual traits undergo genetic divergence by sexual selection. However, sexual selection may also promote plasticity. The resulting increased plasticity can then shield populations from the effects of selection, thereby inhibiting genetic divergence. We show that a combination of mate choice and male-male competition can maintain extreme phenotypic plasticity in a sexually selected male trait. In the cichlid species *Astatotilapia burtoni*, males are either blue or yellow. We show that adult males frequently change between yellow and blue color with blue males showing more color plasticity than yellow males. We then show that this remarkable plasticity in male color is directly influenced by the social environment: more males express yellow coloration in environments with more intense male-male competition. In staged combats, yellow males are more successful competitors than blue males, which could explain the higher proportion of yellow morphs in more competitive environments. However, females express a strong sexual preference for blue males. The trade-off between different components of sexual selection could promote the persistence of plastic coloration. Our work suggests that sexual selection may maintain phenotypic plasticity and potentially inhibit genetic diversification in sexually selected traits.

66-2 DILLON, ME*; PETRANEK, C; University of Wyoming; *Michael.Dillon@uwyo.edu*
Induced flow cools hovering bumble bees
The advent of flight likely facilitated insect dominance of the terrestrial biosphere. In particular, rapid wing oscillations made possible by asynchronous flight muscle allow small insects to hover and maneuver in nearly all habitats on earth. To keep an insect aloft, the flapping wings must produce a sufficiently strong downward draft of air to offset body weight; with this induced flow comes induced power, a major component of aerodynamic power required for flight. Although developments in technology and theory have facilitated rapid advances in our understanding of how insects meet the aerodynamic and energetic demands of flight, the thermal consequences of exposure to a swiftly moving self-generated column of air have received little attention. To better understand the role of induced flow in heat loss for flying insects, we focused on bumblebees, which must maintain high body temperatures to maintain flight necessary for feeding from flowers, and which have relatively high flapping frequencies (and therefore induced flows) to offset their large body size. We measured induced flows and associated wingbeat kinematics for bumblebees of different sizes hovering in free flight in front of artificial flowers. We then measured rates of heat loss from bumblebee models when exposed air streams of the same velocity and basic structure as those measured. As expected, induced flows depended strongly on body mass and wingtip velocity, ranging from 0.2 to nearly 2 m/s. These induced flows resulted in rapid cooling of non-metabolizing bumble bees: a heat balance model suggests that ignoring induced flow underestimates heat loss, leading to erroneous predictions of rapid overheating of hovering bumblebees. These findings likely apply broadly to hovering insects, with the effects of induced flow on heat balance predictably varying with wing kinematics and body size.

24-4 DIMOS, BA*; MACKNIGHT, NJ; BRANDT, M; MYDLARZ, LD; University of Texas at Arlington, University of the Virgin Islands; *bradford.dimos@uta.edu*

Differential Disease Susceptibility Between Closely Related Coral Species is due to Regulation of Mitochondrial Genes

Marine diseases affecting reef building corals have radically transformed Caribbean reef ecosystems where disease-resistant species are favored to persist. In order to respond to pathogenic microbes, corals possess a well-stocked innate immune arsenal, and recent evidence indicates that like model organisms their innate immune system is regulated in large part by mitochondrial function. To investigate inter-species disease resistance mechanisms, we conducted a disease transmission experiment of the coral disease White Plague (WP) between two closely related species of coral: *Orbicella faveolata*, and *Montastrea cavernosa*. We found that *O. faveolata* is highly susceptible to this disease while *M. cavernosa* appears to be completely resistant in a laboratory setting. By using a comparative transcriptomics approach, we find a set of genes that are differentially expressed during disease exposure in both species. This analysis highlights a largely conserved response to disease including oxidative bursts and mitochondrial dysfunction. By applying a network-based gene expression analysis we also identify sets of genes with species-biased expression patterns which indicate differential regulation of mitochondrial genes. Additionally, pathway level analysis shows that these species activate and repress alternate pathways and regulatory molecules when challenge with White Plague. Overall, this investigation indicates that differential regulation of mitochondrial processes and subsequent employment of alternative cellular pathways during disease exposure may underlie the divergent disease resistance phenotypes between these two species.

63-6 DINH, JP*; AZZA, J; PATEK, SN; Biology Department, Duke University; *jpd29@duke.edu*

Assessing Your Opponent: Snapping Shrimp Use Indirect Cues to Settle Ritualized Contests

Animal contests occur over indivisible resources. On average, winners have higher resource holding potential (RHP), which is a composite measure encompassing variables like size, physiological state, and skill. During mutual assessment, animals estimate the relative RHP of their opponent to decide when to leave contests. However, the cognitive mechanisms underlying mutual assessment are unknown. One possibility is that animals indirectly assess RHP by assessing a correlated but more accessible attribute - the heuristic attribute. Using a heuristic allows animals to make fast decisions with readily available information. Here, we show that snapping shrimp conduct mutual assessment using a heuristic based on recent contest success. In snapping shrimp, recent contest winners signify recent success through a chemical signal. We hypothesized that snapping shrimp use this signal as a heuristic attribute for RHP. To test our hypothesis, we collected 52 snapping shrimp from Beaufort, SC. We tested predictions made by different assessment types by staging 26 randomly matched contests and 24 RHP-matched contests. Then, we tested if snapping shrimp use a heuristic based on recent contest success by staging an additional 24 contests between individuals with recent contest experience - 12 between small recent winners and large recent losers and 12 between large recent winners and small recent losers. We found that snapping shrimp settle contests using mutual assessment and a heuristic based on recent contest success. This minimizes the energetic costs and risk of injury associated with gathering reliable information. Similar heuristic-based decision rules might be widespread across animals and behaviors because they facilitate quick decisions while minimizing costs.

P1-40 DIORIO, RD*; HOWEY, CAF; University of Scranton; *raymond.diorio@scranton.edu*

The Persistence of Resistance to Timber Rattlesnake Venom in Small Mammals

Some snakes use venom to subdue their prey, but some prey species have evolved resistance to these toxins. Previous studies have shown that small mammal populations that overlap with rattlesnake populations are more resistant to a venomous bite. Resistance to venom allows the animal an increased chance of survival but comes at the energetic cost of maintaining resistive proteins. Our objective was to investigate small mammal resistance to timber rattlesnake (*Crotalus horridus*) venom in areas where there are currently rattlesnakes (rattlesnake treatment) and in areas where rattlesnakes have been extirpated (extirpated treatment) to determine if resistance persists in the prey population once the predator is removed. Rattlesnake venom and small mammal blood samples were collected from a rattlesnake treatment site and small mammal blood samples were also collected from an adjacent, extirpated treatment site within the state of Pennsylvania. The initial activity of the venom proteins was determined using a Bradford Assay, and the venom activity in the presence of small mammal serum was determined using the EnzChek Gelatinase/Collagenase Assay Kit. We hypothesize that small mammals at the rattlesnake treatment site will have resistance to the venom while mammals at the extirpated treatment site will show no signs of resistance since creating and maintaining unnecessary resistive proteins expends energy which could be allocated elsewhere. This study will further our knowledge on how selective pressures within an environment alter the physiology of local organisms.

107-2 DIXON, G*; MATZ, MV; University of Texas at Austin; *grovesdixon@gmail.com*

Three-way genomic characterization (molecular evolution, gene expression, and DNA methylation) of the key morphological Innovation of the coral genus Acropora

The role of DNA methylation in invertebrate gene regulation, if any, remains uncertain. We examine this question using axial and radial polyps of the coral *Acropora millepora* as a model for gene regulation. These dimorphic polyp types represent a key innovation of the *Acropora* genus, giving it uniquely rapid growth rates and morphological diversity. We compare gene expression and DNA methylation between these two polyp types from two colonies, assaying gene expression using Tag-seq, and DNA methylation using three different methods: whole genome bisulfite sequencing (WGBS), Methylation binding domain sequencing (MBD-seq), and methylation-selective restriction enzymes (MethylRAD). We begin by benchmarking the three methylomic assays, showing that they provide similar readouts of DNA methylation. We then examine the covariation between methylation and transcription, both between polyp types and coral colonies. Finally, we take a molecular evolutionary approach to identify genes under positive selection in the lineage preceding *Acropora* diversification. We compare these genes with those showing differential expression and methylation between polyp types to identify candidate genes involved in the evolution of polyp dimorphism key innovation.

P2-244 DIXON, G*; MATZ, MV; University of Texas at Austin; *grovesdixon@gmail.com*

Generalized Environmental Stress Response in Acropora corals

Alarming decline of coral reefs has motivated efforts to understand mechanisms of coral resilience to stress. A popular method for addressing such ecological molecular questions is genome-wide gene expression profiling. However, in isolation, these studies cannot tell if gene regulation is specific to a particular stress or general to all coral stress. Here we investigate the hypothesis that the coral genus *Acropora* possess an Environmental Stress Response (ESR): a stereotyped gene expression response enacted under all forms of environmental stress. We analyze data from over 600 previously published and newly generated RNA-seq samples and show that transcriptional responses to diverse stressors are correlated, with core sets of up- and downregulated genes detectable for all but one (low pH) of the most commonly studied environmental stressors. Predictive models trained on one stress type are generally accurate in predicting stressed condition from other stressors. We conclude that a generalized Environmental Stress Response indeed exists in *Acropora*, and that careful consideration of this generality is important when linking genes to particular stresses such as temperature.

P1-128 DOBKOWSKI, KA*; FARR, D; Bates College, University of Southern California; *kdobkows@gmail.com*

What regulates the growth of bull kelp (Nereocystis luetkeana) recruits: competition for light or for space?

Competition is an important factor structuring where new bull kelp (*Nereocystis luetkeana*) recruits begin to grow in nearshore environments of the Salish Sea. This annual species must complete its entire life cycle, from swimming zoospore to mature, reproductive sporophyte, in a single growing season, often emerging into a subtidal "field" of perennial macroalgal species. However, it is not clear what the new bull kelp recruits are competing for: light or space. We established a subtidal field experiment near Point Caution, San Juan Island, Washington State to assess which of these factors is most important in determining where new bull kelp begin to grow. Our factorial design experiment included four treatments (n=5 each): cleared and shaded, cleared and unshaded, cleared and partially shaded (to control for the changes in flow attributable to the shade itself), and uncleared and unshaded. The "shades" were constructed of PVC pipe, plastic mesh, and window screen (fully shaded treatment only). Our data demonstrate that clearing and shading influence where new bull kelp begin to grow, indicating that there is likely some level of competition for both space and light. Fully "shaded" plots (either artificially with screens or naturally via interspecific macroalgal competitors) did not grow new bull kelp recruits while plots with some amount of light (cleared, partially shaded) and space did show growth of new individuals. This work helps to elucidate the possible effects of ecological succession in the nearshore subtidal and will help to inform future management and restoration efforts in a changing ocean.

P3-96 DOERR, H*; PALMISCIANO, M; FLANNERY, C; HAMILTON, S; LOGAN, C; Moss Landing Marine Labs and California State University - Monterey Bay, Moss Landing Marine Labs, Humboldt State University, California State University - Monterey Bay; *hdoerr@mlml.calstate.edu*

Effects of fluctuating vs. static exposure to hypoxia and high pCO2 on gill transcriptomes in three rockfish species

Anthropogenic climate change is predicted to trigger large-scale changes in ocean chemistry over the next few decades, resulting in ocean acidification and hypoxia. These conditions may be exacerbated in coastal upwelling regions where strong, seasonal increases in pCO_2 and hypoxia are expected to intensify under climate change. Nearshore rockfishes (genus *Sebastes*) may already be adapted to fluctuating upwelling environments along the West coast of North America, but intensified conditions could push individuals beyond their physiological thresholds. We examined the effects of fluctuating vs. static levels of combined high pCO_2 and low dissolved oxygen on gill transcriptomes of three juvenile rockfish congeners with different life histories: copper (*S. caurinus*), gopher (*S. carnatus*) and black rockfishes (*S. melanops*) to examine potential shifts in ion regulation and metabolism. Preliminary findings show significant changes in DGE of fishes treated under fluctuating-relaxation conditions vs. control. These differing expression profiles may reflect recovery from upwelling or acclimatory preparation for subsequent upwelling exposure. Species-specific and shared responses across species will be discussed in context of life history differences and possible mechanistic underpinnings of conserved physiological responses. Comparing rockfish responses to static vs. fluctuating conditions provides insights into effects of intensified upwelling in an ecologically and economically important group of marine fishes in North America.

P2-21 DOHR, SD*; HAHN, KH; TUFFIELD, MS; WARD, RS; BOYER, SL; Macalester College; *sdohr@macalester.edu*

New species of New Zealand Mite Harvestmen in the Genus Aoraki (Arachnida, Opiliones, Cyphophthalmi, Pettalidae)

Putative novel species of mite harvestmen in the genus *Aoraki*, one of three pettalid genera in New Zealand, are investigated using morphology and genetic data. Two new species are identified using scanning electron microscopy (SEM). A third novel species is suspected based on morphology. Images of the anal plate and fourth tarsus of male individuals were compared to images of described *Aoraki* specimens in published literature. Specimens were sequenced for two mitochondrial loci: cytochrome oxidase 1 (COI) and 16S. A phylogeny based on these data supports the monophyly of two new species, each sister to its closest geographic relative. Morphological, phylogenetic, and geographic findings support the presence of these two novel species within the genus. Although much of the diversity in this genus is thought to be known, questions remain regarding potential undescribed species and their relationships to described species. Thus, further investigation of the diversity and phylogenetic relationships within the genus *Aoraki* is required.

32-2 DOLAN, JE*; MUSIAL, NA; HAMMOND, KA; UC, Riverside; *jdola001@ucr.edu*
Energy expenditure of cage activity versus wheel running in deer mice
In the lab, mice are often kept in cages seemingly without any way to exercise, thus restricting their voluntary energy expenditure. Because of this their daily energy expenditure in a cage may grossly underestimate the amount of energy they would expend in the wild. We have been interested in understanding how much energy mice would expend if they could be more active in cages. In recent laboratory experiments we have included wheel access for the deer mice to allow them to have that voluntary component. However, deer mice in cages without wheels often jump up and down and do backflips in their cages. The energy exerted in these behaviors, is non measurable and could be equal to that of wheel running. In order to determine if this is the case, daily oxygen consumption (as a proxy for daily energy expenditure) was measured in mice without and then with wheels. In addition, food intake was measured in each mouse before and after they were given wheels. Measurement without wheel access was always done first because introduction of a wheel could affect future activity. Mass did not differ between treatments and was not a significant covariate for statistical tests. Using age as a covariate, an ANCOVA showed that mice with wheels ate 15% more food that those without wheels ($p = 0.008$; Age was significant at $p = 0.025$). Likewise mice with wheels expended 34% more energy than those without wheels ($p=0.0002$). Also, the average maximal 10 minutes of oxygen consumption was higher in mice with wheel access ($p=0.006$) and the minimal 10 minutes of oxygen consumption was higher in mice with wheels ($p=0.020$). In conclusion, this study suggests that mice can expend more energy if given access to a wheel. The back flips and jumping that occurs in the cage overall leads to less energy expended. Inclusion of a wheel should be considered in future experiments with the goal of testing the limits of energy expenditure.

39-1 DOLPHIN, KE*; FISCHER, EK; HUGHES, KA; HOKE, KL; Colorado State University, Stanford University, Florida State University; *kedolphin@gmail.com*
What in your right mind would make you do that!? Identifying neural components of courtship decisions
Animals can adjust mating strategies flexibly by integrating information about acute contexts. To understand constraints on animal decision making, we are characterizing mechanisms by which external sensory and internal physiological cues guide behaviors. We attempted to open the black box of mechanisms controlling behavioral flexibility by identifying neurons activated while male Trinidadian guppies (*Poecilia reticulata*) rapidly decide between two mating tactics. We used a selective RNA-seq method to compare transcripts expressed in recently activated neurons in males exposed to reproductive and asocial contexts. Our results characterize transcripts that vary in expression when males decide between alternative mating tactics. Follow-up experiments will analyze region-specific expression to identify the neural substrates of reproductive decisions.

P3-247 DONATELLI, CM*; SANDERS, E; POLAVARAM, T; TONER, M; PFIEFFENBERGER, J; TYTELL, ED; University of Ottawa, Ottawa, Ontario, Tufts University, Medford, MA; *cassandra.donatelli@gmail.com*
A Thousand Fibers: The Functional Morphology of Fish Skin Collagen Fibers
Fish skin is a complex biomaterial containing collagen fibers that wrap around the body in half a helix pattern on each side. Various researchers have hypothesized functions for the fibers, but we have relatively little data on their functional role during swimming or their distribution across species. Past studies showed that fiber angle and the material properties of the skin vary along the length of the fish. However, they have not examined the correlation between the angle of the collagen fibers and the material properties of the fish skin. Engineering and model studies suggest that there are two critical angles in fiber wound tubes. Fibers at 45 degrees maximize torsional stiffness, while fibers at 55 degrees resist buckling and prevent changes in length due to internal pressure. In this study, we quantified collagen fiber angle in eight species of fishes with known swimming kinematics and created physical models to determine the passive effects of skin fiber on the mechanics of the body. We found that collagen fiber angles in these fishes generally fall between 45 and 55 degrees. Change in angle along the length of the body is correlated with species and habitat. Body twisting during swimming and torsional stiffness also correlate with fiber angle, though the sign of that correlation differs between groups from different habitats. We also found that there is a nonlinear relationship between fiber angle and bending stiffness in our physical models. These results show that skin fiber angles may have a complex but important role in the passive mechanical properties of fish bodies, and may ultimately affect swimming performance.

128-6 DORNHAUS, A*; KELEMEN, EP; RIVERA, MD; University of Arizona, York University, University of Illinois at Urbana-Champaign; *dornhaus@email.arizona.edu*
Designed for Comparative Advantage: Body size, Division of Labor, and the Benefits of Worse Workers in Bumble Bees
In many complex systems, individual units show diversity in form and function. Often this is in the service of division of labor, such that specialized units perform particularly well in their tasks; in other cases, variation among individuals seems like random noise. Here we introduce another group-level benefit of diversity coupled with division of labor, based on the trade-off between unit costs and output. In social insect colonies, individual workers perform different tasks such as brood care, foraging, and others. Workers often differ in many traits, including body size. In bumble bees, worker body size variation is substantial (3-10fold within colonies). Overall, we show that smaller workers, while specializing on brood care over foraging, do not perform either task particularly well, and specifically are worse than larger workers. However, the optimal body size, taking into account production costs for workers, is different for brood care and foraging. Smaller workers perform less badly at brood care than they do at foraging, giving them a comparative advantage in this task, and generating a colony-level benefit of producing workers that differ in body size. We demonstrate theoretically that given a certain amount of resources to invest in producing workers, colonies do better by investing in a diversity of worker sizes, and that colony performance is driven more by the size of the largest workers than the average body size. We also show that how bumble bee colonies make these investment decisions under high or low food availability is consistent with this hypothesis. Our results indicate that benefits of worker diversity are varied and not restricted to producing highly efficient but narrow specialists.

108-4 DOWNS, AM*; KOLPAS, A; BLOCK, BA; FISH, FE; West Chester University, Stanford University; *ad846650@wcupa.edu*
Turning Performance by Bluefin Tuna: Novel Mechanism for Rapid Maneuvers with a Rigid Body
Scombrid fishes are known to attain exceptional swimming speeds due to their thunniform, lift-based propulsion, large muscle mass, and a rigid fusiform body shape. A rigid body should restrict maneuverability in regard to turn radius and turn rate for aquatic organisms. To test if turning maneuvers by the rigid-bodied Bluefin tuna (*Thunnus orientalis*) are constrained, captive animals were video recorded from above as the animals routinely swam around a large circular tank or during feeding bouts. The turning performance was observed and classified into three different types of turns: 1) Glide turn, where the tuna uses the caudal fin as a rudder to passively move through the turn, 2) Powered turn, where the animal uses continuous symmetrical strokes of the caudal fin to propel itself through the turn, and 3) Ratchet turn, where the overall global turn is completed by a series of small local turns by asymmetrical stokes of the caudal fin. Individual points of the rostrum, peduncle, and tip of the caudal fin were tracked and analyzed using Tracker software. Frame-by-frame analysis showed that the glide turn had the fastest turn rate at all three points tracked, with a maximum of 224.1 deg/sec. During the ratchet turn, the rostrum exhibited a minimum global turn radius of 0.43 m. However, the local turn radii were only 18.6% of the global ratchet turn. The minimum turn radii ranged from 0.38 m to 1.62 m as a proportion of body length. Compared to the performance of other swimmers, Bluefin tuna are not constrained in turning performance due to the rigid body because of flexibility of the tail and specialized turning behaviors.

41-5 DOWNS, CJ*; SCHOENLE, LA; MARTIN, LB; SUNY College of Environmental Science & Forestry and Hamilton College , Hamilton College and University of South Florida, University of South Florida; *cjdowns@esf.edu*
How Does Microbicidal Capacity of Serum Scale with Body Mass in Mammals?
Body mass is likely to affect the way organisms evolve, develop, and use immune defenses. We investigated how variation in microbicidal capacity of serum scales with body mass among >175 species of terrestrial mammals spanning 7-orders of magnitude in size. Specifically, we tested whether predictions derived from existing theories (e.g., Protecton Theory) best-predicted slope coefficient of the microbiocidal capacity of serum collected from healthy, zoo-housed adult animals against *Escherichia coli* (EC). We measured microbicidal capacity at 12 serum dilutions and fit a non-linear regression to the data to describe the full shape of the microbicidal capacity. We used the curve parameters as the response variables in our scaling models. A preliminary analysis showed that phylogeny explained less than 17% of the variation of each curve parameters for EC. We then used a mixed-effects, multivariable model to simultaneously estimate the interspecific scaling exponents (b) for the curve parameters. Our response variables had repeatabilities of 1-80%. Low repeatability for some parameters was a statistical artifact partially explained by species that switched from 100% killing to 0% at a dilution close to our least concentration samples. Large species needed less concentrated serum to kill 50% of EC ($b = -0.22$), had higher maximal killing capacities ($b = 0.52$), and had steeper killing slopes than small species ($b = 8.0$). These results indicate that the strength of constitutive microbicidal capacity increased disproportionately with body mass. They are consistent with the performance-safety hypothesis, but additional analyses of other forms of microbicidal activity are ongoing.

68-7 DREW, JA*; MCKEON, MG; State University of New York College of Environmental Science and Forestry, Columbia University; *jadrew@esf.edu*
Shark-based tourism presents opportunities for facultative dietary shift in coral reef fish
Tourism represents an important opportunity to provide sustainable funding for many ecosystems, including marine systems. Tourism that is reliant on aggregating predator species in a specific area using food provisioning raises questions about the long-term ecological impacts to the ecosystem at large? Here, using opportunistically collected video footage, we document that 61 different species of fish across 16 families are consuming tuna flesh at two separate shark dive tourist operations in the Republic of Fiji. Of these fish, we have resolved 55 to species level. Notably, 35 (63%) of the identified species we observed consuming tuna flesh were from ostensibly non-piscivorous fishes, including four Acanthuridae species, a group primarily recognized as browsers or grazers of algae and epibenthic detritus. Our results indicate that shark diving is having a direct impact on species other than sharks and that many species are facultatively expanding their trophic niches to accommodate the hyperabundance of resources provided by ecotourism.

11-7 DROWN, RM*; ANDERSON, CV; University of South Dakota; *rachel.drown@coyotes.usd.edu*
Does individual performance influence antipredator behavioral strategy choice in chameleons?
Animals are under a constant selective pressure to avoid predation. They are often equipped with several anti-predatory behavior strategies based on their morphology, physiology and behavior. Maintaining a suite of behaviors allows animals to choose strategies that may be better equipped for particular environments and types of predators. Chameleons are a particularly interesting model to study the relationship between these adaptations because of how they have specialized to their environment. These animals have adapted traits that are well-suited for a largely arboreal lifestyle, but as a consequence, produce relatively slow locomotion. As a result, they may need to rely on alternative strategies that do not hinge on speed. Chameleons may still choose to flee to avoid predation, but they may also undergo cryptic color changes or behave aggressively. Previous work also suggests that their antipredator strategies vary significantly with body size and habitat type. We examined the functional basis for variation in antipredator behavioral decisions in veiled chameleons (*Chamaeleo calyptratus*) of small, medium, and large size classes. Individuals underwent a series of mock predation trials and their behaviors were classified into "fleeing," "crypsis", "aggression", or "other." We then quantified the performance capacities underlying each strategy by measuring sprint speed and acceleration for fleeing, degree of color change for crypsis, and bite force for aggression. Our results indicate that certain performance capacities across size classes influence which strategy is chosen during mock predation trials. The importance of the functional capacity to perform each behavior in antipredator behavior decision making provides considerable insight into the relationship between behavior, environment, and physiology.

P1-144 DRUMMOND, JA*; BRANDAO, PB; BRANDT, ME; EGAN, SP; CORREA, AMS; Rice University, Houston TX, University of the Virgin Islands, USVI; *jenn@rice.edu*

Environmental DNA captures shifts in Caribbean fish communities associated with the invasive seagrass Halophila stipulacea

Native Caribbean seagrasses, like coral reefs, are able to support diverse and abundant marine organisms in part because their wide range of physical characteristics and epibiotic communities generates varied food and shelter resources. Invasion of a native seagrass bed by an exotic seagrass therefore has great potential to disrupt existing marine communities by replacing or altering vital habitats. The seagrass *Halophila stipulacea* spread to the Mediterranean Sea from the Indian Ocean over a century ago, but has only recently (2002) been introduced to the Caribbean region. Little is known about the specific changes made to Caribbean communities by the arrival of this seagrass. This study uses environmental DNA techniques to characterize fish and other communities associated with native versus invasive seagrass habitats in St. Thomas, U.S. Virgin Islands, where *H. stipulacea* was first observed in 2012. Our primary hypothesis is that the diversity and abundance of fish and other organisms will decline in heavily-invaded areas. However, there are also indications from prior research that alterations may be counterintuitive and/or complex; shifts in habitat utilization by different fish feeding guilds may arise, rather than substantial declines in standard diversity metrics. The environmental DNA approach applied here complements past and upcoming traditional trap-based studies, and provides a crucial level of detail about fish communities in native and invaded seagrass habitats.

P3-13 DUBOIS, S; RAHMAN, A.F; RAHMAN, MD*; Department of Biology, University of Texas Rio Grande , School of Earth, Environmental, and Marine Sciences, , University of Texas Rio Grande; *md.rahman@utrgv.edu*

Investigating Environmental Contamination in the Lower Laguna Madre Through CYP1A Expression in Pinfish Liver

Debris slowly degrades in water into smaller pieces known as microplastics. Microplastics and other man-made substances are harmful in marine and coastal environments, and adversely impact health of aquatic organisms. Cytochrome P450 1A (CYP1A) is a monooxygenase enzyme and commonly used as a toxicological biomarker in tetrapod and teleost fishes. Pinfish *Lagodon rhomboides* is a highly abundant saltwater species commonly found in the Atlantic coast and Gulf of Mexico. In our study, pinfish were collected by angling from five sampling sites in the Lower Laguna Madre. Fish liver and stomach were collected and preserved in paraformaldehyde for biochemical and immunohistochemical analyses. Three fish were also kept in the laboratory aquariums for three months to serve as control before their liver and stomach were removed. Stomach and intestines were examined under microscope for presence of microplastics. CYP1A expression was determined by immunohistochemical analysis to compare the environmental contaminant level in pinfish liver tissues. Plastic can be found floating on the surface of the water, laying on the beaches and also in the coastline of both South Padre Island and Port Isabel, but microplastics were not found in stomach or intestines of pinfish collected from Lower Laguna Madre. Significantly higher signals of hepatic CYP1A were observed in pinfish collected from Lower Laguna Madre compared to fish in laboratory condition. Collectively, our results suggest that other environmental pollutants, not microplastics, present in the Lower Laguna Madre are impacting the health of marine organisms as seen in the high expression of CYP1A in pinfish liver.

P2-131 DUGAN, Z; VAN BREUGEL, F*; University of Nevada, Reno; *zduganashlock@gmail.com*

Temporal Memory Modulates Olfactory Search in Drosophila

Efficiently searching natural environments for food, mates, and nesting sites is critical to the survival of all moving organisms. Since most habitats are a mixture of patches that have variable amounts of food, animals must decide when to leave a patch in search of a new one. This decision making process requires that animals either utilize spatial and temporal memory or use a simple rule of thumb. How this type of information is encoded in the brain, and how these decisions are made, is a major open question in neuroethology. The fruit fly, Drosophila melanogaster, is uniquely suited for answering these questions because (a) they exhibit the capacity for temporal/spatial memory; (b) genetic tools make it possible to remotely activate and inactivate small subsets of neurons; and (c) it is possible to observe their behavior in relatively large but controlled environments. To examine the role of temporal/spatial memory in flies' search behavior, we placed three odor emitting, but food-barren, patches in a 60x60x120 cm^2 wind tunnel. We selected ethanol for the odor because it is highly attractive to flies in search of fermenting fruit. We released six flies into the wind tunnel at a time, and used a machine vision system to track their activity on each of the three patches over the course of 14 hours. Each fly was labeled with a different color of nail polish so that we could keep track of their identities over time, and across patches. Our results indicate that flies spend more time searching for food on their first odor patch. Furthermore, we found that flies spend more time searching on patch if more time has elapsed since their last visit to a patch (p=0.01). Together, these behavioral trends show that flies use temporal memory to make decisions. More research is needed to determine the details of their foraging algorithm, and the exact role that their neurons play in their memory.

3-2 DUMAN, A*; AZIZI, E; University of California, Irvine; *aduman@uci.edu*

Olympians of Controlled Deceleration: Cane Toads Stick the Landing Across Surface Stiffness

Moving in the real world requires that animals – including humans – effectively maneuver obstacles and navigate terrain with complex properties. Variation in the mechanical properties of the environment, like surface compliance, can alter impact forces and energies that an animal must absorb and dissipate. *Rhinella marina*, the cane toad, is already a model species for understanding controlled decelerations which makes it an ideal organism for exploring the effects of surface compliance and damping on its locomotion. Using inverse dynamics during landing in toads (n = 8) we generated joint-level work across four compliance treatments (0, 2.5, 5 and 10 mm BW^{-1}) and two platform masses (123 and 725 g). We furthered our initial analyses by collecting muscle activity of the *palmaris longus, anconeus, pectoralis,* and *deltoideus* throughout 186 jumps from five toads landing on 0, 2.5 and 5 mm BW^{-1} compliance treatments. Our results suggest muscles at the shoulder are more involved as compliance increases and as surface damping increases while the elbow exhibits the inverse trend. We also found preparatory activation of forelimb muscles in a proximal-to-distal pattern which corresponds to observed shoulder protraction followed by elbow and wrist extension. Additionally, all four muscles investigated exhibit activity after impact providing support for our inverse dynamics findings across each joint. This work can help us understand how animals coordinate robust behaviors in the face of environmental variation.

39-2 DUNCAN, CM*; CHRISTIAN, H; CHMURA, H; BUCK, CL; BARNES, BM; LOUDON, A; WILLIAMS, C; Univ. of Alaska Fairbanks, Fairbanks, AK, Univ. of Oxford, Oxford, UK, Northern Arizona Univ., Flagstaff, AZ, Univ. of Manchester, Manchester, UK; *cmduncan3@alaska.edu*

Ultrastructural Changes of Reproductive Neuroendocrine and Endocrine Responding Cells Associated with Circannual Timing in a Hibernating Mammal

Reproductive timing strongly influences the fitness of individuals. While most vertebrates rely on changes in daylength to induce seasonal reproduction, the arctic ground squirrel (AGS) naturally undergoes reproductive maturity in a photoperiod-independent manner. In addition, male AGS spontaneously activate their reproductive axis during hibernation, but the timing of hibernation and reproduction are sensitive to external cues. We hypothesize that changes in pars tuberalis (PT) thyrotroph morphology underlie hibernation and reproductive phenology in a photoperiod-independent manner. We used electron microscopy to examine, define, and measure ultrastructural remodeling in PT thyrotroph cells, hypothalamic tanycytes, and pars distalis (PD) gonadotroph cells, as the AGS transitioned from hibernating to reproductively active. We also quantified how cell morphology corresponds with measures of reproductive axis outputs, including changes in sex steroid gene expression and development in the gonads, and plasma steroid concentrations. Finally, we examined mechanisms that underlie plasticity in hibernation and reproduction phenology, and whether hypothalamic and PD activity can become dissociated from the PT signaling pathway by assessing cellular remodeling in males placed in a 30&degC room during mid-winter, which induces early reproductive onset. This basic system-level investigation of reproductive control mechanisms may inform researchers on how cell ultrastructure influences connections between neuroendocrine circuits and the role these play in triggering puberty onset.

P1-60 DUNN, PO*; HENSCHEN, A; WHITTINGHAM, LA; University of Wisconsin-Milwaukee, University of Memphis; *pdunn@uwm.edu*

Gene Expression and Reliable Signaling in a Plumage Ornament

Birds have a spectacular array of brightly colored ornaments that has long been studied in terms of mate choice. However, little is known about the genetic basis of colorful ornaments, other than in a handful of genes that produce pigments. In this study we constructed a de novo transcriptome to examine gene expression in the 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 a large variety of genes, including those related to immunity and oxidative stress, are differentially expressed in the mask of males, compared with feathers from areas of the plumage that are not sexually selected. These results point to mechanisms that allow ornaments to become revealing indicators of male quality.

P2-121 DUNTON, AD*; BAUTISTA, NM; CRESPEL, A; BURGGREN, WW; University of North Texas; *aliciadunton@my.unt.edu*

Transgenerational Neurological and Behavioral Effects of Combined Exposure to Crude Oil and Hypoxia

Exposure to crude oil and hypoxia in fishes affects physiological processes and leads to behavioral impairment such as increased anxiety and aggression. The effects of the combination of hypoxia and oil parental exposures on the F1 generation remain poorly understood. We quantified behavioral effects in larval zebrafish offspring of parents exposed to: 1) Control (normoxia, control diet); 2) Hypoxia (~60% air saturation, control diet); 3) Oil (normoxia, oil-loaded diet); and 4) Hypoxia+Oil (~60% air saturation, oil-loaded diet). After exposure, all adults were bred at either 0 or 30 days post exposure (dpe) to determine if transgenerational effects wash in or out over time. Additionally, brain morphology of exposed parents was assessed. Tests of sociability and boldness were performed in clean, normoxic water on F1 larvae 19 days post fertilization. Sociability tests examined swimming speed, distance traveled, and time spent close to conspecifics. Boldness was assessed by introducing a focal fish to a novel object and determining time and distance spent around the object. Adult brains dissected at 0 and 30 days dpe showed differences in lobe volume between treatments. Social behavior such as time spent near conspecifics of F1 larvae from parents exposed to hypoxia, oil, and hypoxia+oil, was decreased up to ~75% compared to control F1 groups. However, time to initially locate conspecifics did not differ. Because the brain plays a vital role in regulating behavior, future and ongoing experiments are aimed at understanding the mechanistic underpinnings of altered behavior, its transgenerational transfer, and fitness consequences.

P2-145 DUONG, P; RILEY, GF; ROMERO, MF; PIERMARINI, PM; GILLEN, CM*; Kenyon College, Gambier, OH, Mayo Clinic, Rochester, MN, The Ohio State University; *gillenc@kenyon.edu*

Immunohistochemical Localization of aeCCC2 in Aedes aegypti Larvae

The genome of *Aedes aegypti* contains three genes with sequence similarity to the sodium-dependent cation-chloride cotransporters (CCCs). AeNKCC1 groups in a clade with Drosophila ncc69, which is a canonical Na-K-Cl cotransporter and participates in potassium secretion by Malpighian tubules. AeCCC2 and aeCCC3 group with Drosophila ncc83 in an insect-specific CCC clade. Previous work showed that transcripts of aeCCC3 are highly expressed in the anal papillae of larvae. AeCCC2 is most highly expressed in hindgut of adult mosquitos, but also found in Malpighian tubules of larvae and adults. We hypothesize that aeCCC2 contributes to salt transport across *Aedes aegypti* epithelia. To assess cellular localization of aeCCC2, we developed polyclonal antibodies against isoform-specific peptides from the C-terminal cytoplasmic region of aeCCC2 and aeCCC3. The specificity of the antibodies was confirmed by reactivity to oocytes expressing either aeCCC2 or aeCCC3. We performed immunohistochemistry on whole-mounted larval and adult *Aedes aegypti* gut tissue, and visualized Alexa 488-coupled secondary antibody by confocal microscopy. In both larvae and adults, the aeCCC2 antibody stained Malpighian tubules and hindgut. Staining of the larval Malpighian tubule was primarily on the basolateral membrane of principal cells. In adult females, aeCCC2 stained midgut and hindgut, with detectable but lower staining on the Malpighian tubules. The ovaries of adult females were also stained. These data support the hypothesis that aeCCC2 contributes to transepithelial salt transport, but further work is needed to understand its specific roles. Funding: NSF-IOS-1557230, Kenyon College, and State and Federal funds appropriated to the Ohio Agricultural Research and Development Center of The Ohio State University.

P1-161 DUPIN, MK*; DAHLIN, CR; WRIGHT, TF; New Mexico State University, The University of Pittsburgh at Johnstown; *mdupin@nmsu.edu*

¬¬¬Assessment of Population Size and Dialect Presence in the Endangered Yellow-Naped Amazon, Amazona auropalliata

Successful planning for species conservation requires a thorough understanding of behavior and communication in wild populations that have the potential to host reintroduced individuals. A lack of knowledge about cultural dynamics such as shared vocalizations could result in the failure of reintroduced individuals to assimilate into a population. Yellow-naped amazons, *Amazona auropalliata*, have undergone a recent and rapid decline in Costa Rica and Nicaragua, a region that once harbored a healthy population, and are suspected to have experienced similar declines across their range, which extends from southern Mexico to northwestern Costa Rica. We aimed to evaluate both population size and geographic variation in contact calls across the yellow-naped amazon range and determine whether vocal dialects previously documented in Costa Rica are characteristic of the entire range of the species. Contact calls and roost size data were collected during 2016, 2018 and 2019 from 10 sites in Mexico, 2 sites in Guatemala, 4 sites in the Bay Islands, Honduras, 16 sites in Nicaragua, and 21 sites in Costa Rica. Roosts in Mexico, Guatemala and Honduras were small and geographically isolated. Contact calls in the northern part of the range exhibit strong divergence among sites, as previously found in Costa Rica and Nicaragua. The presence of vocal dialects throughout the range of the yellow-naped amazon suggests that reintroduction programs should consider the vocal behavior of releasable birds to facilitate their assimilation.

138-8 DUQUE, FG*; MONTEROS, M; NASIR, I; UMA, S; RODRIGUEZ-SALTOS, CA; CARRUTH, L; BONACCORSO, E; WILCZYNSKI, W; Georgia State U, Atlanta, GA, Inst Nacional de Biodiversidad, Quito, EC, Emory U, Atlanta, GA, U San Francisco de Quito, Quito, EC; *fduque1@student.gsu.edu*

Dialects in the high-frequency song of a hummingbird

Vocal signals convey information about affiliation, aggression, sexual state, and the identity of an individual. Variations in song structure across populations of the same species, known as dialects, have been described in frogs, birds, and mammals. The Ecuadorian Hillstar (*Oreotrochilus chimborazo*) is a hummingbird species in which males produce a high-frequency (HF) song (7-16 kHz) which consists of frequency-modulated introductory motifs followed by a series of trills. We investigated the variation in song structure of the HF song in this species to determine whether *O. chimborazo* exhibits dialects. We examined 8 populations along the Ecuadorian Andes, covering both subspecies, *O. c. jamesonii* and *O. c. chimborazo*. We found four dialects characterized by differences in the introductory motifs. The dialect found in the northern populations of *O. c. jamesonii* consists of an introductory whistle at §10 kHz, followed by a frequency-modulated introductory motif and trills at higher frequencies. The second dialect belongs to the subspecies *O. c. chimborazo*. Unlike the former, this HF song lacks the introductory whistle but instead, it exhibits two introductory motifs at §14.6 kHz. The third and fourth dialect songs are found in the two southern populations of *O. c. jamesonii*. These dialects differ from the others in the structure and number of introductory motifs. Although our findings map onto the microsatellite variation of the species, we found greater variability in the HF song than that present in the microsatellite analyses. These findings suggest that dialects may be the result of genetic variation and cultural evolution in the Ecuadorian Hillstar.

P3-79 DURICA, DS*; WOLFARD, F; SHYAMAL, S; DAS, S; MYKLES, DL; University of Oklahoma, Norman, OK, University of Oklahoma, Colorado State University, Fort Collins, CO, Colorado State University; *ddurica@ou.edu*

Examination of Ecdysteroid Hormone Biosynthetic Enzyme Genes in the Y-Organ Transcriptome and Developing Limb Bud Transcriptome During the Crab Molt Cycle

Ecdysteroids are synthesized from cholesterol by a conserved group of cytochrome P450 enzymes. In insects, specific P450 ecdysteroidogenic enzymes have been identified and are referred to as ‘Halloween' genes due to their ‘ghostly' mutant larval cuticle phenotype. In crabs, the Y-organ (YO) contains the enzymes that produce 20-hydroxyecdysone and is consequently important in molt regulation. We have analyzed crab YO next generation sequencing data from animals where molting has been stimulated using two molt-inducing experimental methodologies—eye stalk ablation (ESA) and multiple limb autonomy (MLA). This data was collected using the blackback land crab, *Gecarcinus lateralis*, as the YO tissue source. The ESA dataset represented YO mRNA populations from intermolt, early, mid and late premolt. The MLA data represented mRNA populations isolated through these four physiological molt stages, as well as postmolt. In addition, these datasets were also compared to transcriptomes from the fiddler crab, *Uca pugilator*, built from limb bud tissues undergoing progressive stages of regeneration during the molt cycle following MLA. Analysis of these datasets indicated: 1) Halloween gene homologs of the insect P450 enzymes were identified in both YO libraries; 2) Halloween gene mRNA levels increased over the molt cycle for ESA induced animals; 3) Halloween gene mRNA levels did not increase over the molt cycle for MLA induced animals, i.e, in parallel with increasing circulating hormone titers; 4) Halloween gene homologs were also identified in regenerating limbs. Whether other tissues may be a source of circulating hormone remains to be investigated. Supported by NSF (IOS-1257732).

131-2 DUTTA, B*; GOODISMAN, MAD; GOLDMAN, DI; Georgia Institute of Technology; *bahnisikha3474@gmail.com*

Prey and mound manipulation by fire ant collectives

Collective feeding represents a vital routine task for social insect societies. While many studies have focused on collective foraging and transport of food, fewer examine how the local environment and the food itself can be manipulated to facilitate food transfer to the colony. Here we perform studies with laboratory built fire ant mounds to determine how food is manipulated and retrieved for the entire colony in the presence of a soft, reconfigurable mound. The lab mounds were offered diverse prey ranging from insects to laboratory controlled food items. Ant-prey-soil interactions on and below the nest surface were recorded using industrial cameras and X-ray imaging respectively. Three distinct engulfment scenarios were observed from these experiments: whole prey transport to mound tunnels, prey dissection followed by transport, and prey dissection with simultaneous burial of the prey. Individual ants involved in feeding exhibited heterogeneity in tasks which included food maneuvering, dissection, and mound reconfiguration. We varied parameters such as food characteristics and colony fragment properties, and monitored individual and collective response. We found that a smaller colony fragment tended to bury food more (approx. 3 times as often) than a fragment with more ants. We also observed that the number of ants recruited to the food surface scaled linearly with the size of the colony fragment. Measurements of flow dynamics of both food and substrate suggested that the burying behavior was a passive mechanism caused by active tunnel reconfiguration of the mound to accommodate food flow in narrow tunnels where size of the colony fragment dictated the food flow. Our research provides new insights into how a collective task is affected by the presence of a contending reconfigurable environment in a decentralized system.

126-5 EARL, A.D*; KIMMITT, A.A; SIMPSON, R.K; YORZINSKI, J.L; Columbia University, Indiana University, University of Windsor, Texas A&M University; *ade2102@columbia.edu*

Female Ornamentation in a Lekking Bird: Bright Females Dominate

The study of male ornamentation has been fundamental to advancing our understanding of sexual selection, yet we are only now beginning to examine elaborate ornamentation of females. Although female ornamentation was once thought to be non-adaptive, recent studies have demonstrated that female ornamentation functions in both intrasexual competition and male mate choice; however, few studies have examined the role of female ornamentation in lekking species. We investigated the function and mechanisms of female ornamentation in Indian peafowl (Pavo cristatus), a lekking species in which females exhibit an elaborate ornament (iridescent green neck plumage). We tested whether female ornamentation predicts dominance status and whether female dominance affects courtship behavior. Finally, we examined whether steroid hormones (estradiol and corticosterone) are related to female ornamentation and dominance. We found that dominant females have brighter ornaments than subordinate females. Additionally, dominant females copulated more than subordinate females and prevented subordinate females from interacting with displaying males. Our data did not find a relationship between steroid hormones and ornamentation or dominance status. This study provides insight into the evolution of conspicuous female traits by suggesting a role for female ornamentation in intrasexual competition in a lekking species.

P2-39 EARLY, CM*; IWANIUK, AN; RIDGELY, RC; WITMER, LM; University of Florida, Gainesville, FL, University of Lethbridge, Alberta, Canada, Ohio University, Athens, OH, Ohio University, Athens, OH; *cearly@floridamuseum.ufl.edu*

A Quantitative Framework for Inferring Vision-related Neuroanatomy from the Endocasts of Extinct Birds

Brains do not fossilize, so endocasts provide the most direct evidence of neuroanatomy and potential functional capability in extinct birds. The optic lobe and the Wulst are structures that are visible on the endocasts of a majority of birds. They overlie the optic tectum and hyperpallium, respectively, two brain structures that have roles in the visual pathways of birds and whose relative size seems to correlate with emphasis on visual information. Researchers have inferred potential functional capabilities of extinct birds from relative endocast structure size, but it is unknown if the size of the endocast structure faithfully represents the size of the brain structure. We measured the size of the endocast and brain structures of interest in a diverse evolutionary sample of extant birds. We regressed the volumes of optic tecta on the surface areas of the optic lobes and the volumes of the hyperpallia on the surface areas of the Wulsts. Both regressions yielded a strong, significant, positive relationship between the volume of the brain structure and the surface area of the overlying endocast structure. A phylogenetic prediction method based on Bayesian inference was used to calculate the volumes of the brain structures of a few extinct birds based on the surface areas of their endocast structures. Phylogenetic ANCOVAs indicated that no extinct birds studied had hypertrophied optic tecta relative to brain-rest volume, nor were their hyperpallial volumes significantly different from the extant sample. The optic tectum of *Dinornis robustus* was significantly smaller than any of the extant birds in our sample. Our results provide an analytical framework within which hypotheses of potential functional capabilities of extinct birds based on their endocasts can be tested.

100-6 EBERTS, E.R*; GUGLIELMO, C.G; WELCH, K.C; University of Toronto Scarborough, University of Western Ontario; *ebertser@gmail.com*

Seasonal Changes in Body Composition and Torpor Use of Ruby-throated Hummingbirds (Archilochus colubris)

Hummingbirds can use torpor to reduce metabolic rate overnight as part of a strategy to manage daily energy balance or to maximize energy storage during certain life stages. However, the rules that govern torpor use are unclear. While torpor may be used only during times when energy stores fall below a critical level, an ‘emergency only' strategy may be abandoned to facilitate fat conservation prior to and during migration. We tracked body composition and torpor use in male ruby-throated hummingbirds (*Archilochus colubris*) throughout the breeding season and the beginning of the fall migration period using quantitative magnetic resonance, respirometry, and thermal imaging. During the summer, birds that entered torpor did so at very low estimated fat stores (~5% of body mass). Interestingly, torpor use occurred repeatedly during the migratory period in birds that had accumulated high body fat stores (>20%). Overall, our preliminary results suggest that in the breeding season, hummingbirds use torpor only when their energy reserves are especially low. However, torpor use with high fat stores in the migratory season suggests that some individuals are able to use torpor to facilitate storage of fat needed to fuel their migratory journey. Ongoing analyses aim to explore individual variation and to elucidate the mechanistic link between torpor use, and seasonal changes in body condition.

138-2 ECHEVERRI, SA*; ZUREK, DB; MOREHOUSE, NI; University of Pittsburgh, Pittsburgh, University of Cincinnati, Cincinnati; *echeverri.sa@gmail.com*

Male Habronattus pyrrithrix Jumping Spiders Adjust Their Attention-Grabbing Courtship Display Based on Spatial and Environmental Context

To communicate effectively, signalers must capture the attention of potential receivers, and may do so with conspicuous "alerting” displays. Although many different animals use alerting displays, we know relatively little about how display variation and the sensory environment affect attention capture, especially in arthropods. In the jumping spider *Habronattus pyrrithrix*, males perform a complex courtship dance that includes elaborate movements and colorful ornaments. However, females can only see a male's colors when facing him. While females often turn away from courting males, males perform a waving display that may function to capture and/or redirect her attention. However, males show intraspecific display variation, which may be linked to spatial and/or temporal variation in the visual environments they display in. Using video playback, we asked how signal variation and visual environment affected how effectively a display attracted female attention. We then asked whether and how males respond to variation in their signaling environment. We found that increasing background complexity decreased female responsiveness in general, but male waving displays continued to effectively attract female attention even under increasingly complex signaling conditions. Males adjusted their displays in different signaling conditions by 1) performing larger waving displays when farther from the female, and 2) courting at a closer distance in more complex environments.These behaviors should improve signal effectiveness by increasing the size of the male display in the female's field of view. How well signalers manage receiver attention may be an axis for mate choice in this and other species.

65-1 ECHEVERRI, SA*; WETZEL, DP; BROUWER, NL; University of Pittsburgh, Pittsburgh; *echeverri.sa@gmail.com*

De-Jargonizing SciComm: Does having to use simple words make students better at writing for most people?

Scientists often have to share their work with people who are not experts in the same field, including students, the media, and politicians. However, the communication training offered at many undergraduate and graduate programs tends to focus only on how to talk to and write for other scientists. As a result, many scientists over-use complicated words with field-specific meanings ("jargon"), making understanding difficult. This bad habit can begin early in scientists' careers and become set over time.To improve how undergraduate students communicate their research, we asked how being required to write without jargon improved students' writing for non-experts. We asked students in a scientific communication course (n=16) to write a 250-500 word popular science article on a topic they were already researching for a semester-long project. We then challenged them to rewrite their first draft using only the 1000 most common English words, as inspired by the webcomic XKCD. Then, they wrote a final version with no restrictions. We used a rubric and the "DeJargonizer" online tool to ask how this improved the amount of jargon used, and the content and quality of the final article. Even with limited in-class practice, most students wrote competent articles for non-experts and successfully explained their topic without jargon when required. However, most students did not incorporate the phrasing and explanations from their jargon-free assignment into the final article, choosing instead to only edit their original draft. Despite this, several students said that they enjoyed the activity and felt that it helped them talk about their research in presentations. With modifications such as peer-feedback, this activity could be a fun way to improve science communications.

35-4 EDDINS, HMS*; KLIGMAN, BT; NESBITT, SJ; MARSH, A; PARKER, W; STOCKER, MR; Virginia Tech, Blacksburg, VA , Virginia Tech, Blacksburg, VA, Petrified Forest National Park, Petrified Forest, AZ, Petrified Forest National Park, Petrified Forest, AZ; *ehanna7@vt.edu*

New Triassic Reptile Reveals Oldest Record of a Complete Envenomation Apparatus

Little is known about the evolutionary history of vertebrate venom delivery systems owing to a sparse record of fossils preserving aspects of this morphology. Previously, only four Mesozoic reptile records existed: *Sinornithosaurus millenii* (Early Cretaceous: China), *Sphenovipera jimmysjoyi* (Early Jurassic: Mexico), *Uatchitidon kroehleri* (Late Triassic: Virginia, USA), and *Uatchitidon schneideri* (Late Triassic: North Carolina and Arizona, USA). Here we present a new, likely venomous, reptile collected from a microvertebrate-bearing horizon (~214 Ma; Norian age) in the Upper Triassic Chinle Formation of Arizona. This new taxon is represented by a fragmentary dentary bearing three conical, labiolingually-compressed teeth with mesially curved tips and ankylothecodont attachment. Each tooth bears a lingual and labial groove that extends from the base of the tooth to the apex. Computed tomographic data reveal foramina in the bone tissue at the base of each groove on either side that connect to internal cavities within the dentary. We interpret this morphology as an envenomation apparatus of venom glands within the dentary connected to venom-conducting grooves on the teeth, strongly convergent on the morphology of the extant squamate *Heloderma*. This new taxon is one of the oldest venomous reptiles and one of the only examples of a complete envenomation apparatus in the fossil record. The occurrence of the new taxon and records of *U. schneideri* in microvertebrate assemblages in the Upper Triassic of North America show that venomous reptiles were a common component of the vertebrate ecosystem in equatorial Pangaea.

109-6 EDMONDS, KE*; GIBSON, L; ROEDERER, L; Indiana University Southeast; *kedmonds@ius.edu*

Corticosterone and Estradiol Regulation of Gastrointestinal (GI) Development and Reproduction in the Marsh Rice Rat (Oryzomys palustris)

Environmental factors and subsequent hormonal changes can regulate the development of various physiological systems. Steroid hormones are known to affect significantly the reproductive system in seasonal breeders, but effects on the GI tract have not been as extensively studied. The present studies examined whether corticosterone or estradiol affect GI development and reproduction in juvenile male and female rice rats. Rice rats were subjected to subcutaneous Silastic implants of corticosterone or estradiol from 21-56 days of age. The following masses were examined: body, testes, seminal vesicles, Harderian glands (males only), spleen (males only), female reproductive tract, 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. Corticosterone had no effect on body mass or any reproductive or GI variable examined in males or females. Estradiol, on the other hand, increased female reproductive tract mass, WSt, WSI, DSt, and DSI masses relative to animals with empty implants, but decreased SI and Co lengths. These data show that estradiol most dramatically affects reproduction and GI development in females, but that corticosterone was without effect on any reproductive or GI endpoints in either sex. It was hypothesized that changes in the GI tract may be a necessary mechanism for coping with likely seasonal changes in metabolic requirements brought about by changes in steroid hormone levels. We are currently examining the effects of reducing steroids via ovariectomy on these same variables in females.

P1-222 EDWARDS, KM*; REZNICK, DN; University of California, Riverside; *kedwa007@ucr.edu*

Feeding Performance Differences in High and Low Predation Guppies Raised with Different Food Presentations

Trinidadian guppies (*Poecilia reticulata*) are found in the mountain streams of northern Trinidad, where they co-occur with a diversity of predators. However, the distribution of these predators is limited by large barrier waterfalls, leading to upstream populations experiencing significantly lower predation risk and allowing them to grow to large population sizes. High population density in upstream reaches has led to a diet shift in these populations to incorporate a larger amount of algae and detritus than in downstream populations, which primarily feed on small invertebrates. These two diets should require different feeding mechanisms: a "picking" motion for invertebrates and a "scraping" motion for attached algae and detritus. Previous studies have demonstrated significant morphological differences between the head and jaws of high and low predation guppies, but it remains unclear to what extent these differences are evolved or plastic and whether they lead to differences in performance. We bred wild-caught guppies from one high and one low predation locality in the Aripo River in northern Trinidad to an F2 generation in the lab. These fish were then raised on a gel food presented in one of two ways: as a slurry that required picking food particles from the water column and as a thin layer spread onto a tile that required a scraping feeding motion. Mature fish were then filmed while feeding on both food types and these videos were analyzed to measure kinematic variables such as gape width, gape angle, angle of approach, and duration of the feeding sequence as a proxy for feeding performance.

P2-164 EL-SHESHENY, IA*; MATOO, OB; DELONG, JP; MONTOOTH, KL; University of Nebraska-Lincoln, USA & Tanta University, Egypt, School of Biological Sciences, University of Nebraska-Lincoln; *i.elshesheny@yahoo.com*

Connecting thermal performance from mitochondrial physiology to population growth rate in an outbred insect population

Climate change and global warming are affecting wildlife species across different ecosystems, warranting the integration of mathematical and physiological models of thermal performance to make robust predictions and capture context-dependent variability in population responses. Our approach is to connect thermal performance at different levels of biological organization in order to mechanistically understand how temperature will impact population dynamics. Here we present data on thermal performance curves for population growth rate and for its underlying life-history and physiological components, including female fecundity, development rate, survivorship, metabolic rate and mitochondrial function from an outbred population of *Drosophila melanogaster*. By modeling the thermal performance curve at each level as a function of an underlying set of nested thermal performance curves, we aim to connect the temperature dependence of underlying mitochondrial metabolism up through levels of organization to population growth. We discuss how our research may provide a predictive framework for forecasting the dynamic responses to environmental change from thermal metabolic responses through a series of currently unknown nested functions up to population level responses.

P3-148 ELCOCK, JN*; SUMMERS, AP; HALL, KC; Howard University, University of Washington; *jaidaelcock@gmail.com*

Skating on Egg Shells: Microstructure of Skate Egg Cases and Attachment to Substrate

Skates, a specious group of cartilaginous fishes, lay egg cases in which embryos develop for months to years. These cases sit on the bottom of the seafloor and are subject to dislodgement by ocean currents and attack by predators. We investigated the factors that affect how well egg cases from 8 species, found in the North Pacific and Arctic Ocean, resisted being swept away by currents. To better understand the hydrodynamic principles that each species is capable of withstanding, before breaking away from the substrate, we quantified the maximum currents, friction, and turbulence using a flume and a tilt table. Further, we used scanning electron microscopy in order to visualize the variation in morphology of the microstructures covering egg cases and to determine if there was a relationship between egg case texture and attachment to the substrate. While egg cases exhibit an increased ability of attachment in certain orientations with regard to flow or friction (anterior, posterior, or lateral), we found that preferred orientations did not remain the same between species. Maximum flow speed and friction are dependent on species, as well as the individual, indicating that some species are better able to withstand a wide disparity of flow speeds, or stronger currents, and friction forces than others. We attribute this to the vast diversity of egg case microstructures found across species. Lastly, Reynold's numbers were calculated for each egg case to determine laminar or turbulent flow in each orientation. Overall, this research has implications for predictive models of skate egg nursery habitats, locating new nesting site locations, and fisheries management models across the North Pacific Seas to include strategies for avoiding nursery grounds and areas where bycatch occurs.

121-6 ELLIS, LV*; BOLLINGER, RJ; WEBER, HM; MADSEN, SS; TIPSMARK, CK; University of Arkansas, University of Arkansas and University of Southern Denmark, University of Southern Denmark; *lvellis@uark.edu*

Aquaporin Expression in the Gill of Japanese Medaka

Aquaporins (Aqps) are theorized to regulate cell volume homeostasis through water and solute transport. This study examined Japanese medaka (*Oryzias latipes*) gill Aqp1 and Aqp3 expression and localization in response to salinity challenges and osmoregulatory hormones, cortisol, and prolactin (PRL). Expression of *aqp3* was elevated in ion-poor water (IPW) compared to normal freshwater (FW), and very low transcript levels were observed in seawater (SW). Aqp3 protein levels decreased with acclimation to SW. Aqp1 expression however, was unaffected by salinity. PRL stimulated *aqp3* mRNA in *ex vivo* gill incubation experiments in both a dose and time-dependent manor, but was unaffected by cortisol. In contrast, *aqp1* was unaffected by both PRL and cortisol. The combination of cortisol and PRL had an additive stimulatory effect on *aqp3* , while *aqp1* remained unchanged. Confocal microscopy showed Aqp3 in the periphery of epithelial cells in gill filaments and co-localized at low intensity with Na^+,K^+-ATPase in ionocytes. While Aqp1 was found in most filament epithelial cells at low intensity and red blood cells, no immunoreactivity to Aqp3 or Aqp1 were found in the epithelial cells of the gill lamellae. We suggest that both Aqps contribute to cellular volume regulation in the gill epithelium and that Aqp3 is essential under hypo-osmotic conditions, while expression of Aqp1 is constitutive.

32-6 ELLIS, HI*; SAN FRANCISCO, S; University of San Diego, Texas Tech University; *ellis@sandiego.edu*

Sustained Metabolic Scope: Verification from Eared Grebe Time and Energy Budgets

Time-activity budgets of Eared Grebes (*Podiceps nigricollis*) have been measured at least four times at fall staging areas on two continents. We created a time-activity budget based on focal animal sampling on a post-wintering lake, Salton Sea, California and converted it to an energy budget based on respirometry studies done earlier on captive grebes. Our study covered five periods from late February to late April, 2014. We found that the amount of time devoted to specific activities changed with observational period, but that the grebes' daily energy expenditure (DEE) varied very little from a mean of 542 kJ/d and even less from a mean 2.4 x BMR. When we compared our study with those of fall staging grebes from other studies, we again found large variations in how the birds used their day, but consistency in DEE and again a 2.4 multiple of BMR. We believe the BMR multiple we are seeing in our non-breeding sedentary grebes represents the sustained metabolic scope (SusMS) predicted by Peterson et al. (1990) but never reported before as a recurring value in different situations.

81-8 ELLISON, CI*; MASLAKOVA, SA; Oregon Institute of Marine Biology, University of Oregon; *cellison@uoregon.edu*
Diversity of Benthic Nemerteans of the Caribbean
Unbeknownst to most people, the majority of species on Earth, especially in the marine environment, remain undescribed. In the context of the current biodiversity crisis, it is clear that characterizing existing diversity should be a priority, in order to establish a baseline for monitoring change. Biodiversity researchers must deal with the challenge of cataloguing the vast number of undescribed species while operating under deficit of time, funding, and taxonomic expertise. Characterizing undescribed diversity is further complicated by cryptic speciation, outdated and inefficient standards of species descriptions, and the need for revisionary systematics. Understudied taxa, like ribbon worms (phylum Nemertea), are in particular need of attention. In the Caribbean Sea there are ~38 described species of nemerteans, but DNA-barcoding of specimens collected over the past 20 years suggests there are several times that number of operational taxonomic units (OTUs), i.e. putative species, most of which are undescribed, cryptic, and a large fraction only known in the larval form. Preliminary species accumulation curves based on 108 OTUs (361 adult individuals as of early 2018) suggested a further ~50 species would be discovered by barcoding an additional ~1000 individuals. We now sequenced a few hundred additional adult individuals, and already surpassed the predicted number of species. How can we describe all of this diversity in our lifetimes? How does one deal with describing cryptic species (morphologically indistinguishable, yet distinct) or those only known as larvae? And how many species of nemerteans are there in the Caribbean Sea? Here we offer an update on the diversity of Caribbean nemerteans, and discuss some of the challenges associated with identifying and describing this diversity.

124-3 ELLISON, A; PACE, DA*; California State University, Long Beach; *douglas.pace@csulb.edu*
Protein metabolism and food-induced developmental plasticity during echinoid larval development
Previous research from our lab modeling energetic growth efficiency in larvae of the sand dollar, *Dendraster excentricus,* has shown that large-scale physiological plasticity occurs in concert with morphological plasticity during larval development in response to different food rations (1,000 and 10,000 algal cells ml^{-1}). In particular, low-fed larvae had higher protein growth efficiency (PGE, protein grown standardized to protein ingested) than high fed larvae early in development, but this advantage diminished rapidly and in later development, fell below that of high fed larvae. Given the importance of protein growth in planktotrophic larval development, we sought to further understand these large differences in PGE by measuring rates, costs, and efficiencies of protein metabolism in low- and high-fed larvae. While low- and high-fed larvae had similar mass-specific rates of protein synthesis, amino acid transport rates were almost 2-times higher in low-fed larvae. No differences were observed in either the energetic cost of protein synthesis (~ 5 J (mg $protein)^{-1}$) or the proportion of aerobic energy that was used to drive protein synthesis (~40% of metabolism). Major differences, which mirrored changes in PGE with development, were observed in protein depositional efficiency (PDE, protein growth standardized to protein synthesized). Low-fed larvae exhibited a decrease in PDE from 85% to 40% from 4 to 28 days post-fertilization while high-fed larvae increased from 55% to 65%. These differences in PDE provide a physiological explanation for the large differences in PGE between low- and high-fed larvae. These results demonstrate that protein metabolism is a critical response element in the developmental plasticity pathway of larvae experiencing different food environments.

P3-197 ELLISON, M*; BUSH, J; University of Tennessee, Knoxville; *Melliso4@vols.utk.edu*
Hierarchical shifts in green anole social networks following brown anole invasion
Invasive species have a variety of impacts on our natural world, ranging from habitat destruction and species displacement to single population evolutionary shifts. On occasions where the invasive species is closely related to the native species, even social behavior can be impacted and disrupted. In our study, we looked at the effect of invasion on a population's social network; specifically, hierarchy. Current studies on brown anoles (*Anolis sagrei*) note their aggressiveness and ability to quickly displace green anole (*A. carolinensis*) populations, leading us to believe they might also be more socially dominant. Utilizing large, outdoor enclosures in Oak Ridge, Tennessee, we housed two captive populations of green anoles and recorded their behavior for 10 days. We then introduced brown anoles to one of the enclosures, mimicking an "invasion", and continued to monitor the green anole behavior for another 10 days. The other enclosure served as our control, where we introduced more green anoles to create a mock "invasion". Looking at post-invasion interaction behaviors, we found no evidence that introduced brown anoles are more socially dominant than introduced green anoles. In fact, during almost all "invasions" both species maintained an average level of social interactions, with brown anoles displaying slightly more than the introduced green anoles. These results indicate that brown anoles, despite quickly being able to displace green anole populations upon invasion, do not greatly change the social networks through more dominance.

100-8 ELOWE, CR*; GERSON, AR; University of Massachusetts Amherst; *crelowe@umass.edu*
Flux Capacity: Seasonal Changes in Body Composition and Metabolism in Migratory White-Throated Sparrows (Zonotrichia albicollis)
Migratory birds seasonally increase fat stores and the enzymatic capacity for fatty acid transport and catabolism to fuel long-distance migratory flights. However, catabolism of lean mass is also well documented in migratory birds and, if adaptive for migratory flight, seasonal changes in the capacity for protein metabolism should occur. To investigate seasonal changes in fuel storage and metabolism in preparation for migration, I conducted a photoperiod manipulation using captive White-throated Sparrows (*Zonotrichia albicollis*). I measured body composition and water-restricted metabolic rate through a "winter" photoperiod, and after exposing half the birds to a "spring" photoperiod. Lean mass peaked for all birds during the winter, but after photostimulation spring birds rapidly increased fat mass and the activity of fat catabolism enzymes while displaying peak *Zugunruhe*. There was a 25-fold increase in muscle sarcolipin transcript levels in spring birds, which may stimulate mitochondrial biogenesis and fat catabolism through sarco/endoplasmic reticulum Ca^{2+} ATPase (SERCA) uncoupling. Body composition remained stable in winter birds and metabolic rates did not differ significantly between seasons. However, spring birds lost more water for a given metabolic rate, driving greater rates of lean mass loss alongside altered protein catabolism enzyme activities. This suggests that protein may be catabolized at a greater rate during migratory seasons, potentially to cope with higher rates of water loss.

86-6 ELSHAFIE, SJ; University of California, Berkeley; *selshafie@berkeley.edu*

Body Size Changes Across Lizards and Crocodylians Correspond to Climatic Changes Through Deep Time

Climate is known to influence body size in living reptiles. However, this relationship has not been investigated over geologic time intervals, nor compared among higher-order groups of extinct reptiles. Here I test the hypothesis that body size range undergoes holistic, synchronized change in lizards and crocodylians in response to climatic transitions over geologic time scales. I estimate snout-vent length (SVL) in lizards and crocodylians from intermontane basins in the Western Interior of North America through the Paleogene (66-23 million years ago), spanning several warming and cooling periods. The range of SVL increases in both lizards and crocodylians in the early Eocene. Maximum SVL increases 4X in lizards relative to the middle Paleocene (150 mm vs. 600 mm) and doubles in crocodylians (1 meter vs. 2 meters) and remains elevated through the Eocene. Meanwhile, minimum SVL remains consistent through the Paleogene in both groups (approximately 100 mm in lizards, 200 mm in crocodylians). This pattern is observed with no consistent latitudinal gradient across intermontane basin communities through the Paleogene. The observed changes in maximum SVL correspond to changes in mean annual paleotemperature in the Western Interior through the Paleogene. These results suggest that climatic changes may drive overall body size changes in lizards and crocodylians over deep time scales.

63-5 EMBERTS, Z*; ST. MARY, CM; FORTHMAN, M; MILLER, CW; University of Florida; *emberts@ufl.edu*

The evolution of autotomy in leaf-footed bugs

Sacrificing body parts is one of many behaviors that animals use to escape predation. This trait, termed autotomy, is classically associated with lizards. However, several other taxa also autotomize, and this trait has independently evolved multiple times throughout Animalia. Despite having multiple origins and being an iconic anti-predatory trait, much remains unknown about the evolution of autotomy. Here, we combine morphological, behavioral, and genomic data to investigate the evolution of autotomy within leaf-footed bugs and allies (Insecta: Hemiptera: Coreidae + Alydidae). We found that the ancestor of leaf-footed bugs autotomized, and did so slowly (> 15 min). Rapid autotomy (< 2 min) then arose multiple times. The ancestor likely used slow autotomy to reduce the cost of injury or to escape non-predatory entrapment, but it is unlikely that autotomizing this slowly would be advantageous during a predation event. This suggests that autotomy to escape predation is a co-opted benefit (i.e., exaptation), revealing one way that sacrificing a limb to escape predation may arise. We also found that across species variation in the rates of autotomy can be explained by body size, distance from the equator, and enlargement of the autotomizable appendage.

P3-150 ENG, CM*; YAWAR, A; VENKADESAN, M; Yale University; *carolyneng@gmail.com*

Functional Curvature and the Stiffness of Rayed Fins

Rayed fish use their lightweight pectoral fins, comprised of bony rays and a membranous skin fold, for propulsion, steering, and maneuvering and need sufficient bending stiffness to exert hydrodynamic forces. Previous mathematical work identified the principle of curvature-induced stiffness as a key factor for the bending stiffness of rayed fins. The underlying mechanics, demonstrated by slightly curling a dollar bill to stiffen it, arises from the coupling of longitudinal bending and in-plane stretching due to curvature. By examining the internal morphology of a mackerel pectoral fin, the past work hypothesized that even an externally flat fin may manifest functional curvature and exhibit the same mechanics as a curved structure. Functional curvature couples bending and stretching because the preferred bending directions of adjacent rays are misaligned and bending the fin rays stretches the membrane. Here, we experimentally demonstrate stiffening due to functional curvature through load-displacement tests on intact and membrane-transected pectoral fins of the mackerel (*Scomber scombrus*). The fin was removed from the body and rays were clamped 1-2 mm distal to the radial joint before mounting on a force sensor. The distal fin was vertically displaced by a knife-edge and the reaction force was recorded. Then, without removing the fin from the clamp, the membrane connecting adjacent fin rays was incised for the proximal-distal extent of each ray and the test was repeated. Upon transecting the membrane, the elastic energy (area under the load-displacement curve) was substantially reduced, by 23% and 57% for two fins that we tested. Importantly, the fins were held externally flat. Therefore, these results support the hypothesis that functional curvature is manifested within the internal structure of the mackerel pectoral fin.

16-1 ENGLISH, P; SILVERTHORN, DU*; University of Texas at Austin; *silverthorn@utexas.edu*

The Minimal Marking Technique: Grading Writing Assignments while Promoting Active Learning

Requiring students to write can enhance their analytical, elaboration, and critical thinking skills while giving them an opportunity to explore the scientific literature. Writing out ideas is a very different process than correctly answering content-laden multiple choice questions, and many students do not get enough writing experience in their science classes. One reason may be that for the instructor, grading and commenting on a large number of student writing assignments is time consuming. It is also frustrating, since simply copy-editing student work often has no impact on the student's writing, with the same errors showing up repeatedly. Minimal marking is a grading technique in which minimal feedback based on structured error codes requires students to actively engage in the editing process. It is faster and simpler for the grader, and it improves awareness of writing skills for the student. In this presentation we will demonstrate how to use the minimal marking technique, with examples from a writing-intensive inquiry lab course.

18-5 ENNS, JL*; PURDEY, L; STOJKOVIC, L; WILLIAMS , TD; Simon Fraser University; *joannae@sfu.ca*

Is Coordination Key? Investigating the Timing of Provisioning Visits in a Biparental Songbird Species

Parental care increases the inclusive fitness of parents by increasing offspring survival. However, in species that take part in biparental care, there is sexual conflict due to differential costs of investment, where each parent benefits from their partner putting in more effort. Turn-taking (or coordination) of nest visits during chick provisioning has been suggested as a strategy to mitigate this conflict. In order for coordination to work, each bird must have access to information about its partner's behaviour, allowing pairs to respond to each other "in real time". To date, evidence in support of this type of cooperation has come from species that forage close to the nest (within 45 m) and/or synchronize feeding visits, which likely provides direct information for each partner. We aim to fill this literature gap by investigating variation in feeding-visit intervals in the European starling, *Sturnus vulgaris*, where foraging distance is greater (~800 m) and therefore direct information on the partner's behaviour is likely less available. Considering feeding-visit interval as a behavioural phenotype, we tested the hypothesis that parents adjust their interval length based on knowledge of their partner's feeding behaviour (or indirect cues via chicks). Preliminary analysis suggests feeding-visit interval is a plastic trait, and may vary among years, 1st and 2nd broods, and with brood size. Finally we describe an experiment to directly test the coordination hypothesis, removing one bird during chick-rearing and then measuring their partner's ability to respond to manipulation of this putative 'information cue'.

92-1 ENSMINGER, DC*; PRITCHARD, C; GINGERY, T; LANGKILDE, T; University of California, Berkeley and The Pennsylvania State University, The Pennsylvania State University; *dls_david@yahoo.com*

The influence of hunting pressure and ecological factors on fecal glucocorticoid metabolites in wild elk

Climate change and a growing human population have increased anthropogenic threats to biodiversity and habitat fragmentation. Ecologists and conservationists have focused on how to assess the effect of these ecological and environmental perturbations on organismal fitness. Glucocorticoids (e.g. cortisol and corticosterone, CORT) are commonly used to assess animal welfare as they integrate various factors such as anthropogenic disturbances, predation, food, or environmental stressors. Here we tested the hypothesis that anthropogenic hunting pressure increases fecal CORT metabolites (fecal GCM) in wild female elk (*Cervus elaphus*) and examined the influence of herd size, year, and food availability on fecal GCM. We found a trend for decreased fecal GCM with as the hunting season progressed. We also found a negative relationship between fecal GCM and number of cows in the herd, and a strong effect of year on fecal GCM, with samples collected in 2016 having lower CORT than those collected in 2015, 2017, and 2018. However, yearly variation was not driven by availability of hard mast forage. The potential negative association between hunting pressure and CORT and identifying what is driving yearly variation in CORT warrants further study. We highlight the influence of herd size, possibly due to vigilance, on fecal GCM and the importance of examining ecologically relevant covariates to accurately identify main treatment effects, such as hunting pressure.

131-7 ERDMANN, JA; Oklahoma State University; *james.erdmann@okstate.edu*

Aggressive anglers, seductive serpents, and titillating toads: a discussion of luring and prey manipulation strategies

When a predator hunts a cryptic or mobile prey item, it has two general options: actively seek out the prey or remain stationary and wait for prey to approach. In the latter case, predators employ an assortment of strategies to increase the encounter rate of their prey-to-be. Perhaps the most recognizable of these strategies is the lure, wherein the predator creates some attractive stimulus to their potential prey, causing the prey to unwittingly approach the predator. However, the literature is equivocal on what constitutes a lure, as well as how to go about testing it. I critique the conditions when the term 'lure' is applied and suggest ways of quantitatively measuring it against behavioral alternatives to create a more robust foraging theory.

33-6 ESBAUGH, A.J*; LONTHAIR, J; University of Texas at Austin , University of Texas at Austin; *a.esbaugh@austin.utexas.edu*

The Development of Acid-base Pathways in Marine Fish: Implications for Ocean Acidification

Ocean acidification (OA) caused by elevated carbon dioxide is an imminent environmental stress to marine organisms, and is hypothesized to have a suite a detrimental effects. In fish, elevated carbon dioxide causes a respiratory acidosis that is compensated through ion transport pathways at the gills. This disturbance is thought to be the underlying cause of many of the effects of OA, including reduced survival in many marine fish larvae. Importantly, little is known about the development and function of acid-base pathways in marine fish larvae. We therefore sought to explore the development of acid-base pathways in a model marine fish, the red drum (*Sciaenops ocellatus*), and assess the role of phenotypic plasticity in early life resilience to carbon dioxide stress. We first explored the dose response effects of carbon dioxide, which resulted in significant reductions in larval survival at OA relevant partial pressures. However, a significant proportion of tested individuals also exhibited surprising resilience to carbon dioxide with approximately 50% survival when exposed to partial pressures over 10x those relevant to OA. Gene expression and confocal microscopy were used to assess acid-base pathways, which provided evidence for functional pathways and CO_2-induced plasticity as early as 36 hours post-fertilization. A scanning ion electrode technique was used to verify the function of these pathways, which was evident from a dose-dependent increase of proton flux across the larval epithelium. Interestingly, proton flux was both bafilomycin-sensitive and EIPA-sensitive suggesting the presence of multiple acid excretion mechanisms, which likely contributes to the observed resilience of red drum to carbon dioxide stress.

P3-38 ESHLEMAN, MA*; KLUG, PE; WISSEL, B; GREIVES, TJ; NDSU, Biological Sciences Department, Fargo, ND, USDA-APHIS-WS, National Wildlife Research Center, Fargo, ND, University of Regina Department of Biology, Regina, SK ; *michelle.angelucci@ndsu.edu*

Migration and Reproduction: Is There a Reproductive Advantage to a Shorter Migration?

To avoid harsh conditions at their breeding grounds, many birds migrate south during the winter. Individuals migrating to a more southern location may experience more favorable conditions but at the cost of a long, energetically-demanding migration that may delay their spring reproductive development. The relationship between migration distance and reproduction has primarily been investigated in monogamous species with a focus on early season testosterone production in both males and females. Our study presents a new perspective by assessing the importance of migration distance in a polygynous species with increased pressure for both males and females to arrive and breed early. Males that arrive early are able to compete for high-quality territories while the nests of females that lay earlier receive increased paternal care. We collected blood and claw samples from male and female red-winged blackbirds (*Agelaius phoeniceus*) before breeding began in the Alice Waterfowl Production Area in North Dakota. We measured baseline levels of estradiol and testosterone in females and baseline and GnRH-induced testosterone levels in males. We estimated the migration distance of an individual using stable isotopes of hydrogen from a claw sample. We predict that males with shorter migration distances will have higher baseline and post-GnRH testosterone levels, larger harems, and more offspring. Similarly, we predict that females with shorter migration distances will have elevated baseline estradiol and testosterone levels, earlier lay dates, and more offspring.

P1-244 ESTRADA, RS*; GORMALLY, BMG; ROMERO, LM; Tufts University; *rodolfo.estrada@tufts.edu*

Assessing Background DNA Damage across Tissues in House Sparrows

For several decades, measuring plasma corticosterone levels has been a staple in studying the stress response. More recently, additional downstream metrics such as DNA damage have been studied using blood samples of animals with nucleated erythrocytes, such as house sparrows (*Passer domesticus*). However, the biological relevance of blood DNA damage is unknown; baseline levels of DNA damage across multiple tissue types must first be established in order for this method to be further validated. We assessed the background levels of DNA damage in the blood, abdominal fat, hippocampus, hypothalamus, and the liver in house sparrows in three life-history stages: captive adult, wild-caught adult, and wild-caught juvenile house sparrows. The tissues studied play different roles in the stress response and health of the individual, suggesting they could be differentially affected by stress. The use of captive and wild-caught adults as well as juveniles allows for the effects of captivity and life-history to be controlled for. Tissues were collected upon capture and comet assays were used to measure DNA damage. The damage for each tissue was averaged across the individuals of the experimental groups, and the data mostly supports the hypothesis that unstressed individuals have low levels of DNA damage and low variation across tissues, with the exception of: elevated average blood tissue damage in juveniles, decreased hypothalamus damage in captive adults, and elevated hippocampus damage in captive adults. We hope these data will help further the understanding of DNA damage as a metric for stress and the overall physiology of the stress response.

P1-176 EVANGELISTA, D*; FIGUEROA, S; United States Naval Academy; *evangeli@usna.edu*

Biomechanics of Herndon Climb

Collective behaviors, in which an aggregation of cooperative agents form a structure to traverse an obstacle have been studied in ants, termites, and other small animals. Some study of this topic has been done in large animals (e.g. the tradition of *castelles* (human towers) in Barcelona, dating to the 18th century). The United States Naval Academy is home to an annual, world-famous example of human tower building, with recorded data as far back as 1962, that provides a unique study system for examining a structure constructed by cooperative agents. During Herndon Climb, the entire "plebe" (first year) class works as a team to attempt to scale an monument that has been generously lubricated with shortening and a fine mist of water. Maximal performance is motivated by the promise of quick promotion for the first to the top, and that upon completion the members of the class are considered "plebes no more". We analyze video of the climb from multiple angles, interview and survey participants, conduct modeling and simulation, and examine correlations with measurements of midshipmen strength and endurance (e.g. physical readiness tests administered to all participants). The results could be applicable to robotic constructions in which individual agents arrange themselves to defeat obstacles and gaps. The results also allow comparison between studies in small insect taxa and the large body mass system studied here.

P1-134.5 EVANGELISTA, D*; EDWARDS, C; HALL, M; MARTIN, W; NEMANI, S; US Naval Academy, United States Navy; *evangeli@usna.edu*

Thermal imaging of a sea turtle arribada using an Unmanned Aerial System (UAS)

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, including at night. We used a thermal imaging cameraoperated from a UAS to study olive ridley sea turtles (*Lepidochelys olivacea*) at night during an arribada in Ostional, Costa Rica, in the spring of 2019. During 59 flights and approximately 5 hours of air time spread over two evenings, we repeatedly surveyed a 0.8 km (0.5 mile) transect along the main nesting beach in the Ostional National Wildlife Refuge. We observed the turtles, their tracks, and nests, as well as some known predators on sea turtle eggs, all of which have distinctive signatures in visible and thermal imagery. Hot, subsurface sand provides nests and tracks with a particularly conspicuous thermal signature. Post mission image processing includes photostitching of geotagged thermal imagery and use of machine vision, Haar cascades, deep learning, and convolutional neural networks to identify and count the turtles as well as other animals of interest. The field team consisted of engineering students in a "School of Drones" curriculum at a primarily undergraduate institution, who were presented with a challenge to develop tools for biological study and to advance use of UAS in science missions by "owning the night" and engaging with scientists and local partners.

60-4 EVANS, KM*; SPERSTAD, ZE; WESTNEAT, MW; Brown University, University of Minnesota, University of Chicago; *kory_evans@brown.edu*
Evolutionary Convergence and Constraints on the Skull Shape of Burrowing Wrasses
The evolution of behavioral and ecological specialization can have marked effects of the tempo and mode of phenotypic evolution. Head¤first burrowing has been shown to exert powerful selective pressures on the head and body shapes of many vertebrate and invertebrate taxa. In wrasses (Labridae: Percomorpha), burrowing behaviors have evolved multiple times independently, and are commonly used in foraging and predator avoidance behaviors. While recent studies have examined the kinematics and body shape morphology associated with this behavior, no study to¤date has examined the macroevolutionary implications of burrowing on patterns of phenotypic diversification in this clade. Here, we use three¤dimensional geometric morphometrics and phylogenetic comparative methods to study the evolution of neurocranium shape in fossorial wrasses and their relatives. We test for skull shape differences between burrowing and non¤burrowing wrasses and evaluate hypotheses of shape convergence among the burrowing wrasses. We also quantify rates of skull shape evolution between burrowing and non¤burrowing wrasses to test for whether burrowing constrains or accelerates rates of skull shape evolution in this clade. We find that burrowing wrasses and non¤burrowing wrasses exhibit similar degrees of morphological disparity and exhibit indistinguishable rates of skull shape evolution. These results suggest that patterns of skull shape diversification in wrasses are not constrained by head-first burrowing and that several phenotypes are capable of this behavior.

S2-4 EYCK, HJF; SARMA, RR; CRINO, OL; WATERS, PD; CROSSLAND, M; SHINE, R; ROLLINS, LA*; UNSW, Sydney, NSW, Deakin University, Geelong, VIC, Macquarie University, Sydney, NSW; *l.rollins@unsw.edu.au*
Corticosterone response to experimental manipulation of methylation in invasive amphibian larvae
The role of epigenetic variation as a powerful driver of evolution has received increased attention in recent years. In endocrine systems, it is well-established that the methylation status of certain genes can affect the expression of hormone receptors and patterns of hormone release. For example, across taxonomic groups, epigenetic alterations have been linked to changes in glucocorticoid (GC) physiology. GCs are important metabolic hormones that influence growth/development, transition between life-history stages, and fitness. Few studies to date have examined the role of epigenetic modifications in altering phenotypic traits and fitness in wild animals. Here, we examined the effects of experimentally manipulated epigenetic status on genome-wide methylation and CORT patterns in cane toad (*Rhinella marina*) tadpoles. Cane toads are non-native to Australia and have rapidly expanded their range across the continent, displaying considerable variation with respect to morphology, behavior and epigenetic status. Here, we manipulated methylation via exposure to zebularine and/or predator alarm cues and examined genome-wide methylation patterns and whole animal CORT metabolites at late stages of tadpole development to determine the impacts of these treatments. In full siblings of these individuals, we examined the effects of methylation treatments on time to metamorphosis, adult morphology, and survival. We found that both treatments result in altered methylation, faster time to metamorphosis, and changes in adult morphology and survival. We discuss these results in relation to treatment-induced changes in CORT physiology and the role that epigenetics plays in rapid evolution during invasions.

P2-128 FABER-HAMMOND, JJ*; RENN, SCP; Reed College, Portland, OR; *faberhaj@reed.edu*
Transcriptomics of Haplochromis burtoni parental and fasting behavior reveals extensive differentiation between stocks
Parental behavior has evolved multiple times in animals. Although it is a costly reproductive strategy for the parents, it increases fitness through a higher survival rate in offspring. Cichlid fishes are an evolutionary model system since they have a high propensity for speciation and have undergone recent radiation. In cichlids, parental behavior has independently evolved multiple times. In *Haplochromis burtoni*, for example, females house their broods in buccal sacs in their mouths, which protects underdeveloped fry from predation and environmental pathogens. During mouthbrooding, the females voluntarily fast so they do not accidentally swallow their offspring. In this study, we sequenced transcriptomes from female *H. burtoni* whole brains at different timepoints throughout the reproductive cycle in order to discover candidate genes linked to these recently evolved mouthbrooding and fasting behaviors. We found a suite of genes that are differentially expressed between reproductive timepoints that are involved in oxygen transport, lipid metabolism, and other metabolic processes. Interestingly, genetic background of individuals was far more predictive of transcriptome profiles and may point to bottleneck effects and/or domestication pressures having an outsized influence on gene expression in the brain.

P3-70 FABIAN, ST*; LIN, HT; Imperial College London; *s.fabian@imperial.ac.uk*
Dissecting the Implementation of Dragonfly Guidance Behaviours
Most animals must physically navigate the world towards goals whilst avoiding obstacles. Both elements demand an animal to update its navigational course en route. For dragonflies, these problems are embodied in the daily struggle to hunt enough to eat, navigate to and from perches, and to compete in possibly agonistic conspecific interactions. The selective pressures on the steering requirements of each task may be completely different, despite some conceptual similarities. For instance, while prey, perch, and conspecific may all at times be moving targets, the flight capabilities of conspecifics will rival the dragonflies own, while perching may require more delicate final approaches. The diversity of phenomenological models for flight behaviors allow us to extract unifying features of flight trajectories with which to make comparisons across animal species. However, this approach falls short in addressing the mechanistic implementation of the behavior. To understand how an aerial animal implements a specific visually guided task, we must examine all the body gestures from gaze control to body reactions. We combined high-speed photogrammetry and motion capture techniques to digitize dragonflies as they performed goal-directed visually guided behavior in a custom flight arena in the lab. We have previously shown that dragonflies incorporate predictive and reactive control during prey interception via a series of internal models. This prompted us to design a series of experiments to identify predictive and reactive control motifs in the behavior.

P1-189 FABRE, A-C*; NOIRAULT, E; FERNANDEZ, V; PORTELA-MIGUEZ, R; GOSWAMI, A; The Natural History Museum, London, UK; *fabreac@gmail.com*

Morphological integration of the skull in marsupials: impact of diet and locomotion

Studying the pattern and magnitude of morphological integration and their interplay with environmental factors inducing functional specialization (e.g., diet and locomotion) are central to understanding the evolution of a complex system such as the skull. Integration in the cranial system has been studied from an ontogenetic, phylogenetic and genetic point of view, but few studies have focused on the functional demands imposed by diet and locomotion and their influence on cranial integration. Here, we aim to test the impact of function and ecology on the evolutionary covariation of the cranial system. To do so, we used marsupials as model group as they display a great diversity in diet (going from herbivory to carnivory) and locomotion (from fossorial to gliders). We used high-density geometric morphometric approaches to characterize skull shape for 70 species spanning the full phylogenetic and functional diversity in marsupials. A total of 74 landmarks and ~1,000 curve and surface sliding semi-landmarks were used to define 10 cranial regions. Each cranial region of the skull was analysed separately in order to test for a correlation between the magnitude of integration, morphological diversity, and rate of evolution. Modularity, integration and disparity analyses were performed in order to test whether a more specialized diet or type of locomotion promotes morphological integration and constrains skull shape diversity. Rates of cranial evolution were calculated for each diet and locomotor category in order to test whether the rates of evolution tend to increase or decrease depending on the degree of functional specialization.

118-2 FABRE, A-C*; BARDUA, C; CLAVEL, J; FELICE, RN; BONNEL, J; BLACKBURN, D; STANLEY, E; STREICHER, J; GOSWAMI, A; The NHM, UK, UCL, UK, University of Florida, Florida, USA; *fabreac@gmail.com*

Morphological evolution of the head of Caudata is correlated to rapid diversification and dispersion during warming events

A positive correlation between diversification and rate of phenotypic evolution is predicted by several evolutionary theories, from the ecological theory of adaptive radiation to the hypothesis of punctuated equilibrium. However, most studies of this effect are limited in sampling or representation of morphology. Here, we investigate the relationship between rate of morphological evolution and diversification in the salamander skull using surface geometric morphometrics. These data were gathered for 148 species belonging to all extant families of salamanders. We conducted analyses of taxonomic diversification and rate of cranial evolution in this dataset. Our results demonstrate an increase of the rate of cranial evolution during the Late Cretaceous and the Paleocene-Eocene thermal maxima. These two warming events correspond to diversification and dispersal events in Caudata, as well as in several other clades, such as angiosperms, arthropods, and birds. The high diversification and rate of morphological evolution observed approximately 50 million years ago also correspond to the sole invasion of tropical regions by plethodontids, as well as to their transcontinental dispersion in the northern hemisphere. Our results demonstrate that rate of salamander cranial shape evolution increases during episodes of global warming, alongside increases in taxonomic diversification and geographic dispersal. Further analysis of fine-scale patterns of climate change, niche availability, and their interactions with life history and ecology will provide important new insights into the causes of these increased rates of evolution, diversification, and dispersal in Caudata during periods of global warming.

P2-56 FAIRBANKS, J*; DEMARAIS, A; University of Puget Sound; *jfairbanks@pugetsound.edu*

Effects of Bisphenol-S and Estrogen on p53 Expression in Ovarian Tissue of Zebrafish (Danio rerio)

Bisphenol A (BPA) is one the most widely used plasticizing compounds. As an endocrine disruptor, BPA could affect ovarian function and embryonic development. Bisphenol S (BPS) has been used in many plastics and resins *in lieu* of BPA. However, the effects of BPS are not widely known. Apoptosis is a type of genetically programmed cell death that is important in ovarian homeostasis. One of the genes that regulates apoptosis, *p53*, has been shown to respond to estrogen in maintaining ovarian homeostasis. We have investigated how exposure to estrogen and to BPS affects *p53* expression in ovarian tissue *in vitro*. Zebrafish ovarian tissue was exposed to 0.01, 0.1, and 1.0 μM of BPS or estradiol (E2) and gene expression was quantified using qPCR. Results confirmed non-monotonic dose responses to both BPS and E2, with a trend of increased *p53* expression at the higher concentration of BPS, while the higher concentration of E2 resulted in a trend of decreased *p53* expression. These data suggest that BPS has the potential to affect ovarian homeostasis.

138-7 FALK, JJ*; RUBENSTEIN, D; WEBSTER, M; Cornell University, Ithaca, NY and Smithsonian Tropical Research Institute, Panama, Columbia University, New York City, NY, Cornell University, Ithaca, NY; *j.jinsing@gmail.com*

Female hummingbirds with male-like coloration may avoid aggressive interaction at food resources

A major source of variation in the animal kingdom stems from differences between the sexes. This concept, sexual dimorphism, is typically studied across species with a phylogenetic approach, but can also be studied within species if variation in dimorphism exists (i.e. when one sex varies in similarity to the other). Though frequently found in males, this type of variation is relatively rare in females. Female-limited polychromatism is an evolutionary conundrum because theories typically used to explain ornamentation (e.g. sexual selection) do not readily explain the observed variation in females. Many hummingbird species contain female-limited polymorphism. In one, Florisuga mellivora, ~30% of females captured had ornamented plumage nearly identical to that of the male, while the others had drab coloration. The contexts in which male-like coloration in females might have evolved have not been previously studied, but sexual or territorial harassment have been hypothesized. We observed interactions of wild hummingbirds with taxidermy mounts of male-like females, drab females, and true males at feeders. Male F. mellivora attempted copulations with drab females more often than with male-like females. However, territorial attacks were also more often directed toward drab females than both male-like females and true males. Territorial behavior toward drab female mounts was more frequent than sexual behavior, and sexual behavior in the wild was seen much less often than territorial behavior toward females. Therefore, both sexual and territorial contexts could be relevant, but territorial harassment may be a more important context for the evolution of male-like coloration in female hummingbirds.

P2-186 FALSO, MS*; GUSTAFSON, KL; MARSHALL, LV; FALSO, PG; Slippery Rock University, Slippery Rock, PA; *miranda.falso@sru.edu*

Investigation of Nuptial Pads in Xenopus laevis Exposed to the Pesticide Imidacloprid

Amphibians populations are experiencing widespread and rapid declines in recent years. Amphibians are extremely sensitive to environmental conditions and 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 exposure to a neonicotinoid pesticide on the nuptial pad in a laboratory model amphibian, the African clawed frog, *Xenopus laevis*. Neonicotinoids are widely used to kill insect pests by mimicking nicotine and disrupting function of the nervous system. The nuptial pad contains keratinized hooks and breeding glands sensitive to androgens. Adult male *X. laevis* were exposed to environmentally relevant concentrations of imidacloprid by immersion for 48 days. Photographs of the forelimb area containing the nuptial pad were taken both prior to treatment and at the end of treatment. The intensity and size of the nuptial pads in these images is currently being determined. 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.

P1-257 FALSO, PG*; MARSHALL, LV; GUSTAFSON, KL; FALSO, MS; ZAJAC, JM; STRAIN, SR; Slippery Rock University; *paul.falso@sru.edu*

Effect of Neonicotinoid Pesticide Exposure On The Stress Response In African Clawed Frogs (Xenopus laevis)

Amphibians inhabiting agricultural regions experience multiple stressors resulting from alterations to both the terrestrial and aquatic environment. Local influences on amphibian populations may vary widely, but contamination of surface waters is ubiquitous in intensively cultivated agricultural regions. Altered glucocorticoid (corticosterone) levels have been observed in amphibians exposed to contaminants in both laboratory and field experiments. In addition to primary effects on metabolism, altered corticosterone regulation may in turn influence diverse processes such as development, immunity, reproduction, and behavior. We investigated the effects of exposure to the neonicotinoid imidacloprid, a common active ingredient in systemic insecticides, on the amphibian stress response and associated physiology. Neonicotinoids are the most widely used class of systemic insecticides, have been detected in surface and ground waters, and have noted toxicity to invertebrates. However, relatively few studies have focused on the effects of neonicotinoid exposure to nontarget aquatic vertebrates. Adult male African clawed frogs (*Xenopus laevis*) were exposed to environmentally relevant concentrations of imidacloprid by immersion for 48 days. Plasma corticosterone and associated metabolic and immune parameters were examined from samples collected under baseline and handling-stressed conditions. This study provides insight into the effects of a common aquatic contaminant on amphibian physiology.

136-4 FALTINE-GONZALEZ, DZ*; LAYDEN, MJ; Lehigh University; *dzf215@lehigh.edu*

Determining the role of oral-aboral patterning on neurogenesis in the sea anemone, Nematostella vectensis

Cnidarian nerve nets are believed to represent the ancestral nervous system that gave rise to centralized nervous systems (CNS), a trait of bilaterians. Determining how neural patterning occurs in the net-like ancestral nervous system will allow us to understand the origin and evolution of patterning mechanisms that gave rise to the CNS. Previous work identified neurogenic programs that act broadly to specify *N. vectensis* early neurogenesis, yet the mechanisms that specify neural subtypes are poorly understood. Our work aims to improve our understanding of the developmental mechanisms that control neuronal fate. Previous work suggests that the Wnt gradient established oral-aboral (OA) axis of *N. vectensis* is homologous to the AP axis of bilaterians, and that molecularly defined spatial domains along the OA axis are like those found to pattern the CNS along the AP axis. We hypothesized that spatial domains established by axial patterning cues contribute to neuronal patterning in *N. vectensis*. To test this, we disrupted the cnidarian aboral domain marker *Nvsix3/6*. Loss of *Nvsix3/6* resulted in loss of aboral neural genes while misexpression of *Nvsix3/6* expanded aboral neural gene expression orally. As *Nvsix3/6* is known to regulate known Wnt inhibitors we wanted to confirm that *Nvsix3/6* promotes aboral neuronal fates directly, independent of suppressing Wnt activity. To test this, we overexpressed *Nvsix3/6* in animals treated with the Wnt agonist azenkenpallone. In a high Wnt background, *Nvsix3/6* promoted aboral neural gene expression suggesting that the Wnt gradient patterns the OA axis and neural subtypes in parallel. Our data demonstrate a link between Wnt patterning and neuronal specification in cnidarians and bilaterians but suggest that in bilaterians Wnt signaling specifies axial domains, which in turn promote neuronal fate specification.

P3-164 FAN, X*; SWARTZ, SM; BREUER, KS; Brown University; *kbreuer@brown.edu*

A reduced order computational model to simulate the dynamics of maneuvering flight

A reduced-order computational model that simulates the dynamics of complex animal flight maneuvers is introduced. The body of the animal is treated as a rigid mass connected to two wings and is free to translate and rotate. Each wing is represented by an assembly of short segments with a unique length, orientation and mass. In this way we can model non-planar wing morphologies that can not only flap and pitch, but can also perform complex motions such as twisting and folding. At present, the wing kinematics are prescribed and the model computes both inertial and aerodynamic forces and torques. Blade element momentum theory is used to estimate aerodynamic forces and torques on each wing segment. The wake is modeled using actuator disk theory so that the computed induced velocity field can be used to correct the effective angles of attack. The resultant inertia of the wing and the fluid (the added mass), along with the aerodynamic forces are used as inputs to a Lagrangian equation which computes the animal's translation and rotation. Finally, an optimization scheme finds the kinematics required to execute a wingbeat cycle with minimum energy expenditure under imposed constraints of overall body translation and rotation. Equipped with this model, we are able to simulate a wide variety of flapping flight behavior representative of insect, bird, bat and bio-inspired robotic flight. We can also assess the relative roles of inertial and aerodynamic forces, and estimate power expenditures. Using symmetric wing motions, we study steady, level, climbing and descending flight as well as pitching maneuvers. Considering non-symmetric wing motions, we can also explore more complex maneuvers such as rolling and turning. In all cases, comparisons with previous simulations and with experimental observations are made.

82-4 FARALLO, VR*; MUOZ, MM; Yale University; *vfarallo@gmail.com*

Out of time and out of room: Are montane salamanders vulnerable to extinction due to climate change?

In response to global climate change, many terrestrial species are shifting their ranges poleward or upwards in elevation. Montane species with restricted ranges, however, are limited in their ability to do so and are especially threatened by rising temperatures. Lungless salamanders (Family: Plethodontidae) are highly diverse in the Appalachian region of the United States. This group includes species with extremely wide ranges, like *Plethodon cinereus,* as well as several species restricted to small ranges at high elevations. Understanding, the specific mechanisms that dictate geographic range limits will be critical for mitigating negative impacts of climate change and preserving biodiversity. We will present data on the metabolic, thermal, and hydric physiology of three species of plethodontid salamanders: a widespread species, *Plethodon cinereus*, and two montane endemics, *P. hubrcihti* and *P. sherando*. We examine differences in their physiology including thermal tolerances, thermal preference, metabolic rate, and water loss rates. We integrate these data with field measures of habitat use in a mechanistic niche framework to assess shifts in conditions under future climate scenarios. We then use these data to discuss the best approaches to conserve geographically-restricted species under rapidly changing environments.

P1-36 FARGEVIEILLE, A*; COX, RM; DELANEY, DM; HALL, JM; KAHRL, AF; MITCHELL, TS; PEARSON, PR; REEDY, AM; WARNER, DA; Auburn University, Auburn, AL, University of Virginia, Charlottesville, VA; *akf0020@auburn.edu*

Phenotypic variation of invasive lizard populations following experimental introduction on small islands

Biological invasion offers an opportunity to address phenotypic evolution. For instance, small propagule pressure should reduce genetic variance, and potentially change trait mean values from the original source population. Even at a small geographic scale, closed populations of introduced individuals from the same source population could rapidly differ in phenotypic mean trait value. However, the lag time between species introduction and detection and the lack of information from source populations make it difficult to test this hypothesis in the wild. Established populations of *Anolis sagrei* in Florida are derived from multiple sources, and exhibit high phenotypic diversity. In April 2011, brown anoles were captured in northern Florida and experimentally released on six small islands with similar ecological conditions, but with different habitat structures. The six populations were monitored twice a year until October 2017 to document patterns of survival, population growth, individual body condition and male dewlap size. We show that survival rate varies across space and time and is relatively higher for females and during non-reproductive season. Additionally, adult males with large dewlaps have higher survival. Globally, body condition was positively related to survival during the non-reproductive season, and this pattern reversed during the reproductive season. These patterns of phenotypic selection were similar among islands and were not associated with the number of individuals released, possibly due to inconsistency in phenotypic selection and fluctuation in survival rate.

106-3 FARIA, S*; GOODBODY-GRINGLEY, G; MARANGONI, L; PEREIRA, C; BATEMAN, S; ZILBERBERG, C; MIES, M; KITAHARA, M; BIANCHINI, A; GARLAND, T; NAVAS, C; Bermuda Institute of Ocean Sciences, Monaco Scientific Center, Federal University of Rio de Janeiro, University of São Paulo, Federal University of São Paulo, Federal University of Rio Grande, University of California, Riverside; *scoelhofaria@gmail.com*

Brazilian Phenotypic Plasticity under Climate Changes: an Evolutionary History Scripted in the Coral-Dinoflagellate Symbiosis

A functional symbiotic association between cnidarians and photosynthetic dinoflagellates is widespread in shallow-water corals. Photosynthesis reaches up to 98% of energetic requirements in corals from oligotrophic environments; heterotrophy contributes up to 60% of the energy demand in eutrophic or turbid waters. Bermuda and Brazilian reefs illustrate such opposing water physicochemistry concerning nutrient status and light availability. We evaluated symbiont density and chlorophyll *a* content in 18 coral species from both sites under natural conditions and simulated climate changes (-0.3 pH/+2.5 ^{o}C), followed by phylogenetic comparisons. We tested for higher symbiont density and chlorophyll *a* content in Bermuda corals; higher tolerance to bleaching in the Brazilian ones; and an environmentally driven evolution of coral-dinoflagellate symbiosis. Under natural conditions, symbiont density was greater in Bermuda; chlorophyll *a* content did not differ between sites. After treatment, mean symbiont density reduced ≈30% in corals from both sites. However, despite that mean chlorophyll *a* content reduced 10% in the northern corals, the Brazilian species increased it in 90%, meaning up to a 7-fold boost in the amount of chlorophyll *a* per symbiont. These results reveal strong plasticity in the Brazilian corals, a resilience without phylogenetic effect and potentially driven by the greater water nutrient status, suggesting higher energy budget to the holobiont during bleaching.

P1-41 FARIA, S; University of São Paulo, Bermuda Institute of Ocean Sciences, and University of California, Riverside; *scoelhofaria@gmail.com*

Learning Evolution from Crustacean Physiology: a Phylogenetic Perspective on Habitat Diversification

The current physiological diversity reflects a temporal moment of the entirety of life history, and "species" that are recognized as discrete units actually represent a continuum of biological forms and functions linked to each other through space and time. Closely related species are more similar due to a recent divergence, while those more distantly related tend to share functional dissimilarities. Thus, physiological characteristics observed in living species can be inherited directly from their ancestors, without an *ad hoc* environmental reason. Thereby, the evolutionary process generates two statistical implications in the comparative physiology: the non-configuration of "species" as statistically independent units, and the correlation between physiological traits and historical patterns of speciation. In the scientific literature regarding crustaceans, physiological data sets derived from multiple species have been traditionally interpreted as "states matched to specific environmental conditions", evoking adaptation and propagating bias in designating natural selection as the formative agent of better organic horizons. Such traditional thinking suggests that a graduated series of successively stronger adaptive mechanisms may have driven habitat diversification, however such linking becomes questionable and may hold true only in specific cases after considering the phylogenetic history. Here, I illustrate such epistemological understanding using osmoregulation and metabolism in decapod crustaceans from tropical to sub-Antarctic South America, and from marine to fresh water and terrestrial travelers. I will exhibit how a hierarchical perspective on physiological diversity can answer evolutionary questions and reexamine old paradigms.

90-5 FARINA, SC*; AMACKER, K; CHENNAULT, M; GIBB, AC; Howard University, Northern Arizona University; *stacy.farina@howard.edu*

Kinematic integration of gill chamber pumping with body movements during burial in two morphologically disparate fish species

The ability to bury in sediment has evolved numerous times throughout the actinopterygian phylogeny. Each group that adopts this behavior must co-opt existing structures, leading to a variety of burial strategies. The majority of burying fishes fluidize sediment by injecting water into the substrate, but the structures involved and how they are used varies widely across groups. In this study, we used high speed video and intracranial pressure recordings to document the use of gill chamber pumping, in coordination with body and fin movements, in two highly disparate species: Isopsetta isolepis (a flatfish) and Leptocottus armatus (a sculpin). Like all flatfishes, I. isolepis has two eyes on one side of its head, and it lays on its lateral surface, with the blind-side gill chamber contacting the substrate and the eyed-side gill chamber pointing upward. In coordination lateral body undulations, I. isolepis passes water out of the blind-side gill opening to fluidize sand, which is facilitated by an anatomical shunt between the eyed and blind-side gill chambers. In contrast, L. armatus is a dorsoventrally compressed sculpin. In coordination with dorsoventral undulation and fin movements, L. armatus uses its left and right gill chambers simultaneously to fluidize sand. The flatfish approach is substantially faster than the sculpin approach, although both strategies are highly effective.

P2-38 FARJO, MN*; GEORGE, AB; WESTNEAT, MW; University of Chicago; *mfarjo@uchicago.edu*

Tail Wagging or Fin Flapping? Alternative Locomotor Strategies Drive Body and Fin Shape Evolution in the Surgeonfishes

The evolution of morphological traits in reef fish can provide insight into their ecology and biomechanics. The Acanthuridae display strong morphological diversity, and are a useful group for morphometric analysis in a phylogenetic context. Due to pronounced differences among acanthurids in locomotor behavior, we predict strong patterns of shape association with locomotor mode across the phylogeny, and we focus on caudal and pectoral fin shapes. We propose a new multi-locus phylogeny for the Acanthuridae, incorporating 90% of species diversity within the family. Morphometric landmarks were used to examine whole body shapes and detailed curves were used to examine fin shapes. Phylomorphospace analyses show that pectoral and caudal fin aspect ratios are strongly associated with locomotor mode across the tree. Ecological data relating to the dietary habits of each fish were also charted on the phylogeny, and trends between diet and fin aspect ratio were examined. Finally, integration tests show a strong relationship between body, tail, and pectoral fin anatomy in two alternative patterns. Some clades exhibit shallow bodies, high-aspect-ratio tails, and paddle-shaped pectoral fins, and others display deep bodies, low-aspect-ratio tails, and wing-like pectoral fins. There is a repeated pattern of convergence on these two morphotypes, which also correlates with dietary and lifestyle patterns. Species of the first morphotype are more likely to be pelagic and planktivorous than their reef-associated counterparts. The evolution of morphology and ecology in the Acanthuridae is a story of two alternative patterns determined by locomotor strategies, each with its own strong morphometric signal. Funded by NSF IOS 1425049 and DEB 1541547

P3-109 FARMER, L.*; KRAJNIAK, K.; Southern Illinois University Edwardsville; *lofarme@siue.edu*

The effects of FMRFamide and APKQYVRFamide on the same isolated crop-gizzards of earthworm, Lumbricus terrestris

The motility of the earthworm crop-gizzard is modulated by several neurotransmitters and neuropeptides. Among these molecules are FMRFamide and APKQYVRFAmide. FMRFamide has been found in worms from every annelid class and APKQYVRFamide has been predicted in the mRNA of the earthworm *Lumbricus rubellis*. Previously we examined the effects of these peptides on isolated crop-gizzards of the related worm, *Lumbricus terrestris*. In those experiments, different animals were used to examine the effects of each peptide and we found that both peptides caused decrease in contraction amplitude. However, their effects on contraction rate were highly variable. Since these animals are wild types, we decided to examine the effects of each peptide on the same tissue to determine if there were any changes in contraction rate. The crop-gizzard was removed from the animal and placed in a tissue bath filled with aerated saline. One end of the organ was connected to a stationary support and the other was tied to a force-transducer. Contractions were recorded on a computer using Iworx Labscribe software. Alternating concentrations of APKQYVRFamide and FMRFamide were injected into the tissue bath. The resulting data were used to create log-concentration responses for each neuropeptide. Both peptides caused a decrease in contraction amplitude at 10^{-6} and 10^{-5} M, but FMRFamide showed to be more effective at inhibiting muscle contraction than APKQYVRFamide. FMRFamide caused a biphasic change in contraction rate, with an increase at 10^{-6} M and a decrease at 10^{-5} M. APKQYVRFamide caused an increase in contraction rate at 10^{-6} and 10^{-5} M. FMRFamide was more potent and efficacious in causing the contraction rate increase compared to APKQYVRFamide. The results of this study show that using the same organs to test both peptides yields clearer data than when they are tested in different organs.

P2-107 FARR, D*; DOBKOWSKI, K; University of Southern California and Friday Harbor Labs, Bates College and Friday Harbor Labs; *dfarr@usc.edu*

Scrumptious Sargassum: Feeding Preferences of Pugettia producta

Invasive wireweed (*Sargassum muticum*) may be causing changes in the distribution and abundance of native bull kelp (*Nereocystis luetkeana*) beds in the Salish Sea. *S. muticum* is a perennial seaweed species that may outcompete juvenile *N. luetkeana*, an annual species, for light and/or space at the beginning of the growing season. This interspecific competition prevents the formation of bull kelp forests that are a critical habitat for many ecologically and economically important species. The Northern Kelp Crab, *Pugettia producta*, lives on both *N. luetkeana* and *S. muticum* but previous whole tissue feeding assays in the lab indicate that *P. producta* prefer to eat *N. luetkeana* over *S. muticum*. Here we created artificial food (agar discs "flavored" with *N. luetkeana* or *S. muticum*) to remove the individual algal morphology as a confounding factor in feeding choices. Choice and no choice feeding experiments in this study show that *P. producta* do not show a clear preference for *N. luetkeana* or *S. muticum* when provided with a single food option ("no choice"). However, when given a choice between the two, *P. producta* unexpectedly consumed greater quantities of food containing the invasive *S. muticum*. This has possible implications for the integration of *S. muticum* into nearshore food webs, but surveys are still needed to determine if kelp crabs are actually eating *S. muticum* in the field. If *S. muticum* is consumed in the field and/or has favorable nutritional value, this could help explain our unexpected result. Additionally, kelp crab feeding on *S. muticum* might also indicate some level of top-down control of this introduced species by native herbivores, ultimately leading to additional changes in community structure within nearshore ecosystems.

116-5 FARRAR, VS*; VIERNES, RC; FLORES, L; CALISI, RM; University of California, Davis; *vsfarrar@ucdavis.edu*
Prolactin maintains a parental phenotype in both sexes of the biparental rock dove
Parents of many species often experience reduced sexual behavior and fertility while caring for young to prioritize offspring survival. To test how such reproductive trade-offs are mediated, we investigated the role of prolactin in promoting parental behaviors over sexual ones. As in mammals, prolactin drives avian parental care, including "lactation" in both sexes of the biparental rock dove (*Columba livia*). These traits make rock doves an ideal model for investigating the effects of prolactin on the maternal and paternal brain without the potential for sex-biased confounds of lactation. To test how prolactin alters behavioral priorities, we first removed the nests and eggs chicks of actively breeding pairs, forcing birds to experience a drop in circulating prolactin and revert back to a sexually active, non-parental state. Then, we experimentally manipulated their prolactin levels to reinstate circulating concentrations seen during the parental care period. When offered novel chicks, both sexes given prolactin retained their parental care behaviors, unlike controls, suggesting that elevated prolactin can maintain a parental phenotype, even after loss of a nest. Now, we are testing the effect of prolactin on gene activity of key reproductive neurohormones and their receptors to determine causal mechanisms behind this behavioral shift.

49-5 FASSBINDER-ORTH, CA; Creighton University, Omaha, NE; *carolfassbinder-orth@creighton.edu*
Effects of Arbovirus Infections on Digestive Physiology, Growth, and Survival in Young Animals
Arthropod-borne virus (arbovirus) infections are known to exhibit age-dependent patterns of virulence in their hosts, with the young and old often being the most susceptible to severe infection. In very young mammals and birds, infections with a specific class of arboviruses, called alphaviruses, often result in neuroinvasive disease, impaired growth, and digestive function disturbance. The mechanism by which these viruses impair growth and digestive function is likely complex and not fully understood. In birds, developmental and digestive impairment due to alphavirus infection is evident in both precocial and altricial nestlings, although more severe disease symptoms have been recorded in my laboratory in altricial nestlings compared to precocial nestlings. Alphavirus infection impairs bone growth, tissue maturation, digestive enzyme production, and digestive efficiency in altricial nestling birds in laboratory settings and growth impairment and poor survival have been recorded in nestling birds with alphavirus infections in the wild. This work highlights the high cost of viral infections in young animals and the potentially dire consequences on development and survival.

87-6 FATH, M*; NASIMI, F; TYTELL, E ; Tufts University; *michael.fath@tufts.edu*
Kinematic responses to rolling perturbations during swimming in the bluegill sunfish
Many fishes are unstable in roll. Staying upright thus requires constant coordinated input from multiple fins. To quantify how fish maintain roll stability, we developed a miniature device that produces a controlled jet of water. We sutured it on to bluegill sunfish (*Lepomis macrochirus*), so that they would receive a brief rolling perturbation during swimming at 3 speeds. We measured the kinematics associated with swimming before, during, and after the perturbation, and quantified the time it took the fish to recover. Before the perturbation, the pectoral fins we synchronized in phase or roughly 180 degrees out of phase, but did not coordinate with the caudal fin. The pectoral fin contralateral to the perturbing device was extended to dampen the roll and the fish was able to return to pre-perturbation swimming kinematics within 1.2 seconds at lower swimming speeds and within 0.9 seconds at higher swimming speeds.

81-5 FEILICH, KL*; NITTA, JH; FRIEDMAN, M; University of Michigan, Ann Arbor, Smithsonian Institution, Washington, DC; *kfeilich@umich.edu*
Distribution of morphological diversity, phylogenetic diversity, and speciation rate of freshwater fishes of the United States
The freshwater fauna and hydrography of the United States has been the subject of intense study for more than a century, resulting in an abundance of data concerning the environment and composition of these freshwater communities. We harnessed existing species distribution and phylogenetic resources and joined them with a novel body shape dataset for more than 900 species of freshwater fishes native to the contiguous United States to determine how the spatial distribution of species richness relates to morphological and phylogenetic diversity, and to speciation rate. Species richness of freshwater fishes in the United States follows the drainage patterns of major river basins, with the most diverse communities in the lower Mississippi River basin and southeastern Appalachia. Analysis of phylogenetic diversity revealed a similar pattern, with a small number of phylogenetically over-dispersed communities localized to the Mississippi delta and the southern Atlantic coast. Morphometric diversity was highly correlated with phylogenetic diversity. Although species richness is highest in the eastern half of the country, speciation rate was highest in the west. These distributions suggest exogenous geographic controls on the distribution of species richness and speciation rate.

P2-77 FEINGOLD, SR*; ROARK, AM; Furman University; *sarah.feingold@furman.edu*
Skin Deep: The Estrogenicity of Sunscreens and Moisturizers
Many personal care products contain endocrine-disrupting compounds (EDCs). These compounds can occur naturally (e.g., phytoestrogens) or can be synthetic (e.g., ultraviolet filters and phthalates). Many EDCs agonize estrogen receptors (ERs), thereby stimulating expression of estrogen-sensitive genes; such EDCs are said to be estrogenic. The objective of this study was to quantify the concentration of estrogenic compounds in a variety of sunscreens and moisturizers using the yeast estrogen screen (YES). The sunscreens selected for the study included products with both high and moderate sun protection factors (SPFs). Two strains of recombinant *Saccharomyces cerevisiae* that expressed the alpha or beta isoforms of human nuclear estrogen receptor (ER) were used to quantify ER agonism in ethanol extracts of 42 sunscreens and moisturizers, each of which was measured in triplicate. Estrogenic compounds in a sample activated ERs, resulting in the dose-dependent expression of the reporter gene, beta-galactosidase. This enzyme then cleaved a colorimetric substrate and produced a product that ranged from yellow to red, with the degree of color change corresponding to the concentration of estrogenic compounds present. Of the 42 products tested, over half were positive for the presence of estrogenic compounds. The results of this study indicate that many popular sunscreens and moisturizers contain estrogenic EDCs and suggest that caution is warranted when using such products.

37-6 FELICE, RN*; POL, D; O'CONNOR, PM; GOSWAMI, A; UCL, London, CONICET, Trelew, Ohio University, Athens, OH, NHM, London; *ryan.felice@ucl.ac.uk*
Crocodyliform Cranial Constraint and Convergence
Mesoeucrocodylia (alligators, crocodiles, gharial, and their extinct relatives) is a surprisingly diverse clade of archosaurs that includes carnivorous, omnivorous, herbivorous forms that once occupied a wide range of habitats. Whereas the crown group is comparatively uniform in their morphology, this apparent lack of variation may be a result of functional or developmental bias or homoplasy due to shared semi-aquatic ecology. Here, we investigate the dynamics of skull shape evolution to understand how rates of evolution and disparity have varied across mesoeucrocodylian lineages through time. Previous investigations of skull evolution in the group have focused on subgroups or on 2D geometric morphometric approaches that exclude key aspects of cranial variation (e.g., palate and pterygoid). We quantify whole-skull morphology across the diversity of Mesoeucrocodylia (n=45, including 19 fossils with 7 notosuchians, 2 thalattosuchians, and 10 crocodylians) using high-dimensional geometric morphometrics (1291 surface landmarks and semilandmarks). The most variable parts of the skull are the pterygoid and ectopteryoid, as well as the premaxilla, illustrating that other parts of skull shape beyond craniocaudal elongation are important parts of morpho-functional diversification in this clade. Modelling phenotypic evolution under a variable-rates Brownian motion model reveals high posterior probability of increased rates of evolution at the split between Crocodilia and Alligatoridae and on the terminal branches, suggesting rapid evolution in the crown group. Phenotypic integration is negatively correlated with disparity, supporting the hypothesis that intrinsic bias has constrained cranial evolution. Together, this whole-skull approach illustrates the importance of constraint and convergence in crocodyliform skull evolution.

51-3 FELLER, KD*; SUPPLE, J; GONZALEZ-BELLIDO, PT; Univ of Minnesota, Univ of Cambridge; *kfeller@umn.edu*
Multimodal sensory responses from descending neurons in Squilla stomatopod crustaceans
Though stomatopods (commonly known as mantis shrimp) possess one of the world's most complex visual sensors, we know very little about how this information is used to modulate the animal's motor outputs. Behavioural experiments demonstrate that mantis shrimp modulate their strike speed relative to incoming sensory information, which led us to hypothesize that interneurons in the descending nerve cord encode this information. To test this, two electrophysiological preparations were developed to record from descending neurons in the circumesophogeal connectives (CECs) in t*Squilla mantis* and *Squilla empusa*. During recordings, animals were presented with a variety of visual stimuli as well as tactile stimulation to the anterior antennae. Robust responses were observed in response to looming and moving target visual stimuli, and light touches to the primary antennules. Both looms and mechanical stimulation of the antennules were associated with recruitment of the strike muscles. Light microscopy revealed a population of 7-8 extremely large (50-100 μm) diameter axons that are hypothesized to be the source of these large extracellular responses. These interneurons are good candidates for targeting future intracellular recording experiments in stomatopods and are hypothesized to relay multimodal information from the cerebral ganglion to the inferior motor centers, including the strike motor centers in the subesophogeal ganglion. This study is the first to present stomatopods as a tractable system for investigating the neuroscience principles that govern predictive movement.

105-7 FELTMANN, A*; GIFFORD, M; FIELD, E; University of Central Arkansas; *afeltmann1@cub.uca.edu*
Effect of Selection and Genetic Drift on Phenotypic Diversification in the Eastern Collared Lizard
Organisms display a wide diversity of traits that selection acts upon causing phenotypic change over time. When organisms disperse, however, the resulting small population can experience genetic drift due to decreased genetic diversity within the population. Reintroduction is a common form of population restoration in conservation management plans. The reintroduced populations face challenges that colonizing populations face (i.e. a reduced population number and possible inbreeding). These issues may lead to genetic drift which can majorly impact fitness in the population, potentially leading to population crash. We examined the effects of selection and drift on a metapopulation of the Eastern Collared Lizard (*Crotaphytus collaris*) on Stegall and Thorny mountains in southern Missouri. We measured a suite of morphology and performance traits to assess levels of differentiation between mountains and developed a phenotypic variance-covariance matrix (***P***). Multiple matrix analyses suggest that ***P*** and the levels of covariation between traits differ between populations. Additionally, univariate analyses suggest some traits have diverged between mountains.

P2-33.5 FEO, TJ*; MATLOFF, LY; LENTINK, D; Smithsonian Natural History Museum, Stanford University; *FeoT@si.edu*

The structure and function of feather microstructures related to silent flight in owls.

The flight feathers of owls have several notable features that have long been associated with silent flight including a stiff leading vane comb, flexible vane fringe, and a soft, velvety dorsal surface. However, the precise mechanisms by which these feather features contribute to silent flight is still unclear. Here, we present high resolution CT scans of owl flight feather microstructure obtained from the Advanced Photon Source facility at Argonne National Labs. These scans provide unprecedented insight into the 3D structure and orientation of feather microstructures associated with silent fight. Comparisons of feather microstructure and function with bird species that have noisier flight shed light on possible mechanisms that contribute to reduced sound production during owl flight.

P1-80 FERNANDEZ, Y*; DOWDY, N; CONNER, W; Wake Forest University, Winston Salem, NC; *ferny15@wfu.edu*

Acoustic Communication in Bertholdia trigona (Lepidoptera: Arctiinae): High Duty Cycles Promote Survival and Mating

Tymbalar clicks produced by tiger moths play a role in both natural selection and sexual selection. Some species use clicks to jam bat echolocation and enhance survival. To jam sonar, moth clicks should be produced in a narrow time window, just before the arrival of an echo. One strategy to achieve this time coincidence could be to produce clicks at higher duty cycles (DC). Tiger moth sounds are also involved in the courtship behavior. In most species, males produce sound and females choose among males based on their acoustic signals. Little is known about the critical characteristics of the sound influencing mate choice and the effectiveness of sonar jamming. This study combines behavioral and neurophysiological experiments to evaluate the effect of the DC of moth signals on bat foraging performance and on the moth's mating success. We recorded the echolocation behavior of big brown bats (*Eptesicus fuscus*) attacking tethered moths in a flight room, under the effect of *Bertholdia trigona* signals with different DC (5% – 45%). High DC signals were more effective at deterring bats performance. Neurons from the inferior colliculus of *E. fuscus* were recorded in response to echolocation calls and *B. trigona* signals. The temporal pattern of the neural response to the echolocation signals was disrupted in the presence of moth clicks produced at 25% and 45% DC. Female choice experiments during the mating behavior showed that *B. trigona* males with lower acoustic capabilities (moderate-clickers or silent males) were less successful in mating. These results suggest that both sexual selection and natural selection drive the evolution of high duty cycles and, thereby mold the acoustic repertoire of *B. trigona*.

P3-78 FERREIRA, LF; GARCIA NETO, PG; TITON, SCM; TITON JR, B; GOMES, FR; ASSIS, VR*; Santo Andre Foundation University Center, University of Sao Paulo; *v.regina.a@gmail.com*

Exploring toads immune response with molecular techniques

Glucocorticoids and melatonin show integrated and complex immunomodulatory effects described for mammals, but underexplored in amphibians. In this context, the oligonucleotides development to quantify gene expression of molecules mediating inflammatory processes in amphibians is an innovative way to explore the relationships among molecular biology, stress physiology and immune response in these animals. In this study, toads (*Rhinella diptycha*) received an intraperitoneal injection of saline (APBS) or lipopolysaccharide (LPS; 2mg/kg). Six hours post-injection, toads were bled to measure corticosterone (CORT), testosterone (T), and melatonin (MEL) plasma levels, neutrophil/lymphocyte ratio (NL), and bacterial killing ability (BKA). Then, toads were killed by decapitation and lavage fluid and spleens were collected to measure phagocytosis from peritoneal leukocytes (PP) and quantify gene expression (IL1β, IL6, IL10, IFN-γ and C1s), respectively. As partial results, we found increased CORT ($p=0.05$) and a trend of increased NL and decreased MEL, T and PP in response to LPS. We found IL6 and IL10 upregulation in LPS-injected toads compared to saline-injected ($p \leq 0.05$). These results show toads responded to LPS within this timeframe by secreting cytokines related with immune cells attraction to inflammatory site (IL6), but also secreting anti-inflammatory cytokines (IL10), which would inhibit pro-inflammatory cytokines such as IL1β and IFN-γ. Even without significant differences in most physiological variables for these preliminary results, the patterns found were expected for an inflammatory stimulus: increased circulating CORT (activation of hypothalamus-pituitary-interrenal axis) and decreased circulating MEL (possible activation of immune-pineal axis).

112-5 FETKE, JK*; FLICK, RW; MARTINSON, JW; SEE, MJ; PILGRIM, EM; BIALES, AD; University of Cincinnati, US EPA, Cincinnati, OH, US EPA; *fetkeje@mail.uc.edu*

Investigating the effects of DNA methylation on EE2 induction of Estrogen Receptor alpha gene expression in fathead minnows (Pimephales promelas)

Estrogens present in the environment interfere with endocrine function and cause decreased fecundity, fitness, and sperm production in fish, as well as feminization of male fish. Physiological effects and alterations of gene expression resulting from estrogen exposure have been thoroughly described in fish. Despite this, little is known about epigenetic alterations, although these changes are believed to provide the critical linkage of gene expression with the development of adverse effects at higher biological levels. This study investigates alterations of DNA methylation of *estrogen receptor alpha (ER&αlpha;)* in brain and liver tissue in fathead minnows *(Pimephales promelas)* exposed to either 2.5 ng/L or 10 ng/L of the synthetic exogenous estrogen, 17α-ethynylestradiol (EE2). Methylation differences were assessed across all CpG sites in a 2.5KB region encompassing exon 2 and 1.5KB upstream of the start site of the *ER&αlpha;* gene by targeted deep sequencing of bisulfite treated DNA isolated from liver and brain tissue. Additionally, DNA methylation was assessed from fish depurated for 7 and 14 days to determine the kinetics of methylation. Finally, relationships between *ER&αlpha;* methylation status and gene expression for individual fish were evaluated. Results from this work will provide information regarding the drivers of response to estrogens and the linkage between alterations in methylation status and gene expression.

71-6 FIALKO, KY*; PRICE, TP; University of Chicago; *fialko@uchicago.edu*

Comparative kinematics of Phylloscopus warbler territorial display behaviors

The relationship between animal signals and signaling environment is an active area of research, especially with regard to the adaptation of animal color with respect to visual environment. Recent studies in visual communication have integrated behavior, exploring the interaction between static color signals and dynamic visual displays. However, only recently have all three components – color, display and environment – began to be analyzed together. Old World leaf warblers in the genus *Phylloscopus* are a classic example of the Sensory Drive Hypothesis. In the Western Himalaya, previous research has shown a correlation between habitat darkness and degree of ornamentation, such that species occupying darker habitats have a greater quantity of plumage patches (Marchetti 1993). However, motion in the form of display behaviors also plays a key role in how a visual signal is presented and perceived. With the accessibility of affordable high-speed video cameras, these rapid behaviors can now be quantified and analyzed. We filmed territorial display behaviors of 7 species of *Phylloscopus* warbler and one *Horonis* warbler in the Western Himalaya. We then analyzed the display behaviors by tracking trajectories of wing motion and quantifying shape changes and wing flick rate. Significant variation was found in both the trajectory of wing display behaviors as well as wing flick rate. This work broadly confirms that species with signaling patches tend to display their wings, and this behavior varies interspecifically. A notable exception is in one species that has no patches but lives in exceptionally dark habitats. We discovered this species has a hidden, achromatic patch that is only visible during display, likely functioning in short-range communication.

31-2 FIFER, JE*; BUI, V; BERG, J; GABRIEL, M; BENTLAGE, B; DAVIES, S; Biology Department, Boston University , Marine Laboratory, University of Guam, Marine Laboratory, University of Guam; *jfifer@bu.edu*

Coral Microbial Community Shifts Along a Steep Environmental Gradient

Reef-building corals form complex relationships with a wide range of microbial partners, including symbiotic algae in the family Symbiodiniaceae and various bacteria. The coral's algal and bacterial communities can be shaped to varying degrees by environmental context. Sedimentation can structure a coral's microbial community by altering light availability for symbiotic algae, triggering the coral's stress response, or serving as a reservoir for both pathogenic and essential bacteria and algal symbionts. To examine the influence of sedimentation on a coral's microbial community, we used 16S rDNA and ITS-2 amplicon sequencing to characterize the bacterial and algal communities associated with the massive scleractinian coral *Porites lobata* across a naturally occurring sedimentation gradient in Fouha Bay, southern Guam. In addition to sedimentation, we are also investigating the relative contributions of other environmental parameters (i.e., temperature, salinity) to the coral's algal and bacterial communities and how these communities differ within a single colony (i.e., edge vs center). Along this gradient we see that sedimentation is higher and salinity and temperature are generally lower closer to the river mouth compared to the reef crest. Together these variations in environmental parameters play a strong structuring role in the coral's algal community and microbiome and these spatially structured communities may help corals thrive across this steep environmental gradient.

P3-208 FINKLER, MS*; RHODA, MA; Indiana University Kokomo; *mfinkler@iuk.edu*

Separating the effects of temperature on embryonic growth and development in Chelydra serpentina.

Temperature influences both development rate and growth rate in ectothermic vertebrates, but it is unclear whether both processes have similar thermal sensitivity. To determine whether growth and development rates parallel one another at different temperatures, we incubated snapping turtle eggs under four different thermal regimes: a constant 25°C, a fluctuating temperature of 12h at 29°C and 12h at 21°C (constant temperature equivalent [CTE] = 26.6°C), a constant 30°C, and a fluctuating temperature of 12h at 34 C and 12h at 26°C (CTE = 31.1°C). We used a model developed by Rollinson et al. (2018, J. Therm. Biol.) to estimate the time needed for the embryos at different temperatures to develop to particular development stages corresponding to the end of neurulation (Yntema stage 12), organogenesis (Yntema stage 15), and early growth (Yntema stage 18). At stage 12, embryos in the 25±0°C treatment had the largest head lengths, eye diameters, and dry masses, whereas those incubated at 30±0°C were the smallest. Similar differences in size measures among thermal treatments were present at stage 15 and stage 18. Hatching occurred earliest in the eggs incubated at 30±0°C and was latest in those incubated at 25±0°C and 25±4°C. Live mass, linear measurements, dry yolk sac mass, and dry yolk-free carcass mass at Day 7 post-hatching were generally similar among treatments. The findings suggest that embryonic growth rate may be less sensitive to variation in temperature than is embryonic development rate, enabling embryos at lower temperatures to grow to larger sizes at a given developmental stage. However, the size of the hatchlings appears to be relatively independent of temperature. Rather, egg size appears to be the main factor determining size at hatching.

P3-88 FIRNENO, TJ*; EMERY, AH; ROELKE, CE; FUJITA, MK; The University of Texas at Arlington, Arlington, Texas; *thomas.firneno@uta.edu*

Investigating Toxin Evolution in the Bufonid Parotoid Gland

Defensive toxins are found in a plethora of vertebrate and invertebrate taxa, and have played a large role in the diversification and co-evolution of many taxa. Within the amphibian world there are a number of taxa that exhibit defensive toxins as part of their natural history. Bufonids, or "true toads," are a group of organisms that have gone relatively understudied in terms of their defensive toxins, which are secreted through the parotoid gland on the back of their head. Here we utilize RNA-Seq techniques to characterize and evaluate the bufonid parotoid gland transcriptome. We aimed to identify candidate genes that are involved in the synthesis of toxin peptides and metabolites, identify if any of these genes are different between species of bufoids found in North America, identify if any of these genes are under selection, and identify peptides or metabolites that may play a role in the delivery of the toxins into the prey.

81-3 FIRNENO, TJ*; O'NEILL, JR; PORTIK, DM; EMERY, AH; TOWNSEND, JH; FUJITA, MK; University of Texas at Arlington, Arlington, Texas, Indiana University of Pennsylvania, Indiana, Pennsylvania, University of Arizona, Tucson, Arizona; *thomas.firneno@uta.edu*

Mitonuclear discordance Reveals Cryptic Genetic Diversity, Gene Flow, and a Complex Demographic History in a Problematic Complex of Mesoamerican Toads

Mitonuclear discordance can be caused by several evolutionary processes including incomplete lineage sorting, genetic polymorphism, and gene flow. Here we utilize the *Incilius coccifer* complex, a complex of three species (*I. coccifer*, *I. ibarrai*, and *I. porteri*) found throughout eastern Nuclear Central America that has had a history of taxonomic debate. By integrating mitochondrial DNA and nuclear loci from ddRADseq, along with comparative and integrative model testing, we have uncovered a more resolved population genetic structure amongst the three species that reflects the complex geography of the region, strong mitonuclear discordance between the lineages, and gene flow between populations of *I. poteri* within Honduras. We applied population clustering and phylogenetic inference to test hypotheses of population structure, as well as demographic analyses to test hypotheses related to population divergence and gene flow. Our results support the existence of three separate lineages within the complex, reflecting the current taxonomy; however, the lineage of *I. poteri* does not reflect the current recognized range of the species in Honduras. Our results also indicate the introgression within populations of *I. porteri* in central Honduras. Our results suggest that introgression and also divergence was most likely caused by range fluctuations due to past climatic instability.

18-7 FISCHER, EK*; PIERSON, E; PETRILLO, R; ELLIS, G; LAGERSTROM, KM; O'CONNELL, LA; Stanford University, Harvard University, Harvard University; *efisch@stanford.edu*

Tadpole Fight Club: Neural Mechanisms of Juvenile Aggression in Poison Frogs

Resource competition is a major driver of aggressive interactions among conspecifics, both at acute and evolutionary timescales. Aggressive interactions among siblings competing for resources is well documented; however, the mechanisms mediating juvenile aggression are poorly understood. In poison frogs, increased parental care is associated with decreased water volume of tadpole deposition sites resulting in increased resource competition and aggression. Indeed, the tadpoles of many poison frog species will attack, kill, and cannibalize other tadpoles. We examined the neural basis of conspecific aggression in *Dendrobates tinctorius poison frog tadpoles by comparing patterns of generalized neural activity as well as specific candidate molecules across tadpoles that won aggressive interactions, lost aggressive interactions, or did not engage in a fight. We found that distinct patterns of neural activity predicted whether individuals won or lost aggressive encounters. Increased activity of vasotocin neurons (the non-mammalian homologue of the nonapeptide arginine vasopressin) was associated with increased aggression. We further tested this association by characterizing the effect of vasotocin level manipulation on fight outcome. Given widespread functional conservation of the neural mechanisms underlying social behavior, we suggest that mechanisms mediating aggression in poison frog tadpoles may contribute to juvenile aggression across vertebrates.*

108-7 FISH, FE*; LEAHY, AM; KULKARNI, AA; LEFTWICH, MC; West Chester University, George Washington University, George Washington University; *ffish@wcupa.edu*

Hydrodynamics of a Crenelated Delta Wing Design of the Hindflippers of the California Sea Lion

The pectoral and pelvic appendages of the California sea lion (*Zalophus californianus*), like other pinnipeds, have been modified as flippers for movement in water. Unlike the foreflippers, which have a wing-like appearance and oscillatory movement for propulsion, the hindflippers are not used for thrust production in water, although the hindflippers are involved in terrestrial locomotion. The hindflippers are used as control surfaces for maneuvering underwater. When the digits of the flipper are abducted (spread), the hindflipper has a triangular planform. This design is similar to a highly swept delta wing. In addition, fleshy extensions of the digits provide a crenelated trailing edge to the flipper. To investigate its hydrodynamics, a hindflipper was spread and CT scanned to determine the three-dimensional geometry. Based on the CT scans, three models were printed: unmodified with crenelations, crenelations cut, and crenelations filled in. The lift and drag forces for each model was determined from flow tank testing at 1.0 and 1.5 m/s for angles of attack ranging from -25 to +25 deg. The lift coefficients with respect to angle of attack were similar for the three models and like delta wings they did not stall at highest angles of attack tested. The crenelated flipper had the higher maximum Lift/Drag ratios at higher positive and negative angles of attack compared to the modified flippers. The design of the hindflippers in sea lions as a delta wing with a crenelated trailing edge is useful for sea lions as a passive control surface at high angles of attack to execute sharp turning maneuvers.

P3-120 FISH, FE*; SEGRE, PS; POTVIN, J; GOLDBOGEN, JA; West Chester University, Stanford University, St. Louis University; *ffish@wcupa.edu*

The Upper Jaw of Rorquals Can Act as a Delta Wing for Stability during Lunge Feeding

During lunge feeding by rorquals (e.g., blue, humpback, minke whales), the lower jaw is depressed as the throat pouch is inflated to engulf a large mass of prey-laden water. The resulting increase of mass of the whale and drag from inflation of the pouch could result in down-pitching torque of the head. A previous model for a rorqual estimated that an opposite rotation could produce lift generated from the pectoral flippers to help offset the downward pitch and stabilize the body in trim. Videos from suction-cup tags mounted on the backs of feeding rorquals showed that not only are the flippers deployed with a positive angle of attack for lift generation, but the upper jaw is elevated with a positive angle of attack. The planform of the upper jaw has a modified acute triangular shape that is similar to a highly swept delta wing. Delta wings are capable of generating lift without stalling at higher angles of attack than unswept wings that typically stall at 11 deg. Data from published accounts and videos of lunge feeding rorquals indicate that the angle of attack for rorquals varies from 11.8 to 31.8 deg. Based on morphological data from aerial drones and kinematic data from tags of known whales, a computational analysis based on a delta wing of lift production was performed. The maximum lift from the upper jaw was calculated to be 2136, 8015, and 18562 N for minke, humpback, and blue whales, respectively. The lift from the upper jaw in concert with the flippers could stabilize the body during lunge feeding.

44-4 FISHER II, AL*; DESJARDINS, N; DEGRANDI-HOFFMAN, G; SMITH, B; JOHNSON, M; KAFTANOGLU, O; COGELY, T; FEWELL, J; HARRISON, J; Arizona State University, United Stated Department of Agriculture - Agricultural Research Service; *afishe16@asu.edu*

A widely-used fungicide produces symptoms of colony collapse disorder in honey bees (Apis mellifera)

Honey bee (*Apis mellifera*) and other pollinator populations are declining worldwide for unexplained reasons, threatening over $12 billion in agriculture that depends on pollination services. Fungicides are applied to prevent rot diseases while many crop plants are in bloom, leading to wide consumption by pollinators. Field colonies of honey bees were forced to feed on pollen containing Pristine®, composed of the fungicides boscalid and pyraclostrobin, at four doses ranging from 0.1 to 100x levels previously reported for agricultural pollen. Pristine® consumption produced the symptoms of colony collapse disorder, reducing colony adult populations in a dose-dependent manner with foragers dying outside the hive, and reducing over-winter survival. Pristine® consumption lowered colony populations by causing workers to forage and die earlier. Pristine® consumption reduced forager associative learning abilities, potentially reducing pollination efficiency and contributing to "lost foragers." Pristine® increased colony pollen foraging and storage, suggesting it may act by interfering with protein digestion or absorption, perhaps by inhibiting intestinal mitochondria. Together, these findings suggest that fungicides play a significant role in pollinator decline and that the safety of fungicides for pollinators must be re-evaluated. This research was supported by USDA 2017-68004-26322.

26-6 FISSETTE, SD*; BUSSY, U; HUERTA, B; LI, W; Fisheries and Wildlife, Michigan State University, East Lansing, MI; *sdfissette@gmail.com*

Diel Pattern of Pheromone Production and Release in Sea Lamprey, Petromyzon marinus

During reproduction, it is vital for animals to coordinate the timing of behavioral and physiological cycles. The sea lamprey, *Petromyzon marinus*, relies on pheromone communication for reproduction. Sexually mature male sea lamprey release a multicomponent sex pheromone through their gills that attracts mates. Sea lamprey are primarily nocturnal, but it is unknown if male pheromone release is consistent with this behavioral pattern. We investigated if sea lamprey exhibit a diel pattern of pheromone release, and whether it is driven by biosynthetic production or is a byproduct of elevated respiration due to increased behavioral activity. We quantified pheromone release and production by measuring 3keto-petromyzonol sulfate (3kPZS, a main pheromone component) and its biosynthetic precursor petromyzonol sulfate (PZS) in holding water and tissue samples at 6 different times of day. Behavioral activity and respiration rates were measured using visual observations and video analysis. 3kPZS release exhibited a diel pattern with elevated release during nighttime hours. This pattern was disrupted by holding lamprey in constant darkness or light for 7 days. Trends in hepatic synthesis and circulatory transport of PZS and 3kPZS were consistent with 3kPZS release, whereas trends in respiration rates were less consistent. Our results suggest elevated levels of pheromone production and release at night evolved to match nocturnal increases in behavioral activity. Synchronizing these cycles may be imperative for reproductive success by ensuring reproduction occurs at optimal times, which is especially important in a species having a single, reproductive event.

113-1 FITAK, RR*; WHEELER, BR; NAISBETT-JONES, LC; SCANLAN, MM; NOAKES, DLG; JOHNSEN, S; University of Central Florida, Duke University, University of North Carolina, Oregon State University; *robert.fitak@ucf.edu*

Time-dependent Characterization of Candidate Magnetoreception Genes in the Brain of Chinook Salmon

Although numerous animals are known to use Earth's magnetic field for orientation and navigation, the underlying mechanism of this magnetic sense remains poorly understood. In trout, we previously showed that a magnetic pulse elicits gene expression changes in the brain, whereas this same pulse had little effect in the retina. This result suggested that the brain may be a possible location of a magnetoreceptor and that genes associated with iron regulation (e.g. *frim*) and the development and repair of photoreceptive structures (e.g. *crygm3, purp, crabp1*) are possibly associated with a magnetic sense. Further characterization of these candidate genes is necessary to understand their potential role in a magnetic sense. In this study, we examined changes in the expression of various candidate genes and those involved in iron regulation in the brain of Chinook salmon (*Oncorhynchus tshawytscha*) after exposure to the same magnetic pulse. We quantified gene expression relative to control fish across eight timepoints in a 48 h window (10 m, 30 m, 1 h, 3 h, 6 h, 12 h, and 24 h) using a novel, high-throughput gene counting technology. The results discussed provide important details regarding the potential role of cellular iron regulation and photoreceptive structures in the salmonid magnetic sense.

P3-22 FITZGERALD, RP*; CHANDLER, C; SUNY College at Oswego; *rfitzger@oswego.edu*

Determining Sex Specific Loci in the Genome of the Terrestrial Isopod Porcellio scaber

The sex chromosomes of terrestrial isopods have a complex evolutionary history. This complexity may result from infection by the endosymbiotic bacteria *Wolbachia*, which can exert feminizing effects on male hosts in isopods. Over time, this pressure selects for novel sex chromosomes or sex determination processes in isopods. Being able to chart the sex specific regions of non-infected individuals provides a model for understanding the evolution of sex chromosomes. Using isopods presents a new model organism for testing and mapping the evolution of these unique sex chromosomes. The species of interest in this project, *Porcellio scaber*, has a ZZ/ZW sex determination system, similar to the species *Armadillidium vulgare*. However, phylogenetically, *P. scaber* is more closely related to *Trachelipus rathkei*, which has an XX/XY system. In addition, W-linked markers have been identified in the *A. vulgare* genome, but not in *P. scaber*, and so it cannot be determined if the *P. scaber* W chromosome is homologous to *A. vulgare*, or if it evolved independently. The ultimate purpose of the project is to determine what loci are associated with sex specific portions of the *Porcellio scaber* genome by testing for sex-specific PCR primers, and ultimately to understand how these regions influence development, anatomy, and behavior. This research has the potential to expand the potential range of isopods as model organisms for studies in the evolution of sex and sex chromosomes.

86-3 FLEMING, JML*; CARTER, AW; SHELDON, KS; University of Tennessee, Department of Ecology and Evolutionary Biology ; *jflemi17@vols.utk.edu*

Beetle Pupae Show Tradeoff Between Metabolic Depression and Body Size in Response to Increased Temperature Mean and Variance

Climate change is causing increases in temperature mean and variance. Organisms may respond to temperature changes during development, but few studies have examined physiology of early life stage as a mechanism to mediate the impacts of climate change. Using the dung beetle *Onthophagus taurus*, we investigated the potential of metabolic depression in an early life stage to buffer beetles from climate change. Specifically, we examined the effects of increasing temperature mean and variation on metabolism of pupae and fitness of adults using body size as a proxy. We reared beetles in nine incubation treatments using a full factorial design: three averages (22, 24, 26°C) and three fluctuations (±2, ±4, ±8°C) in temperature. At pupation, we measured thermal sensitivity of metabolism (TSM), the relationship between temperature and metabolic rate. We reared beetles to adulthood and measured body size. The relationship between temperature and metabolic rate was affected by developmental incubation; temperature mean and variation interact to influence pupae TSM (p= 0.002). Beetles reared in the warmest, most variable treatment exhibited significant metabolic depression across temperatures and significantly smaller body size. Thus, the reduction in energetic costs showed a tradeoff with body size. These findings suggest plasticity in early life stages can help beetles cope with thermal environments during development, but this may come at a cost to fitness later in life.

P2-82 FLETCHER, SJ*; DE-JESUS SOTO, MG; RODRIGUEZ, SD; PRETENDS EAGLE, TJ; PETANIDOU, T; TSCHEULIN, T; BARTHELL, J; GIRAY, T; ABRAMSON, CI; Southeastern Oklahoma State University, University of Puerto Rico, St. Philip's College, North Dakota State University, University of the Aegean, University of Central Oklahoma, Oklahoma State University; *sfletcher36@student.se.edu*

Memory of the cap pushing response in honey bees (Apis mellifera cecropia)

In this experiment we investigate whether bees trained to push a cap to reveal a hidden food source (CPR) have memory of such training. Data gathered in harnessed bee preparations such as those associated with the classical conditioning of the proboscis extension response (PER) or of the sting extension response (SER) the memory can last up to two or three days. The memory of free flying bees trained to visit a target has not been as widely investigated, but the published data suggests that it also lasts for several days. Typically, in the free flying experiment bees are terminated so not to contribute potential new recruits to the training situation and to avoid using the same bee in an experiment. In the course of conducting various CPR experiments in Lesvos, Greece, we would dispatch the bees following the specific experiments. To provide some data on memory of the CPR, we decided not to terminate the bees to gather data on whether the bees would retain some memory over a two-week period in June. We decided to report how many bees we observed returning to the target site and pushing the cap. Over the period we observed 29 bees return to the target site and push the cap to reveal the hidden food source. Of the 29 bees, 1 bee returned 48 hours later. The remaining 28 bees returned between 12 and 24 hours. We could not do a formal laboratory experiment because of space and time limitations. Nevertheless, our observations show that bees have a memory of the CPR that can last at least 48 hours. This research was supported by NSF REU grant 1560389 and NSF PIRE grant 1545803 and performed at Skala Kalloni Greece.

P2-83 FLETCHER, SJ*; DE-JESUS SOTO, MG; RODRIGUEZ, SD; PRETENDS EAGLE, TJ; PETANIDOU, T; TSCHEULIN, T; BARTHELL, J; GIRAY, T; ABRAMSON, CI; SE Ok St Univ, Univ of Puerto Rico, St. Philip's College, NDSU, Univ of the Aegean, Univ of Central Ok, Ok State Univ; *sfletcher36@student.se.edu*

Discriminate punishment of the cap pushing response in honey bees (Apis mellifera cecropia)

Our previous experiments with the cap pushing response (CPR) have all used appetitive conditioning. We now explore whether we could incorporate punishment into the CPR paradigm. Both food wells contain a 50% sucrose solution, but only one target was punished (cap or cross). Sixteen honey bees were selected from the laboratory feeder and randomly placed into one of two groups. In one group pushing a cross was punished with a 9 VDC shock and pushing a cap was not. In the other group pushing the cap was punished with a 9 VDC shock and pushing the cross was not. Each bee received 12 training trials in a simultaneous punishment situation in which both targets were presented. For half the bees the punished target was the cross, for the remaining 8 bees the punished target was the cap. The dependent variables were the number of shocks received and the proportion of bees landing on the unpunished target. The results indicated that as the 12 trials progressed, the proportion of bees selecting the unpunished target increased. By trials 11 and 12 no bee received punishment. Moreover, as the number of trials increased the number of shocks received by the bees decreased. Early in training, some bees received 4 and 5 shocks per trial as each push of the incorrect target resulted in a shock. Some bees had a position preference that had to be overcome before they would push the unpunished target. Our results show that punishment is effective in modifying the decisions of honey bees and was similar to what we previously found using a proboscis conditioning situation in harnessed forager bees. This research was supported by NSF REU grant 1560389 and NSF PIRE grant 1545803 and performed at Skala Kalloni Greece.

P2-95 FLETCHER, SJ*; DE-JESUS SOTO, MG; ABRAMSON, CI; BARTHELL, J; PETANIDOU, T; TSCHEULIN, T; GIRAY, T; SE Ok St Univ, Univ of Puerto Rico, Ok State Univ, Univ of Central Ok, Univ of the Aegean; *sfletcher36@student.se.edu*

Incentive Contrast vs Optimal Foraging in Honey Bee Decision Making

We compared honey bee foragin strategies based on reward and effort on an artificial flower patch. The study aimed to test if bee foraging choice is based on past experience of reward quality and effort (incentive contrast) or on energy gain over time (optimal foraging). The bees visiting a feeder with lower sucrose concentration were trained to visit the flower patch. The patch has 18 blue and 18 white Plexiglas "flowers" of 1.2”x1.2” with a central well for "nectary”. The effort to visit flowers was increased by inserting short (~5mm) or long(~20mm) pins in a pattern on the flowers. We presented low (0.5M), intermediate (1M), or high (2M) reward of 4µl sucrose solution in flowers. In experiment 1 bees began on flat flowers with 1M reward, after 35 visits switched to short stamen flowers (35 visits), later to long stamen flowers (35 visits). After the long, difficult flowers in the 2nd control phase, bees were asked to chose high reward high difficulty blue flowers vs low reward low difficulty white flowers (50 visits). In Experiment 2 bees were asked to make the same choice after the short, low difficulty flowers in the 1st control phase. The Incentive Contrast Hypothesis predicts difference in choices of bees in Experiment 1 and 2. In contrast, the Optimal Foraging hypothesis predicts no difference. Significantly greater number of bees (Median Test, $P<0.03$, Exp 1 median =0; Exp 2 median =3) visited more of the white, low difficulty low reward flowers in Experiment 2 (n=8) in comparison to Experiment 1 (n=11). Results support the Incentive Contrast hypothesis. NSF REU grant 1560389 and NSF PIRE grant 1545803 supported this research at Kalloni Bay, Lesvos, Greece.

P3-113 FLETCHER, ML*; BARRETT, LM; DEAROLF, JL; THOMETZ, NM; BRYAN, A; REICHMUTH, C; Hendrix College, Conway, AR, Univ. of San Francisco, CA, Alaska Department of Fish and Game, Fairbanks, Univ. of California, Santa Cruz; *fletcherml@hendrix.edu*

Fiber-type profile of bearded seal (Erignathus barbatus) longissimus dorsi muscle

Bearded seals (*Erignathus barbatus*) are benthic-feeding, Arctic pinnipeds that typically do not dive past 100 meters. Knowing the physiology of their locomotor muscles could increase our understanding of how they dive, feed on the bottom, and swim between their feeding grounds and haul-out sites. Thus, the goal of this project was to quantify the percentages of slow- and fast-twitch fibers in the longissimus dorsi (LD) muscle of bearded seals. To achieve this goal, 9 and 11 µm thick sections of bearded seal LDs were cut with a cryostat and stained for their myosin ATPase activity after basic incubation. Additional sections were stained for two different myosin heavy chain antibodies: SC-71(anti-fast-twitch type 2A myosin) and A4951(anti-slow-twitch type 1 myosin). All of the stained sections were then imaged, and images of the three stains were taken from identical regions in each section. The images of the ATPase-stained tissue were used to identify and count darkly (fast-twitch) and lightly (slow twitch) staining fibers, as well as intermediately staining fibers. These data were used to determine the average percentages of these fibers in the LDs of bearded seals. We also used ImageJ software to measure the diameter of each type of fiber. The fiber-type profile of the bearded seal LDs, as well as the sizes of the fibers, will be compared to those of the LDs of two other Arctic seals, ringed and spotted. This comparison will allow us to identify any differences in these features between their locomotor muscles that may underlie the differences in swimming and diving abilities that exist between these three Arctic seal species.

P3-11 FLOOD, S*; DEPAOLA, N; MOODY, T; MASS, S; ST. JOHN, P; SUNY New Paltz; *floodb1@hawkmail.newpaltz.edu*

Quantification of BPA Retention in Planaria

Bisphenol-A (BPA) is a xenostrogenic environmental pollutant produced in large quantities by human industry, including plastic manufacturing and packaging for consumer goods, in health and beauty products and in the thermal printing industry. We have developed protocols using High Performance Liquid Chromatography (HPLC) and Gas Chromatography/Mass Spectrometry (GC/MS) to quantify BPA in freshwater planaria (*G. tigrina*) exposed to media containing known quantities of BPA. Continuing refinement of these methods has permitted us to measure BPA in pico molar quantities in planarian tissue. Prior work in our lab has demonstrated that exposure to Bisphenol compounds severely affects planarian behavior and regenerative capacity. These chromatography methods should now permit future work to correlate phenotypic abnormalities with specific quantities of BPA retained in tissue.

P2-219 FLORES, E*; DUMAN, A; AZIZI, E; University of California, Irvine; *aduman@uci.edu*

The effects of extrinsic loading on the coordinated landings of Rhinella marina

During landing the musculoskeletal system is responsible for dissipating mechanical energy, causing the body to undergo rapid decelerations. Previous work has shown that landings are associated with high loading regimes where ground reaction forces can exceed four times body weight. We aimed to understand the upper limits of energy dissipation during landing in *Rhinella marina* by artificially increasing body mass in order to lower the muscle mass to body mass ratio. We compared the kinetics and kinematics of the landing using force plate ergometry and high-speed video *R. marina* (n = 5) across three conditions: 100%, 110%, and 120% Body Weight. The overall landing performance was characterized by quantifying the forelimb kinematics, the rates and magnitudes of impact forces, and the energy dissipated by the forelimbs normalized to the total energy of the system. Our results illustrate a significant difference in landing kinematics after increasing the individual's overall body mass. The result of these experiment shed insight on how decreased muscle mass relative to body mass affects locomotor performance and how locomotor behavior adapts to safely dissipate impact energy. This work may have broad implications for the limits of energy dissipating tasks in conditions such as muscle atrophy, gravidity, or obesity.

P3-114 FLORES, JP *; GAD, M; BUSHONG , E; SCHULZ , JR; Occidental College; *jflores3@oxy.edu*

From Sequence to Activity: Synthetic Neuroexcitatory Peptides from Fish-Hunting Cone Snails

Venomous marine cone snails (genus Conus) possess a high diversity of post-translationally modified peptide neurotoxins (conotoxins) . Our studies focus on the A-superfamily of conotoxin encoding genes from the fish-hunting cone snail, C. catus. A-superfamily members encode α-conotoxins and αA-conotoxins that cause flaccid paralysis by inhibiting nicotinic acetylcholine receptors (Azam and McIntosh 2009). In the pionoconus subgenus of fish-hunters that includes C. catus, the A-superfamily also encodes neuroexcitatory peptides (NEX) that induce rapid tetanic paralysis due to the overstimulation of neurons (Schulz 2004). NEX peptides have a novel target currently under investigation. Additionally, previous studies have shown that α4/7 conotoxins target a variety of neuronal-type nicotinic acetylcholine receptor (nAChR) subtypes, which could provide insight into the physiological roles of these receptor subtypes in pain, inflammation, nicotine addiction, Alzheimer's disease, and Parkinson's disease. Therefore, investigation of sequences encoding peptides in the A-superfamily from a diverse group of cone snail species would likely yield novel peptides for study. The focus of this research is on the isolation of gDNA from museum specimens for deep amplicon sequencing of A-superfamily members. Utilizing a comparative approach, we analyzed the sequences for novel NEX peptides and had select peptides synthesized. These peptides were folded into active conformations, and RP-HPLC was used to purify and quantify the samples. Protein folding was confirmed via mass spectrometry, and the activity of these peptides was investigated utilizing novel approaches developed to identify potential high affinity targets in the zebrafish model system.

117-5 FLORKOWSKI, MF*; YORZINSKI, JL; Texas A&M University; *mflorkow@tamu.edu*

D2 Dopamine Receptor Activation Induces Aggression in Male House Sparrows (Passer domesticus)

Social species, including gregarious birds, often use aggressive interactions to secure resources and establish dominance hierarchies within their social groups. Dopamine is an important neurotransmitter that may play a role in regulating aggression, but we know surprisingly little about its effect on aggressive behaviors. In this study, we tested the hypothesis that D2 dopamine agonists and antagonists influence aggressive behavior in house sparrows (*Passer domesticus*), a social species that lives in groups throughout the year. We monitored the behaviors of pairs of captive male house sparrows before and after they were injected with D2 agonists, D2 antagonists, or controls. Preliminary analyses suggest that D2 dopamine agonists increase aggressive behavior while D2 dopamine antagonists suppresses aggressive behavior. The effects of the D2 dopamine agonists were most pronounced in birds with higher social status. The results of this study suggest that aggressive behaviors are regulated by dopaminergic pathways.

P3-67 FOLFAS, E*; COX, C; MCMILLAN, WO; LOGAN, ML; Univ of Toronto, Georgia Southern Univ, Smithsonian, Univ of Nevada; *edita.folfas@mail.utoronto.ca*

Changes in escape behavior in a terrestrial vertebrate after experimental transplantation to a novel environment

Animal behavior is linked to fitness in novel environments; however, this link is still poorly understood. An important behavioral trait is boldness, which is often indexed as flight initiation distance (FID), or the minimum distance at which an individual flees from a threat. FID is expected to maximize an individual's chances of survival and is inversely related to boldness. Bolder individuals may be favored in the absence of predators as they are more likely to gain foraging opportunities and encounter mates, however as predation rate increases, boldness is likely to be a disadvantage to survival. It is still unclear if this behavior is evolutionarily conserved or responds quickly to rapid environmental changes. To address this question, we transplanted hundreds of lizards (*Anolis apletophallus*) to experimental islands in Lake Gatún, Panama that differ from the mainland in both their biotic and abiotic environments. These islands have fewer predators, are warmer and have brighter understory light conditions. We measured FID on the mainland source population, as well as on island populations that had been diverging from the mainland for one or three generations. At each site, we measured predation pressure via attack rates on clay models and visual surveys of predator communities. We compare these data to a suite of environmental and physiological variables to determine what may drive changes in lizard boldness. Preliminary results show that FID is lower in the island populations that have been diverging for longer, and that individuals on the mainland have higher FID relative to all islands. These results suggest that boldness may evolve rapidly when populations are released from predation pressure.

19-4 FONTAINE, SS*; KOHL, KD; University of Pittsburgh, PA; *ssf20@pitt.edu*

Temporal effects of temperature on tadpole gut microbial communities

Environmental temperature impacts all aspects of ectotherm physiology, and also alters the composition, diversity, and function of their gut microbial communities. Alterations to gut microbiota at high temperatures may result in negative consequences for host performance and survival. However, it is currently unknown how quickly the gut microbiota responds to changes in temperature. Here, we investigated the temporal effects of temperature on the gut microbiota of two tadpole species, the green frog, *Lithobates clamitans,* and the bullfrog, *L. catesbeiana*. We housed tadpoles in captivity, exposed half of the animals to a 5°C increase in temperature, and collected whole gut samples at six time points, ranging from 12 hours to 10 days, following the temperature change. We found host species-specific differences in microbial community response to temperature. Bullfrog-associated communities were altered within 12 hours, while those of the green frog took 4 days to exhibit significant changes. Temperature-induced alterations to gut microbiota could be mediated by host physiological factors, an idea supported by the fact that we observed no change in the environmental microbial communities of tank water. These results suggest that even short-term increases in environmental temperature, which may occur more frequently under global climate change, could result in changes to ectotherm gut microbiota.

128-1 FOQUET, B*; SONG, H; Texas A&M University; *Bert.Foquet@gmail.com*

Behavioral and molecular reaction norms of locust phase polyphenism in a phylogenetic frame work

Locusts are grasshoppers (Acrididae) that form large migratory swarms or marching bands, and show density-dependent phase polyphenism. This polyphenism consists of two phases, solitarious and gregarious, that manifest in response to low and high population density, respectively. The two phases differ in several traits, including but not limited to behavior, morphology, nymphal coloration, physiology and reproduction. From a phylogenetic perspective, locusts are rare among grasshoppers, representing only 19 out of about 6700 grasshopper species. They are a phylogenetically heterogenous group, strongly suggesting that density-dependent phase polyphenism in locusts convergently evolved multiple times. The genus *Schistocerca* contains three locust species and more than 40 non-swarming sedentary species, and the phylogeny of the genus is well understood. In this study, we focus on the Central American locust (*S. piceifrons*) and three closely related non-swarming grasshoppers that, together, are expected to form a spectrum in the degree of density-dependent phenotypic plasticity. We reared *S. piceifrons* and these three related species in isolated and crowded conditions, and subsequently quantified density-dependent reaction norms at a behavioral and a molecular level. We establish that there is indeed a spectrum of density-dependent phenotypic plasticity in this clade at both tested levels. We subsequently discovered clear correlations between gene expression patterns in our study system and behavioral traits using a weighted gene co-expression analysis. This represents the first study of locusts in a phylogenetic framework, and extends our understanding about the evolution of the density-dependent phase polyphenism.

72-3 FORD, KL*; ALBERT, JS; University of Louisiana at Lafayette; *klf8880@louisiana.edu*

Convergent evolution of craniofacial morphologies in apteronotid and mormyrid electric fishes

Weakly electric fishes provide an opportunity to examine multiple instances of morphological convergence across continents. Gymnotiformes and Mormyridae use weak electric signals for prey detection, predator avoidance, and social communication. Species within each lineage inhabit deep river channels, shallow streams, and flooded plains, but it is unclear how these habitat types influence morphology. Snout length and shape are affected by prey type and availability, both of which are strongly influenced by a habitat's water velocity and habitat complexity. Two families of electric fishes, Apteronotidae (Gymnotiformes) and Mormyridae (Osteoglossiformes), exhibit particularly high range of head shape disparity. A few studies have examined the similarities between the external morphologies of species in these two lineages, but we have yet to quantify the morphologies of internal head structures. Individuals from Apteronotidae (14 species, n=40 specimens) and Mormyridae (6 species, n=30 specimens) were analyzed using 3D geometric morphometrics with 22 homologous landmarks. Specimens were CT-scanned and analyzed using the programs *3D-Slicer* and *Geomorph*. Procrustes ANOVA and multivariate regressions were used to analyze morphological similarities, which were then traced on phylogenetic trees. Results indicate multiple instances of significantly convergent morphologies, both within and between the families. Several species are more morphologically similar to those in another family than to species within a family. These results invite further study into the roles of natural selection and developmental constraints in the production of convergent phenotypes.

120-7 FORD, MP*; SANTHANAKRISHNAN, A; Oklahoma State University; *askrish@okstate.edu*

Too close for comfort: importance of inter-appendage spacing in metachronal swimming performance

Metachronal paddling of multiple appendages is a swimming strategy used by many ecologically important marine species across a wide range of body sizes and Reynolds numbers. The appendages in metachronal paddling are stroked in an oscillatory pattern, with a phase lag between each neighboring appendage. The ratio of inter-appendage distance (D) to appendage length (L) has been previously reported to fall within the range of 0.2-0.65 for over 30 crustacean species, as well as one ctenophore species known to use metachronal paddling (Murphy et al., Mar. Biol., 158, 2011). Small inter-appendage spacing could allow for thrust augmentation through shear layer interaction in the fluid, while large inter-appendage spacing could effectively isolate appendages from each other. We developed a self-propelled metachronal swimming robot ("krillbot") in order to determine the effects of varying different physical and kinematic parameters on metachronal swimming performance. In this study, we use krillbot to investigate the effects of varying inter appendage spacing on thrust, swimming speed, and fluid dynamic characteristics of the wake. When kinematic parameters are maintained across varying inter-appendage spacing, decreasing spacing results in increased swimming speed. However, very small inter-appendage spacing restricts the possible kinematics parameter space, requiring either stroke amplitude or phase lag between adjacent appendages to be small to avoid collisions between neighboring appendages for a purely metachronal stroke pattern. Interestingly, animals with low D/L ratios (e.g., mantis shrimp, copepods) typically use their paddling appendages for rapid acceleration rather than routine swimming, performing a hybrid stroke consisting of a metachronal power stroke and nearly synchronous recovery.

57-6 FORLANO, PM; CUNY Brooklyn College, CUNY Graduate Center; *pforlano@brooklyn.cuny.edu*

Evidence for Monoamines as Neurochemical Substrates Underlying Alternative Reproductive Tactics

Species that exhibit alternative male reproductive tactics (ARTs) offer an outstanding opportunity to explore the neural and hormonal mechanisms that underlie often extreme divergence in brain and behavior within a sex. Plainfin midshipman fish, *Porichthys notatus, exemplify such male ART divergence in vocal courtship, territoriality and aggression with correspondingly dimorphic brain, somatic and hormonal phenotypes. Across vertebrates these behaviors are modulated by brain monoamines, which include serotonin (5-HT), and the catecholamines (CA) dopamine and noradrenaline. Focusing on discrete monoaminergic nuclei and the well-delineated intrasexually dimorphic vocal circuitry in this species, we investigated if brain monoamines provide additional neural substrates underlying divergence in reproductive behavior between male ARTs. Indeed, high 5-HT and low CA innervation in the vocal hindbrain is characteristic of the highly vocal, aggressive, territorial "type I" phenotype while the reverse pattern is seen in sneaker "type II" males, suggesting excitatory vs inhibitory action of 5-HT and CA, respectively, on vocal motor neuron output. In contrast, larger 5-HT-ir cell volume to body size ratio in type II males is consistent with a predictably higher serotonergic tone in the non-territorial, comparatively non-aggressive males. In addition, acoustic playback experiments coupled with markers for neuronal activation indicate both similarities and differences in CA responses between ARTs and suggests intrasexual divergence in social acoustic signal processing.*

P3-130 FORMOSO, KK*; HABIB, MB; BOTTJER, DJ; University of Southern California; *formoso@usc.edu*

Assessing the Mosasaur Pectoral Girdle and its Controls on Chest Width: Implications for Mosasaur Swimming Function

Mosasaurs are charismatic marine squamates that were prominent global predators in the Late Cretaceous. Two major clades include most derived mosasaur taxa: Mosasaurinae (*Mosasaurus, Plotosaurus, Clidastes*) and Russellosaurina (*Tylosaurus, Platecarpus, Tethysaurus*). With regards to swimming mechanics, most functional analyses have modeled mosasaurs as lateral undulators with most or all propulsion being generated by the tail. However, the large pectoral elements might have been capable of providing significant propulsion and additionally had a major control on the width of the chest cavity, which would impact propulsion due to the resultant drag forces. Mosasaur chest cavity reconstructions are challenging due to the girdle elements and rib cage having cartilaginous extensions which rarely preserve. Most mosasaur pectoral reconstructions are based on conjecture and tend to imply a wider space between the coracoids. Here we present a mosasaur model suggesting three primary trade-offs affected by pectoral breadth: muscle volume and power, drag, and fast start efficiency. Using *Plotosaurus* as an example, narrowing the pectoral width by 10% of some if its wider estimates reduces the muscle power of the forelimbs, but also results in 2.5 times less drag on the body, and an increased fast start efficiency. Regardless of the pectoral breadth, however, the sternum of *Plotosaurus* is quite craniocaudally elongate and not affected by chest cavity width, therefore we estimate that *Plotosaurus* still had significant retraction capacity at the shoulder and this is supported by the shape of the glenoid fossa. This suggests that large derived mosasaurs may have been capable of utilizing a dual caudal and forelimb propulsion system not seen in extant marine tetrapods.

94-4 FORSBURG, ZR; Texas State University; *frog@txstate.edu*
Effects of artificial light at night and predator presence on the development, growth, and physiology of Rana berlandieri
Artificial light at night (ALAN) alters the natural light dark patterns in ecosystems. ALAN can have a suite of effects on community structure and is a driver of evolutionary processes that influence a range of behavioral, developmental, and physiological traits. While ALAN has been shown to alter corticosterone levels of *Rana berlandieri* tadpoles in a previous laboratory reaction norm study, our understanding of how ALAN affects amphibians in natural environments is lacking, yet research is warranted as ALAN could contribute to stress and declines of amphibian populations, particularly in urban areas. Further, it is unknown if ALAN is interacting with natural environmental stressors such as predator presence. I tested the hypothesis that *Rana berlandieri* tadpoles exposed to ALAN or the presence of a common predator, dragonfly larvae, will be physiologically stressed and exposure to both ALAN & predators will have additive consequences on corticosterone production and survival. I reared tadpoles in outdoor mesocosms using a 2 X 2 randomized factorial design, with two predator treatments (presence or absence of one caged dragonfly larva), and two light treatments (natural light cycle control or constant ALAN from ~200 LUX LED lights). I measured corticosterone levels using a non-invasive water-borne hormone assay from the tadpoles after 7 and 14 days in treatments and continued to rear tadpoles in treatments until metamorphosis. I also measured and weighed individuals to track growth and development and recorded the date of metamorphosis for each individual. Findings from this study broaden our understanding of anthropogenic factors associated with amphibian declines and based on our current findings, mitigation of exposure to ALAN should be considered in management and conservation plans for amphibians.

33-2 FOSTER, S A*; BAKER, J A; Clark University; *sfoster@clarku.edu*
Plasticity and the Origin of Evolutionary Pattern
The role of phenotypic plasticity in evolution has become increasingly apparent in recent years. A primary recent interest has involved the possibility that it could guide evolutionary transitions and influence patterns of adaptive diversification, including the evolution of phenotypic novelties. Here we offer evidence that not only does plasticity influence evolution in these ways, but that it also can produce apparent evolutionary pattern that may in represent plastic loss of ancestral phenotypic expression in novel environments due to the disappearance of a requisite environmental trigger. Under these circumstances lack of expression is the novelty in adaptive radiations, yet, as long as the phenotype is still responsive to the environmental trigger it can be expressed if the environment reverts to ancestral conditions, with the ancestral trait appearing as a novelty. We offer evidence that the capacity to express plastic traits can be retained for thousands of generations, although in some cases, modified in pattern of expression or intensity of the environmental trigger required for expression. Distinguishing lack of expression, or evolutionary loss requires examination of multiple taxa in a radiation to correctly infer novelties versus ancestral traits and to understand transitions in plasticity over time and the possible roles of plasticity in evolutionary change. Such analyses can provide novel insights into the role of plasticity in evolution, but is exceptionally difficult as it requires a clear phylogenetic understanding of the group, understanding of the ecology of the species or populations, and the capacity to evaluate patterns and underlying genomics of plasticity in multiple populations or species.

66-4 FRANKLIN, CE; The University of Queensland; *c.franklin@uq.edu.au*
Unravelling the reptilian thermoregulatory paradigm
The thermoregulatory paradigm for reptiles is that they maintain some control over body temperature behaviourally through basking, shuttling between cool and hot microclimates and via changes in posture and position. Coupled with these behaviours are physiological mechanisms that facilitate thermoregulation, including cardiovascular control of heating and cooling rates. However reptiles have also been shown to maintain performance through thermal independence of physiological processes and by thermal plasticity (acclimation/acclimatisation) and so have a suite of mechanisms to deal with changing environmental temperatures. Using body temperature data from a long term (> 10 years) field study on free-ranging estuarine crocodiles the thermoregulatory paradigm of reptiles is being further elucidated and unravelled.

S3-11 FRASER, GJ*; THIERY , A; MARTIN, KJ; JAMES, K; COOPER, RL; HOWITT, C; JOHANSON, Z; University of Florida, Gainesville, King's College, London, University of Sheffield, Natural History Museum, London, University of Sheffield; *g.fraser@ufl.edu*
Dental EvoDevOmics: Novel and conserved gene expression in shark tooth development
Tooth development and subsequent dental regeneration is governed by highly conserved genetic mechanisms that are common to all toothed vertebrates. However, diversity in tooth patterning, shape and regenerative capacity is widespread. We focus on some of the most extreme forms of dental character divergence in fishes e.g. pufferfish and sharks, to appreciate the development of this diversity. We have established the shark as a model for tooth development and continued regeneration. We explore the dental transcriptome to uncover novel markers that suggest a deviation from the conserved norm of tooth development. We discovered a number of transcripts that are new to tooth development, involved in the unique and unrivalled capacity for continuous dental regeneration in sharks. We sequenced total transcripts associated with 5 distinct compartments of the shark dental lamina, an epithelial sheet from which all teeth are formed. These lamina compartments included (i) basi-hyal taste buds, (ii) the junction between taste-tooth fields, (iii) early stage developing teeth, (iv) later stage developing teeth and (v) the successional lamina, a terminal region of the dental lamina where new teeth are produced. Transcripts returned showed differentially expressed gene clusters highlighting distinct signatures associated with regeneration and stem cell niche identity. These data illuminate the unique characters of the shark dental lamina. Now we can extend our understanding of tooth regeneration more generally, and recognize how this process can become inactive, reducing regenerative ability, seen in many vertebrates.

99-5 FRASER, CJ*; HILL, EC; BUTLER, MA; University of Hawaii; *claire7@hawaii.edu*

Morphological Variation between Terrestrial and Semi-Aquatic Papuan Microhylid Frogs visualized through DiceCTs and Dissection

Papua New Guinea is home to the *Asterophryinae*, an unusually diverse clade of frogs that vary in lifestyle, ranging from burrowers to swimmers. We conducted a morphometric and diceCT study of jumping, hopping, and swimming specialists to determine whether variation in musculature varies with performance. Using morphometrics we characterized general patterns of morphological variation and through diceCT we explored any underlying differences in musculature which might be attributed to their habits. We iodine-stained specimens from three species: *A. palmipes*, *M. lateralis*, and *H. rufescens* to visualize their soft tissues and analyzed the scans using 3DSlicer. We verified diceCT results via gross dissection of 13 hindlimb muscles and the Achilles tendon, specifically focusing on the extensors, flexors, and modeled forces in the hindlimbs around the hip, knee, and ankle joints. We were able to visualize muscle fibers via diceCT and obtain morphological measurements typically obtained via gross dissection, while maintaining physiological positioning and preserving the individuals. For verification, these muscles were isolated through the dissection of the individual muscles, which were then photographed and measured through ImageJ. We discuss muscle and morphological differences key for jumpers, hoppers, or swimmers.

P2-125 FRAZER, R.E*; CURREA , J.P; THEOBALD, J.C; WASSERMAN, S.M; Wellelsey College, Floridal International University, Wellesley College; *rfrazer@wellesley.edu*

Anatomical and behavioral differences in Drosophila melanogaster and Drosophila mojavensis suggest divergence of visual circuits

In order to survive, animals must quickly decide if certain sensory stimuli are salient, then they must assign attractive or aversive values to these stimuli and generate adaptive behavioral responses. However these value assignments vary depending on specific environmental features. We use the small yet complex nervous system of the fruit fly, *Drosophila*, to investigate how organisms assign appropriate value to sensory stimuli and how the local environment plays a role in modulating these assignments. It is known that flies from certain regions of the Mojave desert (*D. mojavensis*) prefer odors specific to the food in those areas (Date et. al 2017 & Schluter 2001). There are also necessary differences in their visual ecology and visuomotor reflexes compared to forest-dwelling (*D. melanogaster*) flies (Park and Wasserman, 2018). Here we measure interspecific differences in eye morphology (surface area, field of view, etc) and visual psychophysics (contrast sensitivity(CS), spatial acuity(SA), and temporal acuity(TA). We find that desert flies have larger eyes, fields of view and optical acuity but lower optical sensitivity compared to forest flies. However, desert flies demonstrate minimal loss in CS and a large loss in SA, with no notable difference in TA. The pattern of having a high acuity and low sensitivity at the optical level but a low acuity and boosted contrast sensitivity shown in behavior, suggests spatial neural summation to improve sensitivity in dim environments. These results further our understanding of how unique features of landscapes can shape visual circuitry required for adaptive behavior.

102-7 FRAZIER, AJ*; JENSEN, NR; YOUNG, SP; COOLEY-RIEDERS, CC; TODGHAM, AE; University of California, Davis, Kootenai Tribe of Idaho; *ajfrazier@ucdavis.edu*

Does a Cannibal Feeding Strategy Impart Differential Metabolic Performance in Young Burbot Lota lota?

The practice of mitigating cannibalism in aquaculture is an important focus for hatcheries seeking to maximize yield and has been maintained in hatcheries focusing on wild stock restoration. We hypothesize, however, that a cannibal feeding strategy may confer performance advantages over a non-cannibal feeding strategy. This study examined metabolic performance differences between cannibal and non-cannibal burbot, *Lota lota*, at the Twin River's Hatchery in Bonner's Ferry, Idaho, USA. After habitat alteration led to a functional extinction of burbot in the region, the Kootenai Tribe of Idaho's Twin River's Hatchery has played a leading role in the reestablishment and conservation of burbot in the Kootenai River, Idaho. We examined morphometric data (weight, length, and condition factor), whole animal resting metabolic rate (RMR), and the enzyme activity of lactate dehydrogenase (LDH), citrate synthase (CS), and 3-hydroxyacyl-CoA dehydrogenase (HOAD) to describe the baseline metabolic performance of cannibal and non-cannibal burbot. Taken together, our results demonstrated significant differences in the metabolic strategies of the feeding strategies, where cannibal burbot relied more heavily on carbohydrate metabolism and non-cannibal burbot relied more heavily on glycolytic and lipid metabolism. This study demonstrates the need to reevaluate the traditional practice of removing cannibal fish in conservation hatcheries, as it may not be the ideal strategy of raising the most robust individuals for release. When natural habitat conditions cannot be restored due to permanent habitat alteration, prioritizing release of higher performing individuals could help achieve conservation goals.

P1-19 FRíAS VELLóN, AI*; KRANTZ, J; MACRANDER, J; Florida Southern College; *andrea.frias.1999@gmail.com*

The Impact of Microplastics on Sea Anemone Behavior, Survivorship, and Gene Expression

The Starlet sea anemone, *Nematostella vectensis*, is a type of burrowing sea anemone most commonly found in nearshore estuarine environments along the east and west coasts of North America. These sea anemones have a high physiological tolerance to salinity, temperature, and pollutant exposure. With the high amount of plastic waste entering our oceans organisms found in these nearshore environments are now facing a new environmental stressor not previously encountered. To study the impacts of plastics on N. vectensis we used two population strains originally from Maryland (now a long-term lab strain) and individuals from the wild found in an estuary in California. Both strains, were used to test survivorship after a 12 week long term exposure to microplastics. Collections for the long term portion occurred every two weeks. Additionally, the lab established strain was used to test survivorship and overall genetic response after short term exposure with an increase in temperature. Collections for the short term portion were taken every two days representing three distinct time points. After laboratory exposure was concluded, total RNA was extracted and sent out for Tag Seq analysis. In addition to stress response genes, our approach provided us with insight into how venom production of the N. vectensis strains are affected as a result of direct exposure to microplastics. Our observations, highlighted behaviour consistent with previous studies that correlated anemones and microplastics, while our results might shed light on what happens to differentially expressed genes like stress response genes and venom when exposed to plastics.

22-6 FREEMAN, AR*; OPHIR, AG; SHEEHAN, MJ; Cornell University; *arf86@cornell.edu*

Doing more with less: African giant pouched rats specialize in olfaction with a typical olfactory receptor repertoire

Rodents use their keen sense of smell to navigate their environment, find food and mates, recognize conspecifics, and avoid danger. Furthermore, rodents are described as having large olfactory receptor repertoires in order to support their specialization in olfactory behaviors. However, among rodents, relatively little work has documented the olfactory receptor repertoires outside of traditional rat and mouse laboratory models. We examined the composition of the olfactory receptor repertoire of the African giant pouched rat (*Cricetomys ansorgei*), a Muroid rodent distantly related to mice and rats. The pouched rat is notable as it has a relatively large cortex and large olfactory bulbs compared to sympatric rodents of a similar size. This anatomical elaboration of their olfactory system has been postulated to support their olfactory behavior, which includes their use as 'biodetectors' in applied olfactory tasks. We hypothesized that in addition to anatomical elaboration, the pouched rat would have an expanded olfactory receptor repertoire, to further support their olfactory behaviors. We identified 1145 functional olfactory genes and 260 pseudogenes in the pouched rat genome. This repertoire is similar in size and composition to mice and rats, but has several family-specific expansions. Whether these expansions provide the pouched rat a specialized ability to detect particular odors remains an open question. We also identified 99 orthologous genes conserved among four rodent species, and 167 genes conserved within Muroidea, suggesting a conserved Muroid-specific olfactory receptor repertoire. Our data suggest that the pouched rat is capable of a suite of specialized olfactory behaviors with a typical Muroid olfactory receptor repertoire.

84-3 FREYMILLER, GA*; SCHWANER, MJ; WHITFORD, MD; MCGOWAN, CP; HIGHAM, TE; CLARK, RW; San Diego State University, University of Idaho, University of California, Riverside; *gfreymil@gmail.com*

Determining the functional significance of bipedalism in heteromyid rodents through comparisons of morphology and performance

Bipedalism is a relatively unique mode of locomotion and it is often accompanied by specialized morphological features. Within rodents, the most well-supported hypothesis is that bipedalism initially evolved to enhance vertical jumping ability for predator evasion. In previous research, we found that kangaroo rats (*Dipodomys* spp.) are exceptional evaders when dodging rattlesnake strikes. However, few studies have directly compared the evasive abilities of bipedal and quadrupedal rodents, and those that have rely on indirect measures (e.g. predator diet studies) or focus on running ability rather than jumping ability. Thus, the hypothesis of predator avoidance has yet to be directly tested in an ecologically meaningful way. We used hind limb muscle dissections and field-based attack simulations to measure muscle morphology and jump performance for three kangaroo rat species and a quadrupedal heteromyid rodent, the desert pocket mouse (*Chaetodipus penicillatus*). Reaction time and take-off velocity significantly differed among the rodent species; interestingly, there was not a significant difference between pooled bipedal and quadrupedal rodents, with larger kangaroo rat species performing more similarly to the pocket mice than to smaller kangaroo rat species. We will combine our morphology and performance data to determine which aspects of the hind limb morphology contribute most to the observed differences in performance. These results will have implications for understanding the selective pressures that drove the evolution of bipedalism in small mammals.

10-7 FRIEDMAN, ST*; COLLYER, ML; PRICE, SA; WAINWRIGHT, PC; University of California Davis, Chatham University, Clemson University; *sarahtfried@gmail.com*

Divergent processes drive parallel evolution in marine and freshwater fishes

Investigating the patterns of evolutionary diversification is vital to understanding the processes governing the rich biodiversity of vertebrates. Habitat can provide ecological opportunity and serve as a catalyst for evolution, resulting in the unequal spread of phenotypic disparity across ecosystems. While both marine and freshwater environments harbor significant portions of fish diversity, they offer a particularly intriguing evolutionary juxtaposition. The different biogeographic and environmental factors between the two ecosystems can have substantial effects on morphological diversification. Yet, both environments offer similar opportunities for diversification within benthic, demersal, and pelagic regimes, which lineages have radiated into with consistent phenotypic trends. Here, we investigate whether the axis of body shape diversity within each of these habitats differs between fishes in marine and freshwater systems. Using specimens from the Smithsonian Museum, we developed a dataset of linear measurements capturing body shape in 2,200 freshwater and 3,300 marine teleost species. By comparing angles between the first principal components, we find that the fish body shapes in corresponding regimes have more similar primary axes of diversity than would be expected by chance, but that different processes are driving these parallel patterns in freshwater and marine environments. Marine diversification is generally phylogenetically constrained, which may indicate widespread phylogenetic niche conservatism. In contrast, ecological signal appears to overpower phylogenetic constraints in freshwater lineages. In spite of these divergent evolutionary processes, our findings imply that habitat imposes strong selective pressures, driving consistent patterns of evolutionary diversification on a global scale.

91-3 FRIESEN, CN*; HAN, J; YOUNG, RL; HOFMANN, HA; UT Austin; *caitlin.friesen@utexas.edu*

Using correlated patterns of behavioral and molecular variation to understand individual variation

Members of social groups often show tremendous variation that can be understood by classifying individuals according to their specific type or role within a group. Across diverse taxa, the molecular traits underlying social types or roles have been well-studied, but the molecular correlates of individual variation have been difficult to experimentally examine. Our research addresses this limitation by utilizing an integrative approach to quantify co-variance across behavioral and molecular traits in response to changing social conditions over time. Here, we examined naturalistic groups of the highly social African cichlid fish, *Astatotilapia burtoni*, to understand how patterns of behavioral and molecular traits contribute to individual variation across contexts. *A. burtoni* males are either bright, territorial, aggressive, and reproductively active (socially dominant, DOM) or dull, non-territorial, and reproductively suppressed (subordinate, SUB). We assayed behavior, physiology, and transcriptomes of key brain regions involved in social behavior before and after defined environmental, social, and physiological perturbations. Our results demonstrate 1) a strong relationship between patterns of space use, social behavior, and physiology that suggest novel DOM styles, 2) behavioral resilience and physiological flexibility in response to perturbations, and 3) complex variance structure at the molecular level. This research provides insight into the causes and consequences of individual variation across levels of organization that can give rise to consistent behavior over time and context.

P3-18 FRITZ, T*; BROGREN, D; BURLEY, A; HOLIHAN, M; GRAHAM, M; CHRYSLER, J; SCOTT, J; Saginaw Valley State University, University Center, MI; *jascott1@svsu.edu*

Dioxin-induced steatosis and liver toxicity is enhanced by a ketogenic diet

Macronutrient changes in the diet correlate with an increased risk of several diseases; however, we are also invariably ingesting environmental contaminants along with it, and these have the potential to modify the effects of diet. Exposure to some lipophilic contaminants alone (e.g., dioxins), have been shown to produce similar physiological effects as a high fat diet. To investigate the influence of lipophilic contaminants on dietary changes in the liver, mice were exposed to both low fat and ketogenic diets in the presence or absence of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) for 4 weeks. The preliminary results suggest that there were no significant changes in body and ependymal fat pad weights, although a trend of an increase in weights was observed in ketogenic diet and ketogenic diet + TCDD mice. Liver histology confirmed that both TCDD and ketogenic diets induce steatosis in liver. The most dramatic increase in steatosis and hepatic morphology was observed in ketogenic diet + TCDD mice, which correlated with a significant increase in liver weights in these mice. Gene analyses data suggested that lowering carbohydrates and increasing dietary fat (ketogenic diet) significantly increased expression of genes involved in cholestasis and xenobiotic/drug metabolism. TCDD altered the expression genes involved in xenobiotic metabolism, fatty acid metabolism, cholestasis; however, expression was more pronounced in mice on a ketogenic diet.

98-1 FROLOVA, AD*; MIGLIETTA, MP; Texas A&M University at Galveston; *frolova.alexandra@outlook.com*

Environmental tolerance ranges and limits suggest differences in habitat preference and resilience to climate change among jellyfish (Class Scyphozoa) congeners in the Gulf of Mexico

Jellyfish are important components of marine foodwebs and form blooms that negatively impact human enterprise. Jellyfish of the genus *Aurelia* (Class Scyphozoa) are common bloom-formers in the Gulf of Mexico (GoM). *Aurelia* have a multi-modal lifecycle where the perennial polyp produces seasonal jellyfish. Tolerance limits for survival are crucial to understanding present jellyfish polyp distribution and how distribution may change in climate change scenarios. We sampled and barcoded two *Aurelia* jellyfish from the GoM and an *Aurelia* species native to Japan: *Aurelia* sp. 9, a possible new species found offshore (*Aurelia* sp. new) and the invasive *A. coerulea*. Using controlled laboratory experiments we determined the temperature and salinity tolerance limits for polyps of the three species. We find that *A.* sp. 9 and *A. coerulea* were tolerant of a broad range of temperatures and salinities, but differed in tolerance limits, suggesting potential differences in habitat and resilience to climate change. *A.* sp. 9 was most tolerant of high temperatures and low salinities, such as those found in the estuaries of the GoM. Summer high temperatures in the coastal GoM exceed the upper thermal tolerance limits of *A.* sp. new and *A. coerulea*. This confirms that *A.* sp. new is an offshore species and suggests that the coastal GoM may not be suitable for the invasive *A. coerulea*. Ocean temperature increase may negatively impact resident *Aurelia* species and deter *Aurelia coerulea* from invading the GoM. This is the first account of *Aurelia* sp. new and the first report of temperature and salinity ranges limits for *Aurelia* species.

S8-4 FU, Q; GART, SW; MITCHEL, TW; KIM, JS; CHIRIKJIAN, GS; LI, C*; Johns Hopkins University; *chen.li@jhu.edu*

Body lateral deformation and compliance help snakes and snake robots stably traverse large steps

Many snakes live in mountains and forests and traverse large 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. Although snake locomotion on flat surfaces is inherently stable, in such complex terrain, snakes must deform their body in three dimensions, during which maintaining stability becomes a challenge. Here, we review recent progress in our group in this problem. We studied how the generalist variable kingsnake traversed a large step as high as 40% body length. We developed a method to reconstruct continuous body 3-D motion (both position and orientation) from marker tracking. We discovered that the snake combined lateral body oscillation and cantilevering to traverse stably. The body sections below and above the step oscillated laterally on the surface, which provided not only propulsion but also roll stability as the body section in between cantilevered in the air to bridge the large height increase. To further understand stability principles, we developed a robotic snake with a similar gait as a physical model to study how traversal depended on step height and body compliance. As step height increased, the robot with a rigid body rolled and flipped over more often, leading to frequent failure. By contrast, the snake that had a compliant body rarely suffered this problem. Adding body compliance to the robot reduced its roll instability during traversal by improving body contact with the terrain. Besides advancing understanding of snake locomotion, our robot achieved traversal speeds surpassing most previous snake robots and approaching that of snakes, while maintaining high traversal probability on steps as large as 40% body length.

20-1 FUDICKAR, AM*; BREWER, DE; Indiana University; *afudickar@gmail.com*

Distance Matters: Experimental Test of the Influence of Avian Migration Distance on Readiness to Breed in Spring

Migration in birds often results in individuals dispersing over large geographic areas after the breeding season. Here we asked if within population variation in wintering latitude, conveyed via photoperiod, contributes to variation in timing of the seasonal activation of the reproductive axis. In response to increasing photoperiod in winter and spring, the avian reproductive axis becomes stimulated, resulting in a transition to reproduction. In late summer we captured male song sparrows (Melospiza melodia) from a breeding population in Indiana, USA (39.16°N, 86.53°W) and assigned them to one of two indoor aviaries under the natural photoperiod of the site of capture. In mid-October, when song sparrows migrate south, we shifted the photoperiod of one aviary to the natural photoperiod at the southern extent of their wintering range (27.95°N, 82.46°W), simulating autumn migration. From mid-October to mid-March, the photoperiods in both aviaries were adjusted to follow the natural seasonal progression of day length at the two latitudes. In mid-March, when song sparrows migrate back to their northern breeding grounds, we shifted the photoperiod of the migrant treatment back to the natural photoperiod at their breeding grounds, simulating spring migration. Once a week, beginning in February, we measured testosterone synthesis capacity using a gonadotropin-releasing-hormone (GnRH) challenge. Despite experiencing longer photoperiods during the winter, birds in the migrant treatment had lower testosterone in spring compared to birds that were exposed to the shorter northern photoperiods. Our results indicate that within population variation in migration distance contributes to variation in readiness to breed in early spring.

101-3 FUESS, LE*; WEBER, JN; STEINEL, NC; DEN HAAN, S; BOLNICK, DI; University of Connecticut, University of Alaska Anchorage, University of Massachusetts Lowell, University of Texas; *lefuess@gmail.com*

Transcriptomic analyses of Gasterosteus aculeatus parasite response reveal mechanisms of resistance

Host-parasite interactions are poorly understood, despite their effects on a range of ecological and evolutionary processes. Specifically, variation in host resistance and the evolution of this resistance is well studied from a theoretical standpoint, but understanding of associated cellular mechanisms is lacking. The three-spined stickleback, *Gasterosteus aculeatus*, is a particularly powerful model of the evolution of host resistance: populations of *G. aculeatus* vary considerably in their resistance to the cestode parasite, *Schistocephalus solidus*. Using transcriptional analyses of experimental infections, we investigated patterns of gene expression that underlay host-parasite dynamics and contribute to variation in host immune response. We examined general host response to infection and compared gene expression across three different cross types (F2s and respective backcrosses) generated from two populations of fish, one resistant and one susceptible. Our findings indicate that infection is associated with suppression of host immunity. Resistant populations may circumvent this suppression. Furthermore, comparison of crosses allowed for the identification of candidate genes that may contribute to observed resistance phenotypes. These findings advance our understanding of the dynamics and evolution of host-parasite interactions in the *G. aculeatus- S. solidus* system. Broadly, the findings presented here are an excellent case study of micro-evolution of immune responses within a population, and contribute to increased understanding of evolutionary immunology and host-parasite coevolutionary dynamics.

115-5 FUIMAN, LA*; WILLIAMS, TM; DAVIS, RW; University of Texas at Austin, University of California Santa Cruz, Texas A&M University - Galveston; *lee.fuiman@utexas.edu*

Underwater Navigation by Weddell Seals (Leptonychotes weddellii) in the Antarctic Fast-Ice Environment

Most activities of Weddell seals occur during dives that extend hundreds to thousands of meters in distance and require the seals to hold their breath for 20 minutes or more. In the fast-ice environment of Antarctica, holes in the ice where seals can surface to breathe are scarce. Consequently, seals must return to a previous breathing hole or locate a new one to avoid drowning; how they navigate underwater with such precision is not known. This study used field experiments to test multiple hypotheses concerning the sensory cues and tactics Weddell seals may employ to navigate underwater in this challenging environment, with special attention to their possible use of geomagnetic cues. An archival data logger was fitted to each of 10 adult seals, which were released at three locations that differed in the orientation of the geomagnetic field, and allowed to perform voluntary dives. Analysis of three dimensional dive tracks demonstrated that outbound paths of dives in a given direction progressively increased in distance from the breathing hole. Seals returned home from long distance dives on remarkably straight homeward paths, or they traveled directly to a frequented route then turned toward home, which is consistent piloting by landmarks. Seventy-five percent of the frequented routes were directly below known linear disturbances in the snow on the top of the sea ice, indicating that Weddell seals primarily used overhead visual cues (pilotage by landmarks and waypoints) to navigate under ice cover. They were able to do so during both daylight and surface twilight, presumably due to exceptional visual sensitivity in low light environments. We did not find evidence that seals used geomagnetic or hydrodynamic cues when returning to a breathing hole under these conditions.

136-3 FUNK, EC*; KURPIOS, NA; MCCUNE, AR; Cornell University; *ef347@cornell.edu*

Ventral-dorsal inversion of the air-filled organ (lungs, gas bladder) in vertebrates

Study of the origin of evolutionary novelties is central to understanding the history of life. With advancements in developmental genetics, we can investigate the genetic basis of evolutionary novelties and their subsequent transformations. The gas bladder, derived from lungs of the common ancestor of bony vertebrates, originated within ray-finned fishes and is important for efficient buoyancy control. As homologous organs, the gas bladder and lungs share many similarities; however, the defining difference between the two organs is the location of budding from the anterior foregut; gas bladders bud from the dorsal wall and lungs from the ventral wall. Therefore, we are investigating whether the inversion of budding location is paralleled by a ventral-to-dorsal inversion of gene expression patterns. To determine the genes involved in gas bladder development and their spatial expression, we used laser-capture microdissection to isolate dorsal and ventral foregut tissue from larval bowfin (*Amia calva*) at three key developmental stages and sequenced the tissue expression profiles. Bowfin are an early-diverging ray-finned fish that possess a dorsal gas bladder and therefore, are an ideal species to study early gas bladder evolution. We identified the genes differentially expressed between dorsal and ventral tissues, and from this set, we characterized when and where known mouse lung-regulatory genes are expressed and whether they exhibit an inverted pattern during gas bladder development compared to lung development. We found *Tbx5* and *Gata4*, both of which are involved in lung development, to have dorsoventrally restricted expression patterns. In particular, *Tbx5* is highly expressed in the dorsal mesoderm surrounding the gas bladder bud, whereas during mouse lung development, it is expressed in the ventral mesoderm.

7-5 FURZE, ME*; DRAKE, JE; WIESENBAUER, J; RICHTER, A; PENDALL, E; Harvard University and Yale University, State University of New York , University of Vienna, University of Vienna, Western Sydney University; *morganfurze@gmail.com*

Tracing Sugars Throughout Whole¤Trees Exposed to Climate Warming

Trees allocate carbon (C) from sources to sinks by way of a series of processes involving carbohydrate transport and utilization. Yet it is unclear how these dynamics will respond to a warmer world. We conducted a warming and pulse¤chase experiment on *Eucalyptus parramattensis* growing in a whole¤tree chamber system to test whether warming impacts C allocation by increasing the speed of carbohydrate dynamics. We pulse¤labelled large, field-grown trees with ^{13}C¤CO_2 to follow recently fixed C through aboveground and belowground organs by using compound¤specific isotope analysis of sugars. We then compared concentrations and mean residence times of individual sugars between ambient and warmed (+3°C) treatments. Trees dynamically allocated ^{13}C¤labelled sugars throughout the aboveground¤belowground continuum. However, we did not find a significant treatment effect on C dynamics, as sugar concentrations and mean residence times were not altered by warming. From the canopy to the root system, ^{13}C enrichment of sugars decreased, and mean residence times increased, reflecting dilution and mixing of recent photoassimilates with older reserves. Interestingly, the presence of raffinose in the phloem provides evidence for a polymer trap mechanism for phloem loading. Our results suggest that a locally endemic eucalypt was able to adjust its physiology to warming representative of future temperature predictions for Australia.

57-5 GABOR, CR*; ASPBURY, AS; UJHEGY, N; BóKONY, V; Texas State University, San Marcos, TX, USA, Plant Protection Institute Centre for Agricultural Research, Budapest, Hungary, Plant Protection Institute Centre for Agricultural Research, Budapest, Hungary; *gabor@txstate.edu*

Environmental Variation From Land Use Conversion Affects Stress in Tadpoles

Land conversion alters water quality variables in freshwater habitats and may have negative consequences on population health of aquatic organisms. Populations exposed to land use conversion may have different abilities to modulate their stress response and their ability to recover (resilience) from stressors. Glucocorticoids, such as corticosterone, play a role in modulation of the immune system, and the level of corticosterone can be used to assess the overall stress and health of their populations. We measured baseline, stress response, and resilience corticosterone release rates in common toad, *Bufo Bufo*, tadpoles from ponds in agricultural, urban, and rural habitats. We also reared eggs from the ponds in a common garden design and measured corticosterone in the developed tadpoles. We hypothesized that tadpole corticosterone release rates would differ between converted habitats and rural habitats. We found that corticosterone was highest in tadpoles from urban ponds and lower in rural and agricultural ponds. All populations showed a stress response and resilience indicating that they are not chronically stressed. The fitness consequences (body condition) to resilience and stress response varied across populations. Corticosterone release rates were repeatable, indicating the ability of this trait to respond to selection. Corticosterone was lower in tadpoles from mesocosms and did not differ by original land use type, suggesting that differences observed in the natural populations were primarily associated with environmental conditions.

P3-158 GABRIEL, AN*; BRAINERD, EL; OLSEN, A; HERNANDEZ, LP; CAMP, A; FARINA, SC; Howard University, Brown University, The George Washington University, The University of Liverpool; *ashton.gabriel@bison.howard.edu*

Influence of mechanical linkages between the buccal and gill chambers on ventilatory kinematics

Gill ventilation is the process by which fishes pump water over the gills by cyclically expanding and compressing the buccal and gill chambers. While these chambers are generally modeled as operating independently of one another, they are mechanically linked, and these linkages play an underappreciated role in ventilatory mechanics. Our goal was to quantify the extent to which mechanical linkages between the buccal and gill chambers influence ventilatory kinematics. To accomplish this, we analyzed XROMM (X-ray Reconstruction of Moving Morphology) animations of catfish ventilatory sequences to calculate (1) the contribution of the suspensorium to opercular expansion and (2) the contribution of the operculum to jaw depression. We found that abduction of the suspensorium contributes 10-30% to abduction of the operculum. Therefore, as the suspensorium abducts and expands the mouth chamber, it is also contributing simultaneously to gill chamber expansion, as opposed to these chambers operating independently. Movements of the opercular bones may also slightly contribute to mouth chamber expansion, which is another way in which these chambers are linked. Our study provides a new framework for the understanding of gill ventilation in terms of mechanical linkages instead of pumping of separate chambers.

28-5 GADDAM, MG*; SANTHANAKRISHNAN, A; Oklahoma State University; *askrish@okstate.edu*

Squishy suction pumps: pore water release by upside-down jellyfish

Cassiopea medusae (upside-down jellyfish) are observed in sheltered marine environments, with their bells resting on the substrate and oral arms directed towards sunlight. Unsteady pulsations of the bell are used to generate feeding and exchange currents, which are significant to these organisms as they inhabit areas with low background flow velocities (e.g., mangrove swamps, seagrass beds). We examine whether bell pulsations can generate sufficient force to release sediment-locked nutrients. 2D particle image velocimetry (PIV) and planar laser induced fluorescence (PLIF) measurements were conducted on *Cassiopea* individuals of varying bell diameters, under initially quiescent flow conditions in a laboratory aquarium. PLIF measurements showed release of fluorescent dye, initially located 2 cm below the substrate, into the water column. Dye concentration was larger in high-shear regions in the medusa-induced flow above the substrate. Starting vortices formed during bell contraction were broken into small-scale structures when the jet was directed through the oral arms. Smaller individuals with higher pulsing frequency showed closer placement of vortices generated from multiple pulsing cycles that aided in augmenting concentration flux. Larger medusae with lower pulsing frequency appear to benefit from the increased time scale for suspension feeding and mixing of released pore water, on account of their wider and slower jets. Our results suggest that bell pulsations of *Cassiopea* medusae can facilitate nutrient cycling and benthic-pelagic coupling.

S6-10 GALL, MD*; DE KONING, M; BEATINI, JR; PROUDFOOT, GA; Vassar College; *megall@vassar.edu*

Directional sensitivity of Northern saw-whet owls: implications for prey and wing sound detection

Many animals localize sound sources using cues derived from sounds arriving at two ears that are segregated in space. Animals can also localize sounds using monaural cues, such as location-based spectral or amplitude profiles. Spectral and amplitude profiles are thought to be generated by the soft tissue of the pinna in mammals and by soft tissue and the facial ruff in barn owls (*Tyto alba*). Asymmetry of ear placement in the skull, in addition to soft tissue asymmetry, is found in only a few species, such as the Northern saw-whet owls (*Aegolius acadicus*). We investigated the effect of spatial location on monaural responses in the Northern saw-whet owl, using auditory evoked potentials to measure the response of each ear to sound sources placed in different locations around the head. The response amplitude changed most dramatically with elevation and the response latency changed most dramatically with azimuth. Furthermore, we found that sensitivity was greatest in the spatial locations above the beak and in front of the head. Sensitivity dropped off dramatically as the sound source was moved behind the head. This directional sensitivity should improve sound detection and processing of prey cues in front of the head, while reducing the effect of noise generated during flight.

P1-181 GALLOWAY, K/A*; PORTER, M/E; Florida Atlantic University; *kgalloway2016@fau.edu*

Lionfish puncture performance is impacted by the target tissue type

Lionfish have a passive puncture defense system in which venomous spines are embedded into a predators skin during an attack. We have previously determined that the anal and pelvic spines of the red lionfish, *P. volitans*, are substantially shorter than the dorsal spines, but are stiffer and can absorb more elastic energy. Here, we quantify the puncture performance of lionfish spines in buccal skin from opportunistic predators in their invasive range, and examine the performance of lionfish spines compared to hypodermic needles in porcine skin. We punctured dorsal, anal, and pelvic lionfish spines from 37 individuals (91 spines) using an Instron E1000 into three regions of buccal skin from black grouper and blacktip sharks, and we tested spines and hypodermic needles in porcine skin. We found significantly higher forces were needed to puncture shark buccal skin with lionfish dorsal, anal and pelvic spines. Spines that punctured shark skin incurred the most macro and micro damage. In comparison, lionfish spines are more effective, based on forces measured and damage incurred, at puncturing grouper buccal skin. We found that lionfish spines required higher forces, compared to two gauges (23 and 25) of hypodermic needles, to puncture porcine skin. Interestingly, lionfish pelvic spines required the greatest amount of force to puncture porcine skin, but were the most effective at puncturing grouper and shark buccal skin. We emphasize that puncture ability is greatly affected by the material the structure is embedding, and is critical to consider in puncture studies. Our data suggest that if grouper and reef sharks recognized lionfish as a consistent food source in their invasive range, their oral cavities would not be affected substantially during predation events.

106-5 GAMBOA, M P*; KOHLRUSS, P S; WOLF, B O; SILLETT, T S; FUNK, W C; GHALAMBOR, C K; Colorado State University, University of New Mexico, Migratory Bird Center, Smithsonian Conservation Biology Institute; *mgamboa@rams.colostate.edu*

Climate variation facilitates morphological, not physiological, divergence in song sparrows

Divergent selection and limited gene flow across varying environments may lead to population differentiation at small spatial scales. On the California Channel Islands, song sparrows (Melospiza melodia graminea) occupy a steep climate gradient and exhibit low dispersal. Population genomic results suggest selection drives observed bill variation with larger bills found on hotter islands, consistent with hypotheses stating the avian bill is a thermoregulatory tool. However, the bill represents only a small proportion of the body capable of heat loss. Furthermore, how the relationship between thermogenesis, thermal conductance, and morphology varies between populations remains unknown. Here, we examine the relationship between (1) climate and feather microstructure and (2) climate and thermal physiology. Specifically, we quantified differences in breast contour feathers between island and mainland sparrows (M. m. heermanni) to infer insulatory ability. We coupled this with respirometry experiments to determine whether populations exhibit differences in metabolic rates and thermal limits. We found no significant difference among regions in physiological traits. Yet, we identified a significant difference in the proportion of the feather that was plumulaceous and evidence for greater barb density in birds from colder islands. Plumage results suggest birds on colder islands have better insulation, likely a plastic response to climate based on work in other species. Together, this suggests that populations may cope with climatic challenges by first modifying morphological characteristics before altering complex, physiological traits.

P3-139 GAMEL, K.M*; ASTLEY , H.C; University of Akron; *kmg205@zips.uakron.edu*

Design and Fabrication of an Underwater Force plate

Underwater walking is the fundamental predecessor in the evolutionary transition from water locomotion to land locomotion. Underwater walking is still used by a wide range of species to move in the benthic freshwater and marine environments. Underwater walking involves a unique mix of forces seen in both swimming and terrestrial walking. Being submerged in water, these animals encounter hydrodynamic and hydrostatic forces such as buoyancy and drag. Like terrestrial walking, propulsive force is generated via substrate interactions, but must overcome the addition of hydrodynamic drag in spite of lower effective body weight due to buoyancy. Due to the lack of a sufficiently sensitive force measurement system, little is known about the substrate reaction forces of underwater walking. This poster describes the design and fabrication of an underwater force plate that can sense small propulsive forces the underwater walking animal applies to the substrate. Similar design to a terrestrial force plate, this underwater force plate is 3D printed using stereolithography and equipped with strain gauges in a Wheatstone bridge configuration, the signals from which are amplified by approximately 4600x. Preliminary calibrations on a uniaxial system showed calibration constants of 5 mV/mN, with a minimum detectable force of 2 mN. The underwater force plate will allow for the investigation of habitat and substrate differences compared with various morphology that utilize underwater walking. Understanding how these animals interact with the substrate and the hydrodynamic environment will provide insight in the evolutionary transition from water to land.

P1-70 GAMS, HC*; YERGA, KM; YOUNG, VKH; Saint Mary's College, Notre Dame, IN; *hgams01@saintmarys.edu*

Rodents of unusual size? Fox squirrel (Sciurus niger) body mass at Saint Mary's College

Urbanization affects abiotic and biotic environmental conditions, which in turn affects the animals that live in those environments. One major consequence of urbanization is an increase in anthropogenic food sources in their diet. This can decrease body condition because these food sources have an insufficient nutrient content. Some species of squirrels have been shown to target anthropogenic food sources when living in urban environments such as trash cans, food on the ground in areas humans commonly eat, or being fed by humans directly. At Saint Mary's College, a major source of anthropogenic food is the Noble Family Dining Hall. We predict that squirrels closer to the dining hall will have a higher body mass compared to those trapped further from the dining hall. We trapped squirrels on Saint Mary's College campus from May - July 2019 and recorded body mass and the distance of capture location from the Noble Family Dining Hall. We then used a linear regression to determine if there was a trend in body mass as distance from the dining hall increased. We found no significant trends with either raw body mass or calculated residual body mass. This is likely because fox squirrel home ranges are large enough that all squirrels on campus have equal access to anthropogenic food sources, regardless of the distance of their capture site from the dining hall. In order to more accurately determine the effects of anthropogenic food sources we plan to continue to expand our data set including trapping squirrels in the Saint Mary's Nature Area where squirrels have no access to anthropogenic food sources. Continuing this research will allow us to examine the effects of humans on local squirrel populations.

20-3 GARCIA, MJ*; TEETS, NM; University of Kentucky; *mjga237@uky.edu*

Genetic Variation and Molecular Regulation of Cold Hardiness in Spotted Wing Drosophila

Managing invasive pests requires a thorough understanding of their basic biology including life history traits, resistance to control treatments (e.g. pesticides), and thermal tolerance. Cold hardiness – ability to cope with low temperature stress – is a key mediator of insect geographic distribution and population structure and influences their ability to invade and establish in novel environments. Variation in cold hardiness within and among populations is driven by complex interactions between environmental and genetic factors and is regulated by multiple physiological and molecular mechanisms. The aim of this study is to leverage genetic variation across genetically distinct lineages of a globally invasive fruit pest, spotted wing drosophila (SWD; *Drosophila suzukii*), to identify key transcriptional regulators of cold hardiness. First discovered in CA in 2008, SWD has since spread to all 48 mainland states. Female SWD lay their eggs into ripening, soft-skinned fruits of economic importance, and subsequent larval feeding leads to product loss. We have generated isogenic SWD lineages derived from field populations along a North-South latitudinal gradient from Wisconsin to Florida. We measured acute cold shock survival, cold-induced deficits in fecundity, and critical thermal minimum temperature (CTmin) across all lineages. Current findings indicate significant variation among lineages for all cold hardiness measures assayed. In ongoing experiments, we will identify key transcriptional regulators of cold hardiness via RNA-seq. Results of this study will provide greater insights into the genetic mechanisms underlying variation in invasion-related traits in SWD and will contribute to improved modeling and control efforts.

P1-211 GARCIA, PA*; DEBAN, SM; JONES, MEH; LAPPIN, AK; Univ. South Florida, Natural History Museum, London, California Polytechnic Univ., Pomona; *pablogarcia@mail.usf.edu*

Effects of bite out-lever and gape angle on bite force in the brown anole (Anolis sagrei)

When a typical vertebrate bites, bite out-lever and gape angle are two behaviorally and ecologically relevant variables expected to influence bite-force performance. With an increase in bite out-lever (i.e., distance from jaw joint to location of bite on tooth row), the law of the lever indicates that bite force should decrease following a linear relationship with a predictable slope. For gape angle, empirical data from mammals generally indicate that bite force should increase with decreasing gape angle. To examine the effects of bite out-lever and gape angle on bite force in lizards, we conducted experiments in which the jaw-adductor muscles of euthanized brown anoles (*Anolis sagrei*) were stimulated directly while bite force was 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 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. The generality of these results is uncertain, given that many species of lizards exhibit various forms of cranial kinesis. Cranial kinesis, including streptostyly (i.e., mobility of quadrate bone) observed in anoles, may affect jaw muscle levers, lines-of-action, and muscle length-tension properties during biting. Therefore, in species that show considerable cranial kinesis, basic lever mechanics may not be entirely predictive of how bite out-lever or gape angle affect bite force. The results of this study can serve as a basis for comparison to other species of lizards with various types and degrees of cranial kinesis.

P3-107 GARDNER, S*; APPEL, A; MENDONÇA, MT; Auburn University; *stg0015@tigermail.auburn.edu*

Chasing cane toads: locomotive and behavioral changes from northward dispersal

The cane toad (*Rhinella marina*) is an invasive species introduced to southern Florida, and populations expanding northward are predicted to have higher locomotive capacity. To assess endurance of toads from Florida, toads from a northern (New Port Richey (NPR)) ($n = 24$) and southern (Miami ($n = 20$)) population were placed into a 1.83m long track and tapped to encourage movement. A principal component analysis was performed on the number of taps, hops, and time it took for the toads to stop moving. The first component, "unwillingness to move", (fewer taps and hops, and shorter time until movement stopped) characterized 91.65% of the data variation. Track dispersal decreased with increasing leg : SVL ratio ($p = 0.05$), and NPR toads traveled less far than Miami toads ($p = 0.01$). Unwillingness to move increased with increasing leg : SVL ratio ($p = 0.04$), and NPR cane toads were more unwilling to move compared to Miami cane toads ($p = 0.005$). Another toad subset ($n = 38$ (Miami) and $n = 34$ (NPR)) was placed inside of a mechanical locomotion setup, where they were forced to move until reaching exhaustion. Each toad was immediately removed, bled to obtain lactate levels, and then allowed to rest. Toads that traveled further had higher lactate ($p = 0.05$). When forced to move, NPR toads traveled 5.12 (+/- 1.78)m further than Miami toads ($p < 0.01$), and NPR individuals had lower lactate at exhaustion than those from Miami ($p = 0.03$). Lactate levels decreased with increasing toad mass ($p = 0.01$), and decreased more in Miami compared NPR cane toads ($p = 0.04$). Lactate decreased over time in resting toads ($p < 0.01$), although the rate of which was the same for both populations ($p = 0.78$). These results indicate behavioral and endurance changes have occurred in these toads from northward dispersal.

P1-256 GARDNER, LE*; WATSON, CM; SHIPLEY, MM; Midwestern State University; *lg99@me.com*

The Physiological Effects of Cannabidiol on Toads

The widespread legalization of recreational cannabis use has expanded the commercialization of cannabidiol (CBD), a phytocannabinoid that accounts for approximately 40% of the extracts from the cannabis plant. It is commonly used in oil form to reduce anxiety and pain in humans but has also been utilized to make pets more tranquil. It has also been promoted as a weight loss agent. Most research on CBD has focused on mammals, but this study aimed to uncover the physiological effects cannabidiol oil has on small amphibians. Specimens of *Incilius valliceps* were acquired and split into control and experimental groups (n=8 for each group). The animals were allowed to acclimate to the lab environment and mass was measured for each specimen before and after experimental protocols. Experimental toads were fed CBD oil in a dropper while control toads were given equal amounts of tap water. The data collected analyzed the effect on heart rate, weight, and metabolic rate. The average weight loss for the experimental group was 3.5 g more than the control group, which corresponds to and increase in metabolism caused by the CBD. Heart rates were higher among the control, which suggests that CBD oil led to a lower heart rate which may aid in a state of relaxation. Based upon these mixed results, further research is required to determine if Cannabidiol oil can act as a stress-reducing agent across animal taxa.

8-8 GARDNER, SA*; AREVALO, L; CAMPBELL, P; University of California, Riverside, Oklahoma State University , University of California, Riverside ; *sgard014@ucr.edu*

Characterizing the placental microbiome in mouse (Mus) hybrids

The developmental environment, including the maternal microbiome (the community of symbiotic bacteria that regulates diverse host processes), can have a lasting effect on offspring phenotypes. In mammals, the microbiome was traditionally thought to establish in the postnatal period after exposure to the maternal vaginal tract. However, recent studies in mice suggest prenatal transfer of maternal microbes via the placenta. This prenatal inoculation is thought to promote the development of the mucosal immune system in offspring. While environment and diet play large roles in shaping microbiota composition, mounting evidence suggests that host genotype also plays an important role. However, the degree to which offspring genotype influences the composition of the prenatally-transferred community is unknown. To fill this gap we crossed two closely related mouse species, *Mus musculus domesticus* and *Mus spretus*. *M. m. domesticus* (n = 10), *M. spretus* (n = 11), and hybrid (n = 9) placentas were collected in late gestation at embryonic day 17.5. Microbial DNA was extracted and the V4 region of the 16S rRNA gene was sequenced for each placental genotype. If the composition of the placental microbiome depends only on maternal species, we should see no difference in community composition between hybrid placentas carried by *M. m. domesticus* mothers and *M. m. domesticus* placentas. If, however, offspring genotype plays a role in determining placental microbial composition, hybrid placentas should be distinct from both parental species. This project will provide a first step in understanding the impact of offspring genotype on microbial community composition during gestation.

P3-225 GARNER, AM*; RAMER, AL; NIEWIAROWSKI, PH; University of Akron; *amg149@zips.uakron.edu*

A Sticky Situation: Anole Adhesive Performance as an Inquiry-based Learning Exercise in an Introductory Biology Course

Principles of Biology Laboratory, an undergraduate introductory biology course at the University of Akron, is inquiry-based and encourages students to design their own experiments/test hypotheses based on faculty research. The laboratory exercises are broken down into two-part modules: (1) students are introduced to new research concepts and laboratory techniques that inform a proposal of an independently-designed research project, and (2) students execute their designed experiment including the collection, analysis, interpretation, and summarization of their data. Historically, however, students routinely struggle to identify the broader impacts of their work, apply what they learned, and forge connections between basic and applied biological research. Considering students' favorite laboratory exercises are those that utilize live animals and that the use of live animals in teaching increases student motivation, we designed an inquiry-based learning exercise built upon the adhesive lizard research of Integrated Bioscience faculty, Dr. Peter Niewiarowski and Dr. Ali Dhinojwala. In this laboratory exercise, students measure shear adhesion of brown anoles on a smooth acetate control and propose an experiment to alter shear adhesion by manipulating the surface properties, environment, or toe pad properties. In the second part of the laboratory, students execute their experimental design and complete a data interpretation exercise based on published work in the field of lizard adhesion. We expect this exercise to not only increase student retention of basic experimental design concepts, but also permit students to identify broader impacts of, and make connections between, basic and applied scientific research (e.g., through biomimetics).

50-5 GARNER, AM*; WILSON, MC; WRIGHT, C; RUSSELL, AP; NIEWIAROWSKI, PH; DHINOJWALA, A; University of Akron, University of Calgary; *amg149@zips.uakron.edu*

Adhesive Setal Morphology and Setal Field Configuration in Anolis equestris

Hundreds of studies have examined gecko adhesion in hopes of informing synthetic fibrillar adhesive design. Fibrillar adhesion, however, has convergently evolved in two other lineages of lizards (anoles and skinks), but comparatively fewer studies have investigated their adhesive pad morphology, function, and properties. This is particularly unexpected for *Anolis* lizards because they are considered to be model organisms for evolutionary ecology, and have been the subject of intensive biological study for several decades. Gecko ecology is relatively cryptic and understudied, but the vast literature detailing the relationships between *Anolis* morphology and habitat use may illuminate ecomorphological hypotheses for geckos. The adhesive setal field configuration has been described for several gecko species, and it appears that setal characters vary predictably along the proximodistal axis of their adhesive pads. *Anolis* setal field configuration remains largely unexplored and the only data available pertain to reports of the gross dimensions of a single seta. In this study, we examined setal morphology and setal field configuration of *Anolis equestris* and compared these data to those currently available for geckos. Overall, we found that the proximodistal variation in setal characters of *A. equestris* differs considerably from that of geckos, suggesting that setal form may be related to differences in peeling behavior. Our findings not only add to the existing comparative literature on the morphometrics and patterning of fibrillar adhesive systems, but also introduce *Anolis* lizards as an additional source of inspiration for bio-inspired synthetic adhesives.

S7-12 GARRETT, AD; BRENNAN, RS; STEINHART, A; PELLETIER, A; PESPENI, MH*; University of Vermont; *mpespeni@uvm.edu*

Linking Genome to Phenome for Complex Traits: Studies of Global Change Adaptive Variation in Marine Invertebrates

Variable environments can promote the maintenance of genetic variation that is adaptive in global change conditions. The genome of the purple sea urchin, *Strongylocentrotus purpuratus*, has adaptive variation that allows developing larvae to survive extreme ocean acidification conditions (pH 7.5), conditions periodically experienced in nature. However, little is known about adaptive responses to variable pH conditions or the genomic capacity to respond to future extreme low pH conditions (i.e., pH 7.0), beyond what has been experienced across space and evolutionary time. Here, we reared purple sea urchin larvae in static and variable, control and extreme acidification conditions (pH 8.1, 7.5, and 7.0) and measured survival, growth, and allele frequency shifts using pooled genomic DNA sequencing. We found decreased survival in extreme static pH conditions, with higher survival in variable conditions. In contrast, we found decreased total body length with decreasing pH, with extreme variable conditions causing the greatest decrease in larval growth. Together, these results suggest a potential tradeoff between survival and growth in extreme variable conditions. Genomic results showed consistent allele frequency shifts among replicate culture vessels with the greatest differences between pH treatments while static and variable pH treatments were most different at the lowest pH (7.0). Forthcoming analyses will reveal more about variation in the functional genetic mechanisms used to survive and grow in static versus variable and low versus extreme low pH conditions.

P2-37 GARRICK, SR*; WESTNEAT, MW; GEORGE, AB; University of Chicago; *sgarrick@uchicago.edu*

Evolutionary Morphometrics of Body Form and Fin Shape in Sharks

Morphological variation is substantial across the 8 orders of living sharks (selachimorph elasmobranchs), with body shape and fin shape predicted to be strongly associated with feeding ecology and locomotor behavioral patterns throughout the shark phylogeny. The goal of this study was to explore the evolution of fin and body shape across a shark phylogeny using geometric morphometric analysis to further understand the phylogenetic patterns of body shape and fin shape among shark species. How has the asymmetrical caudal fin evolved across shark species? It is predicted that fast swimming or high endurance pelagic sharks will have high aspect ratio tails, with greater dorsoventral symmetry to facilitate efficient locomotion. How have dorsal fin shape and positioning evolved across elasmobranchs? We predicted that the relative positions of the two dorsal fins and the presence or absence of the second dorsal fin is associated with body length and shape due to constraints posed by locomotor hydrodynamic principles. We pruned an existing phylogenetic time tree of Chondrichthyes (Stein et al. 2018) to include 225 shark species representing 7 of the 8 extant shark orders, with at least one species per genus. Body shape, fin shape, and fin position of these 225 species were analyzed using geometric morphometric analysis of 108 landmarks, with detailed shapes generated for each fin. Morphometric analysis revealed high variation in dorsal and caudal fin shapes and significant correlation between them, suggesting covariation of fin shapes is driven by hydrodynamic constraints. We conclude that patterns of body and fin shape, including caudal aspect ratio and asymmetry, are strongly associated with locomotor mode, and that fin shapes have undergone multiple patterns of morphometric convergence across shark evolution. NSF DEB 1541547

97-5 GARTNER, SM*; WHITLOW, KR; LAURENCE-CHASEN, JD; GRANATOSKY, MC; ROSS, RC; WESTNEAT, MW; University of Chicago, New York Institute of Technology; *sgartner@uchicago.edu*

Suction feeding of the African Lungfish, Protopterus annectens; XROMM analysis of jaw mechanics, cranial kinesis, and hyoid mobility in a novel feeding mechanism.

Lungfishes (Sarcopterygii:Dipnoi) use strong suction feeding to capture their prey and cyclic chewing to process their food. The skulls of living lungfishes show a substantial reduction in cranial bones compared to actinopterygians, yet still possess a more kinetic skull than extant tetrapods. Despite skull fusion in the feeding apparatus, suction feeding is proficient, suggesting that these animals have developed novel suction kinematics to obtain their prey. Using X-ray Reconstruction of Moving Morphology, we focused on the initial suction strike and determined relative movements of five bones—pterygoid (upper tooth plate), prearticular (lower tooth plate), left and right ceratohyal, and neurocranium—during prey capture in the West African Lungfish, *Protopterus annectens* (N=3 individuals, 15 strikes). Cranial elevation and pterygoid motion were minimal, with rapid lower jaw depression preceding the movement of the ceratohyal. The jaw joint is hinge-like, where the majority of the movement is restricted about the mediolateral axis. The left and right ceratohyals are extremely mobile, undergoing dorso-ventral depression, rotation in all three degrees of freedom, and some translation posteriorly, enabled by an unfused symphysis and no bony connection to the skull. Hyoid timing is highly variable relative to jaw opening and closing, indicating decoupled linkage mechanics for modulation of buccal expansion and suction generation. The lungfish skull exhibits an intermediate stage of kinetic mobility between actinopterygians and tetrapods, with extreme hyoid mobility. NSF DEB 1541547.

40-3 GASSLER, TR*; FLAMMANG, BE; New Jersey Institute of Technology; *trg22@njit.edu*

Animated "Foot" Control During Walking in Skates

Skates are cartilaginous, dorsoventrally-flattened benthic fishes comprising more than 240 species. Several species have been observed to use the anterior lobe of their pelvic fins to locomote in a walking-like behavior. This anterior lobe is separated into three distinct sections, similar to a femur, tibia/fibula, and foot, and has been previously likened to a tetrapod limb. A specific muscle, here named the distal radial retractor (DRR), appears to serve as an antagonist muscle of the protractor to provide stability and extend the crura or "foot". We believe this muscle to be an integral element for generating force during the walking behavior. A three-dimensional model obtained from a µCT scan of a little skate, *Leucoraja erinacea*, pelvic area was used in an animation software to interrogate this muscle. We created two models to look at presence/absence effect of the DRR. The first model included an active DRR while the second model did not. These models allowed for the definition and comparison of relative joint angles for both presence and absence of DRR activity during walking behaviors.

S1-8 GAST, RJ*; SANDERS, RW; Woods Hole Oceanographic Institution, Temple University; *rgast@whoi.edu*

You are what you eat: mixotrophic protists in Antarctic marine plankton communities

Despite the traditional view of protistan species as either phototrophic or heterotrophic, there are many photosynthetic protists that consume prey (mixotrophy). Some modeling studies suggest that mixotrophic activity will increase under warming scenarios and that they have the potential to dramatically alter the flow of nutrients in aquatic environments when compared with food webs dominated by strict autotrophs and heterotrophs. Mixotrophy is a widespread phenomenon in aquatic systems, but the factors known to induce this activity, including light limitation and micronutrient deficiencies, go through dramatic changes in the Southern Ocean. The contribution of mixotrophy is likely seasonal and linked to the taxonomic composition of the community. We have surveyed the presence and grazing impacts of mixotrophic phytoflagellates in Austral spring (2008), summer (2011) and late fall (2019). Our research indicates that these organisms can play a significant role as bacterivores in polar ecosystems, potentially consuming up to 100% of daily bacterial standing stock in the spring and comprising up to 75% of the grazing community in the summer. We have begun to use tracer studies of ingestion to identify unknown active mixotrophic species, quantification using qPCR, and transcriptome comparisons to better understand the taxonomic and functional diversities of the mixotrophic community.

133-8 GAU, JF*; LYNCH, J; GRAVISH, N; SPONBERG, S; Georgia Tech, UC San Diego; *jeff.gau@gatech.edu*

Asynchronous properties of synchronous hawkmoth flight muscles

Insect flight muscles have historically been divided into two distinct classes: synchronous muscles contract once per neural excitation while asynchronous muscles exhibit delayed stretch activation (SA) and shortening deactivation (SD) to produce power when cyclically stretched. However, SA and SD have been observed in synchronous vertebrate skeletal and cardiac muscle. Instead of distinct classes, we hypothesize that insect flight muscles exhibit a continuum of physiological properties. To address this hypothesis, we mounted synchronous *Manduca sexta* dorsolongitudinal muscles (DLMs) in a dual-mode muscle lever at 35°C. At tetanus, we stretched the muscle under *in vivo* conditions while measuring force output. Following a brief hold, we returned the muscle to rest length. Unlike prior work in synchronous locust flight muscle, we found significant SA characterized by a delay of 46 ± 2 ms (n = 7) and tension rise of 330 ± 110 mN (n = 7). Therefore, among flying insects, SA is not unique to asynchronous muscle. Temperature dependences on rise time are consistent with SA in asynchronous beetle and bumblebee muscle but a delay of one wingbeat period is significantly longer than that of the beetle. Despite antagonistic muscle arrangement and SA, *Manduca sexta* is a synchronous flyer because tonic Ca^{2+} is not present *in vivo* and SA may be too slow. Furthermore, we saw no evidence of SD, which may be necessary for asynchronous operation. This also suggests that SA and SD require different molecular machinery. In conclusion, we present asynchronous-like properties of synchronous flight muscle. Instead of distinct muscle classes, perhaps the synchronous and asynchronous operation of insect flight muscle is determined by their operating regime and a continuum of physiological properties.

P1-228 GAUTHIER, SM*; COHEN, KE; SUMMERS, AP; Lewis and Clark College, University of Washington; *sgauthier@lclark.edu*

Getting to the Point: Characterizing the Function of Conical Teeth in Deep-Sea Stomiiformes

If conical teeth are simply a tool used to puncture prey items, why is there such morphological diversity? We propose that they serve a wider variety of functions than their basic shape suggests. We use sharpness as a metric for determining the functions of conical teeth in the species *Gonostoma gracile*, *Cyclothone atraria*, and *Stomias atriventer* from two families of deep-sea fishes: the Dragonfish (Stomiidae) and Bristlemouths (Gonostomatidae). These Stomiiforme fishes share a common trait of conical teeth; however, gonostomatids feed primarily on zooplankton, while stomiids have adaptations for piscivory. We expected teeth to be sharper in piscivores. Additionally, we tested whether sharpness measurements are comparable between microCT and scanning electron microscopy (SEM). We found that sharpness is not an effective way to discern tooth function, as sharpness is correlated with tooth size. Teeth that are too small to effectively puncture prey items are sharper than larger teeth found in piscivorous Stomiiformes. Furthermore, for teeth between 250 µm and 2700 µm, the 18-25 µm resolution of the CT scanner was not sufficient to capture sharpness measurements that were measured by SEM. CT obscured true tooth height and shape and missed small morphological details, including damage. Further analysis of damage, tooth separation, and surface grooves appears to be a more promising tool for understanding how a tooth might be used, as these characters appear to correlate with gut content.

P1-11 GAVAZZI, LM*; COOPER, LN; THEWISSEN , JGM; Kent State University, Kent, OH and Northeast Ohio Medical University, Rootstown, OH, Northeast Ohio Medical University, Rootstown, OH; *lmgavazzi@gmail.com*

Patterning and development of the beluga whale (Delphinapterus leucas) fluke

Cetaceans, the order containing whales, dolphins, and porpoises, utilize a fluked tail as the main propulsive organ during locomotion. The fluke is the lateral soft tissue outgrowth at the caudal-most region of the vertebral column, and the emergence of this structure is evolutionarily correlated with the loss of hindlimbs. It is previously well-documented that the fluke embryonically originates as a diamond-shaped thickening on the tip of the tail. It expands mediolaterally to form a spade shape, before inverting into the final triangular, notched structure. While there have been several studies concerned with the morphogenesis of the cetacean fluke during embryonic development, the molecular underpinnings of this structure are unknown. Using fluke tissue from several fetal belugas, we performed immunohistochemistry and tested for the presence of sonic hedgehog (SHH) and FGF-10, two proteins that are critical during embryogenesis. Staining for SHH was found sporadically in the epithelium and some regions of connective tissue. FGF-10 staining in the epithelium was consistent, with stronger signal found in the lateral and ventral regions of the fluke.

111-1 GAWNE, R*; LEVIN, M; Tufts University; *richard.gawne@tufts.edu*

Planarian Head Shape Control: Regeneration Recapitulates Phylogeny

Planarian flatworms are important model systems for understanding regeneration because many species are able to reconstitute their entire body from small tissue fragments. Contemporary research on these animals has tended to focus on the mechanisms responsible for establishing head/tail polarity, and accordingly, we know a great deal about the factors that determine which end of a wounded body fragment will regenerate a head, as opposed to a tail. Comparatively little is known about how head shape is established, and why regeneration ceases when a specific head shape is achieved. The shapes of planarian heads vary significantly across species, ranging from rounded, to triangular, to square-like, and often change significantly over the course of regeneration. Using techniques from geometric morphometrics, we construct a morphospace for planaria head shapes, and show that species with complex head morphologies go through regenerative stages that resemble the fully formed heads of other species. In light of these, and other findings, we suggest that complex head shapes have evolved by a process of terminal addition. To better obtain a better understanding of how head shape is produced during regeneration, we experimentally inhibited cell-cell communication through the application of a gap junction blocker. This treatment was found to have different effects on the regenerative process in different species, indicating a potential role for non-genetic physiological mechanisms in the evolution of head shape.

S6-11 GóMEZ-BAHAMóN, V*; WORM, A; CASTAñO, M; DONAHUE, E; TUERO, D; CLARK, C; BATES, J; University of Illinois, Arkansas State University, Universidad de los Andes, Universidad de Buenos Aires, University of California Riverside, Field Museum; *vgomez21@uic.edu*
Non-vocal Acoustic Signals in Kingbirds (genus Tyrannus)
Many birds have evolved sonations (non-vocal acoustic signals) produced with tail or wing feathers. Within the family Tyrannidae ≈20% of the species have males with modified wing feathers hypothesized to produce sonations. Kingbirds encompass thirteen species, twelve with different outer primary feather modifications. The questions that this project aims to address are whether non-vocal signals in Kingbirds differ in 1 Acoustic characteristics, 2 The mechanism by which the sound is produced, and 3 The behavioral context. To answer these questions we compared high speed videos and sound recordings of displays in five species of Kingbirds: Eastern, Western and Tropical Kingbirds (T.tyrannus; T.verticalis; T.melancholicus) and Scissor-tailed and Fork-tailed Flycatchers (T.forficatus;T.savana). All species produced these sounds when increasing wingbeat frequency. The sound is produced by males when birds are close to each other during female-male interactions and male-male aggressive displays. In T.savana and T.forficatus the sound is also audible during interspecific aggressive attacks (e.g., against predators). Comparisons among two subspecies of T.savana showed differences in frequency during displays. Individual feathers in a wind tunnel over a range of airspeeds showed that the feathers of T.s.monachus produce sounds at a lower frequencies than those of T.s.savana matching those taken from field recordings. High speed videos of individual feathers in the wind tunnel suggest feathers make sound by fluttering of the trailing vane at the tip of the feather. We conclude that the mechanisms of sound production are similar between species of Kingbirds but that they differ in acoustic characteristics (such as frequency, intensity and duration).

118-6 GóMEZ-BAHAMóN, V*; CHEN, E; ASSIS, M; HEMING, N; MARINI, M; TUERO, D; BATES, J; University of Illinois , Field Museum , University of Brasília, University of Brasília, Universidad de Buenos Aires, Field Museum; *vgomez21@uic.edu*
Egg Shape and Flight Capacity in Birds Implementing a Novel Geometric Model
Among amniotic animals, birds evolved a variety of egg shapes. Two mayor types of hypotheses have been proposed to explain the morphologic diversity of this key avian feature: 1 adaptive hypotheses, which include life history pressures and breeding ecology as major drivers of egg shape, and 2 an indirect hypothesis, stating that egg shape evolves in correlation with skeletal and muscular features because of the physical pressures they exert during egg formation. The latter has recently been backed by evidence showing that at broad taxonomic scales, egg shape is associated with flight capacity, arguing that species with an aerial lifestyle have skeletal and muscular adaptations that differ from those of birds that spend more time on the ground. Studies that test adaptive hypotheses at the intraspecific level have focused on species with highly asymmetric eggs and that nest in cliffs, for which shape adaptations are clearly important. We test the hypothesis of egg shape evolving in association with flight capacity between closely related species and at the intraspecific level. Numerous species of birds have populations that are migratory and others that are sedentary, two behavioral strategies that have been shown to result in differences in wing shape across different families of birds. To test whether egg shape evolves in correlation with flight capacity, we studied egg shape within species of Kingbirds (Tyrannus) that have migratory and sedentary birds. We also developed a novel mathematical description of egg geometry and a computer app to measure egg shape. We find that eggs from migratory individuals are more elongated as was found at higher taxonomic levels, but that eggs from sedentary species are more asymmetrical, contrasting higher taxonomic trends.

122-7 GüELL, BA*; CALDWELL, MS; WARKENTIN, KM; Boston University, Gettysburg College; *bguell@bu.edu*
Treefrog egg-clutch biomechanics and their effect on embryo escape-hatching behavior
Arboreal embryos of phyllomedusid treefrogs hatch prematurely to escape snake predation, cued by low frequency vibrations in their egg clutches. Escape success varies between species, from 80% at 1d premature in *Agalychnis callidryas* to just 11% in *A. spurrelli*. However, both species begin responding to snake attacks at the onset of vestibular function. Egg clutches of *A. callidryas* are thick and gelatinous, while *A. spurrelli* clutches are thinner and stiffer, affecting whole-clutch and individual-egg movements excited by attacks. Since all vibration cues embryos perceive must propagate through their egg clutches, we hypothesized that differences in the hatching responses to snake attacks in *A. callidryas* and *A. spurrelli* are due to the influence of clutch biomechanics on the cues available to embryos. We tested this by embedding egg-sized accelerometers within clutches of both species and performing three standardized excitation tests at varying distances to the accelerometer: pendulum impacts, water droplets, and simulated snake-attacks. Mechanically, thinner egg clutches should have higher resonant frequencies, greater spatial attenuation, and damp more quickly than thicker, more flexible clutches. Initial analyses of clutch free vibrations following impact tests indicate *A. spurrelli* clutches oscillate at much higher frequencies than those of *A. callidryas*. *A. spurrelli* clutches also show greater differences in peak amplitudes between impact distances and faster attenuation of vibrations than *A. callidryas* clutches. Vibrations induced by water droplets and simulated snake-attacks also appear to differ between species. Vibration biomechanics may constrain the information available to *A. spurrelli* embryos and contribute to inter-species differences in hatching responses to predator attacks.

76-8 GECELTER, R*; KIKEL, M; THOMPSON, N/E; NYIT College of Osteopathic Medicine; *rgecelte@nyit.edu*
Hip Moments and Muscle Activity During Compensatory Osteoarthritis Gaits
Hip osteoarthritis (OA) is one of the most common joint diseases. This disorder causes OA patients to alter their gait to compensate for hip pain while maintaining frontal plane balance during walking. These compensatory gaits are likely an attempt to minimize hip abduction moment and/or muscle force. However, different compensatory characteristics exist among hip OA patients, particularly in pelvic motion, step width and muscle activity. Here we investigated the hip biomechanics underlying two compensatory gaits of hip OA: exaggerated pelvic drop and pelvic elevation on the swing side. We recorded full-body kinematics, kinetics and muscle activity in 9 subjects during normal and simulated pathological gaits. Kinematics were recorded via a 12-camera Vicon motion capture system using the Plug-In gait marker set. Subjects walked on an AMTI force-instrumented treadmill at 1.0 m/s under varying pelvic motions (normal, pelvic drop, pelvic elevation). Gluteus medius muscle activity was recorded using a Noraxon surface electromyography system. Compared to normal walking, exaggerated pelvic drop on the swing side entailed an increase in maximum hip abduction moment (~35%). Exaggerated pelvic drop on the swing side also elicited an increase in maximum stance-phase gluteus medius activity in our subjects. On the other hand, pelvic elevation resulted in a decrease in maximum hip abduction moment (~13%) though was accompanied by an increase in step width (~25%) and the highest increase in stance-phase gluteus medius muscle activity (~80%). Our results indicate that different OA gaits may optimize different gait characteristics. Pelvic elevation may be used when prioritizing hip abduction moment minimization, while exaggerated pelvic drop may be a solution to lower gluteal muscle force.

P2-178 GEFEN, E*; RAVIV, D; University of Haifa- Oranim; *gefene@research.haifa.ac.il*
Post-feeding metabolic response and thermal preference in the scorpion Hottentotta judaicus
Relatively little is known on the postprandial metabolic response, often termed specific dynamic action (SDA), in arachnids. In this study we wanted to investigate the effect of temperature on SDA in scorpions, and its possible consequence for post-feeding thermal preference. We hypothesized that the high increase in metabolic cost of digestion associated with infrequent feeding would translate to a behavioral thermoregulatory response, correlated with the expected higher prey energy utilization at higher temperatures. Adult *Hottentotta judaicus* (Buthidae) were collected, fed with grasshopper nymphs and acclimated to laboratory conditions (25˚C; 14L:10D), before being assigned to 25 (N=12) and 30˚C (N=14) temperature treatments. Following two-week food prevention at the experimental temperatures, standard metabolic rates were measured using closed-system respirometry, before the animals were offered prey. Following 5h (at 25˚C) or 4h (at 30˚C) of feeding, post-feeding metabolic rates were measured for up to 7 days. Additionally, scorpions acclimated to 25˚C were placed in a thermal gradient arena (105cm length; temperature range 17-46˚C) after two-week food prevention, and were photographed at 1min intervals for 10h during the night under red-light conditions, before a similar procedure was carried out for the same individuals post-feeding. Calculated SDA and SDA coefficient ($C_{SDA}=E_{SDA}/E_{prey}\times100$) were significantly higher at 30 compared with 25˚C, but SDA duration was significantly shorter at 30˚C, despite larger meal sizes on average. Scorpions showed preference for significantly higher surface temperatures post-feeding (37.2±0.9˚C compared with 34.0±1.0˚C before). We conclude that post-feeding preference for higher temperatures, despite lower prey energy utilization, may benefit the energy budget of scorpions by shortening digestion time and thus maximizing foraging efforts.

87-3 GEMILERE, R*; LDS-VIP, ; GAU, JF; SPONBERG, S; Georgia Tech; *rgemilere3@gatech.edu*
Wingbeat frequency modulation to large lateral perturbations in hawkmoths
Like many synchronous and asynchronous flying insects, steady flight in *Manduca sexta* typically occurs in a narrow band of wingbeat frequencies. However context can modulate this range. Artificial reduction of wing inertia causes a compensatory increase in wingbeat frequency of roughly 10%. Similarly, load lifting experiments increased wingbeat frequency by 20%. These results highlight the capacity for *Manduca sexta* to change wingbeat frequency to compensate for steady state changes in flight requirements. We hypothesize that *Manduca sexta* might also utilize rapid wingbeat frequency modulation to recover from large transient perturbations. To address this hypothesis, we recorded high speed video of hawkmoth flight at 2000 fps (n = 7). After each moth established stable hovering to feed in front of an artificial flower, we perturbed their flight by shooting the moths laterally with vortex rings. We estimated instantenous phase and wingbeat frequency via a Hilbert transformation on wing kinematics. Prior to the perturbation, the moths had an average wingbeat frequency of 24.7 +/- 1.4 Hz. In comparison, average wingbeat frequency over ten wingbeats during perturbation and recovery was 21.5 +/- 6.4 Hz. Although we found no change in mean wingbeat frequency ($p = 0.25$), there was a substantial increase in wingbeat frequency modulation. Pre perturbation, the frequency range was 2.6 +/- 1.0 Hz, which increased to 16.2 +/- 3.9 Hz post perturbation ($p < 0.01$). This range corresponds to roughly 65% of average wingbeat frequency. Furthermore, EMG recordings of the downstroke flight muscles corroborate that changes in wingbeat frequency are driven by changes in neural stimulation rate . These results suggest that synchronous flying insects may have wide control affordance in frequency when challenged with extreme conditions.

135-5 GEORGADARELLIS, GL*; JIMÉNEZ, JM; ALBERTSON, RC; University of Massachusetts, Amherst; *ggeorgad@umass.edu*
Increased Swimming Speed Induces Differential Bone Remodeling in Zebrafish
To better understand how dynamic loading plays a role in zebrafish (*Danio rerio*) bone development and growth, we have designed, built, and characterized a water tunnel. Boundary layer theory was used to design the water channel contraction ensuring thin boundary layers constrained to the near-wall, yielding a uniform flow field for the fish to swim in. Furthermore, turbulent flow theory was used to ensure an isotropic and homogeneous flow field void of velocity gradients. Our design encouraged fish to swim for the duration of the experiment, which is not the case for other swim chambers where fish have been observed to rest on walls to avoid swimming. Thus, we are able to investigate the role of increased swimming speeds on zebrafish bone remodeling in a well-defined flow field. Starting ~30 days post fertilization (dpf), sibling zebrafish groups were either exposed to an exercise regimen starting at a velocity of 1 body length per second (BL/s) for 6hrs/day for 7 days, or maintained in a standard 2.8-L tank of comparable water volume. The velocity was increased in the exercise group by ~10% each day. We noted structural differences between groups in the skeletal architecture of several functional units, including the caudal fin and pectoral apparatus. To determine the role of the Hedgehog (Hh) signaling pathway on bone due to exercise-induced mechanical load, we used two different transgenic fish wherein Hh levels can be up- or down-regulated in a time-specific manner. These experiments revealed a strong gene-by-environment effect, confirming that the Hh pathway is mechanically sensitive with respect to bone formation. Overall, our results provide a better understanding of how mechanical forces affect skeletal remodeling as well as the molecular genetic mechanisms that regulate this process.

95-4 GEORGE, EM*; ROSVALL, KA; Indiana University Bloomington; *georgee@indiana.edu*
How social challenges modulate steroid signaling in the female brain
Little is known about the mechanisms underlying female-female aggression, despite increasing evidence of its adaptiveness in many species. While some male vertebrates socially modulate circulating testosterone (T) levels after aggressive interactions, the same hormonal response has not been found in many female vertebrates, perhaps because selection has favored mechanisms that minimize the potentially high costs of elevated T levels in females. We hypothesize that, rather than changing *systemic* T levels in response to competitive interactions, females instead modulate *local* sex steroid sensitivity and conversion, i.e. by upregulating sex steroid receptors and steroid-modifying enzymes in behaviorally relevant tissues like the brain. Here we tested this hypothesis in tree swallows (*Tachycineta bicolor*), a species in which females compete for limited nesting sites and aggression is at least partially mediated by androgens. We found that females do not rapidly increase, and actually decrease, T levels after both real and simulated social challenges. In light of this result, we further explored whether social challenges induce changes in local steroid processing and binding within the brain. To test this, we exposed females to simulated territorial intrusions and collected neural tissue 2-3 hours later. We used qPCR to measure the expression of genes involved in steroid binding and processing in brain regions thought to mediate aggression, including nodes of the vertebrate social behavior network. These findings will provide novel insight into mechanisms by which individuals can respond to social challenges without increasing T production.

50-3 GEORGE, AB*; WESTNEAT, MW; University of Chicago; *abgeorge@uchicago.edu*

Swimming Performance Informs Patterns of Evolutionary Ecomorphology Among Triggerfishes and Filefishes (Superfamily: Balistoidea)

Triggerfishes and filefishes (superfamily Balistoidea) exhibit a wide range of morphological diversity including median fins that lie on a continuum from high to low aspect ratio. High aspect ratio median fins are associated with increased balistoid endurance swimming performance, while low aspect ratio fins likely facilitate short bursts of speed. We predicted that links between morphology and swimming performance could explain patterns of balistoid fishes convergently colonizing marine habitats from coral reefs to the open ocean and evolving planktivorous, grazing and predatory feeding modes. We hypothesized that balistoid species with high aspect ratio fins are associated with open water habitats and planktivory, ecologies requiring endurance swimming. Conversely, we predicted that fishes with low aspect ratio fins are associated with reefs and benthic grazing, ecologies requiring quick bursts of speed. To test these hypotheses, we calculated fin aspect ratios and conducted geometric morphometric analyses of fin and body shapes of 450 individuals representing 80 balistoid species and classified each species by primary habitat use and feeding mode. Ancestral state reconstructions revealed multiple convergence events on both high and low aspect ratio fins. We discovered multiple ecomorphology relationships such as reef-associated filefishes converging on deep bodies and low aspect ratio fins (Wheatsheaf index = 1.79, $P = 0.023$). The use of swimming performance to inform the interpretation of our ecomorphology results demonstrates the importance of combining functional and ecological research to thoroughly explore how and why species evolve novel morphologies and ecologies. Funded by NSF GRFP 1144082 and 1746045, IOS 1425049 and DEB 1541547.

127-2 GERMEROTH, LM*; SUMNICHT, TP; VERBLE, RM; Missouri University of Science and Technology, Rolla, MO; *lgm9d@mst.edu*

Maintaining Biodiversity of Ant Communities in the Crocker Range, Malaysian Borneo

Borneo is home to 1/16th of the world's ant diversity; however, intensive land use and agricultural practices are destroying forests at an accelerating pace. In 2014, UNESCO designated the Crocker Range as a Man and Biosphere region, which restricted development in core forests entirely and minimized development and impacts in surrounding buffer forests. We examined the efficacy of these zones in maintaining leaf litter ant biodiversity core and buffer highland rainforests in Summer 2019. We sampled leaf litter ant communities at twelve sites (N = 6 buffer; N = 6 core). Each grid was separated by > 50 m and consisted of 16 one-meter quadrats. Leaf litter was sifted using leaf litter extractors and then hung in Berlese funnels for 48 hours. Extracted ants were stored in ethanol, point mounted, and identified to genus using local taxonomic keys. Ant biodiversity in core and buffer forests was similar, and ant activity was highest in buffer forests. Species richness among sites was patchy. Our data support the continued use of zone stratification in these forests as an effective means of maintaining biodiversity reserves.

P1-52 GERRINGER, ME*; YANCEY, PH; TIKHONOVA, OV; VAVVLOV, NE; ZGODA, VG; DAVYDOV, DR; State University of New York at Geneseo, Whitman College, Walla Walla, WA, Institute of Biomedical Chemistry, Moscow, Russia, Institute of Biomedical Chemistry, Moscow, Russia, Washington State University, Pullman; *gerringer@geneseo.edu*

Evolving pressure tolerance in enzymes of abyssal and hadal fishes

We explore the basic principles of pressure tolerance in enzymes of deep-sea fishes using lactate dehydrogenases (LDH) as a case study. We compared enzyme activities under a full range of pressures from two hadal snailfishes (*Notoliparis kermadecensis* and *Pseudoliparis swirei*) with a shallow-adapted snailfish, *Liparis florae*, and an abyssal grenadier, *Coryphaenoides armatus*. We then quantified the LDH content in muscle homogenates to compare the enzymes' catalytic efficiency using mass-spectrometric determination of the LDH-specific conserved peptide LNLVQR. While studying the effect of pressure on LDH activity, we discovered an unexpected aspect of adaptation. Existing theory suggests that piezophilic adaptation necessitates a decrease in volume changes in protein transitions under high pressure. However, we observed a substantial increase in specific volume change of inactivation in deep-living species. With this change, the enzyme activities from abyssal and hadal species do not substantially decrease up to 100–200 MPa, well beyond full-ocean depth pressures. In contrast, the activity of the enzyme from the tidepool snailfish, *L. florae*, decreases nearly linearly from 0.1 to 250 MPa. The increased stability of LDH comes at the expense of decreased catalytic efficiency, which is compensated by increased enzyme contents in high-pressure adapted species. This newly-discovered strategy of pressure adaptation is apparently used when substantial changes in functional enzyme-solvent interactions cannot be eliminated.

P1-30 GHIONE, C*; LOUGH-STEVENS, M; DEAN, M; University of Southern California, University of Southern Caliornia; *ghione@usc.edu*

Male body size evolves more rapidly than female body size

In mammals, males are often bigger than females leading to body size dimorphism (BSD). BSD might arise because big males acquire more mates while females are more constrained due to ecological factors. This leads to the prediction that male body size changes more rapidly over evolutionary time. Body mass data was collected for seven orders of mammals and nineteen orders of birds from multiple online databases as well as published books about body mass. Ancestral data was reconstructed using the ratebytree function of phytools. Rate shifts along the phylogenetic tree were also analyzed using BAMM and BAMMtools. In 4/6 species, male body mass changed more over the same period of evolutionary time. Rate shift analysis shows that there were more body size rate changes for males across the phylogeny. Interestingly, not all rate changes occur in the same nodes of the tree between males and females. Our analysis points to males being less constrained and able to change their body size more rapidly compared to females.

P1-21 GIANCARLI, SM*; DUNHAM, AE; O'CONNOR, MP; Drexel University, Philadelphia, PA, University of Pennsylvania, Philadelphia, PA; *smg432@drexel.edu*

Examining Metabolic Allometry Among Birds: A Phylogenetic Approach

Metabolic allometries typically take the form of power functions, and the Metabolic Theory of Ecology (MTE) asserts a "universal" three-quarter power for such scaling rules. Recent studies have differed over support for the three-quarter allometric coefficient required by the MTE. We have previously argued that such coefficients vary among mammalian clades and that 0.75 is not a universal scaling constant. Also as endotherms with a wealth of metabolic measurements on multiple clades, birds are a natural next step to observe clade-specific variation. Flight-related metabolic constraints may also affect birds' metabolic allometries. In addition, existing literature examining the allometries of basal metabolic rates in birds has not considered the impacts of phylogeny beyond a binary passerine vs. non-passerine classification. Phylogenetic relatedness can account for variation, or lack thereof, in metabolic rate between closely related clades. It is also yet unclear as to whether the broad, "universal" three-quarter power allometries are composed of smaller sub-allometries that correspond with deeper classifications. We have amassed a database of 726 bird species from existing literature. After assigning each of them to one of 15 monophyletic clades we performed regressions using a variety of analytic techniques. For basal metabolic rate, both allometric slopes and intercepts (known as normalization constants) varied significantly among bird clades both between passerines and non-passerines. This parallels our previous findings among mammals.

12-5 GIBSON, JD*; BOTNARU, L; COBB, BA; Georgia Southern University; *jgibson@georgiasouthern.edu*

Mortality and Physiology of Nasonia Hybrids

Nasonia is a genus with four species of parasitoid wasp that can be crossed in the laboratory, producing hybrids that demonstrate varying levels of reproductive isolation between these species. Previous work has shown that F2 hybrid males of crosses between *Nasonia vitripennis* and *N. giraulti* suffer >90% mortality during development when their genotype (*N. vitripennis* or *N. giraulti*) at a single nuclear locus doesn't match their mitochondrial genotype. Due to this pattern of mismatched nuclear and mitochondrial genotypes, we have hypothesized that the mortality is due to deficiencies in metabolic physiology. Unfortunately, the small number of surviving hybrids makes it difficult to assess experimentally any potential mechanisms of this mortality. All male Hymenoptera are haploid so any effect of dosage cannot be measure, however F1 female hybrids (diploids that are heterozygous for each species' alleles) don't suffer this mortality. Despite this, preliminary data on F1 females indicates that they have a lower mitochondrial O2 consumption rate than either parent species. We will present mortality and physiological data based on crosses of these two species in which we generate female F1 hybrids and F2 backcross hybrids that are either heterozygous or homozygous for the mortality inducing genotype. This initial data will allow us to begin dissecting the mechanism of hybrid mortality in *Nasonia* and may provide a more tractable experimental system for studying mitochondrial physiology in these hybrids.

29-6 GIBSON, JC*; SUAREZ, AV; University of Illinois at Urbana-Champaign; *jcgibso2@illinois.edu*

Functional morphology and biomechanics of trap-jaw ants in the Daceton genus group

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 functional morphology and strike kinematics of representative species from the *Daceton* genus group, which consists of the genera *Acanthognathus*, *Colobostruma*, *Daceton*, *Epopostruma*, *Lenomyrmex*, *Mesostruma*, *Microdaceton*, and *Orectognathus*. Despite possessing a latching mechanism that is morphologically analogous to a separate trap-jaw ant group (*Strumigenys*) which produces synchronous mandible closure, we found that *Epopostruma* and *Orectognathus* close their mandibles asynchronously by unilaterally contracting their labral adductor muscles. An exception is the soldier caste of the polymorphic species *Orectognathus versicolor*, which close their mandibles synchronously. We also show that, unsurprisingly, some members of this group do not possess power-amplified mandibles, but exhibit behaviors such as raising of the the labrum between the mandibles while hunting that can be viewed as a preadaptation for evolving a latching mechanism. This study is part of a larger project examining the biomechanics and evolution of power-amplified mandibles in ants.

116-3 GIFFORD, ME*; ROBINSON, CD; University of Central Arkansas, University of Virginia; *megifford@uca.edu*

T3 as a source of hormonally-mediated maternal effects in a lizard

Maternal effects are important mechanisms generating phenotypic variation in offspring with potentially adaptive consequences. Prenatal maternal effects often are mediated through maternal transmission of hormones to the developing embryo. Such effects are particularly well-studied in response to maternally derived steroid hormones. Thyroid hormones (TH), triiodothyronine (T3) and thyroxine (T4), are metabolic hormones having pleiotropic effects across several different life stages. During vertebrate development, THs are critically important for normal development, growth, and metabolism. Recently maternally-derived THs have been shown to vary among individual birds in association with some environmental characteristics including ambient temperature and reproductive timing, and among eggs within a single clutch. Therefore, although data are limited, the possibility exists that maternally-derived THs represent another mode through which adaptive plasticity could arise in offspring. Currently very few studies have examined the potential role of THs in regulating offspring phenotypes; and all studies to date have involved two taxa (birds and turtles) and even fewer have examined such effects in wild animals. We manipulated T3 concentration in eggs of the Prairie Lizard to test for variation in embryonic and hatchling phenotypes potentially related to fitness. T3 manipulation doesn't appear to dramatically affect embryonic traits but causes sex-specific responses in several hatchling phenotypes potentially related to fitness. In addition, hatchling phenotypes show dose-specific responses. In all, it appears that maternally derived THs can potentially serve as a source of adaptive plasticity in lizards.

69-6 GIGLIO, EM*; TRIPP, JA; PHELPS, SM; University of Texas at Austin; *eringiglio@gmail.com*

The role of leptin in social signal decisionmaking in neotropical singing mice (Scotinomys teguina)

Sexual signals are spectacular behaviors. Reproductive rewards for successful display are great, but must be balanced against the many potential costs. To maximize payoff, individuals must monitor both internal and external cues and use that information to adjust display investment. Leptin, a hormone secreted by adipose tissue, is a promising index of body condition that regulates energy allocation to functions as diverse as feeding, sleep, reproductive effort, and immune response. Despite evidence that leptin influences reproductive trade-offs, its role as a putative regulator of courtship display is poorly understood. Here we examine the integration of interoceptive and exteroceptive cues into allocations of display effort using Alston's singing mouse (Scotinomys teguina). We first manipulate individuals' perception of energy balance through intraperitoneal injection of exogenous leptin, and alter social context through playback of conspecific song using a repeated-measures design. Mice injected with leptin sing back more frequently and more quickly than mice injected with saline. Leptin also improved measures based on acoustic parameters thought to be indications of song effort, but not those thought to be markers of identity. In a follow-up experiment using a design that avoided some confounds of our repeated-measures design, we again found that animals injected with leptin sang at a high rate. We are currently examining the acoustic structure of evoked song, and the induction of immediate early genes in brain regions we hypothesize are responsible for integrating social context and body condition.

122-1 GIGNAC, PM*; KLEY, NJ; Oklahoma State University Center for Health Sciences, Stony Brook University; *paul.gignac@okstate.edu*

At the nexus of iodine staining duration and specimen size: repeated-measures study to improve visualization of vertebrate soft-tissue anatomy using diceCT imaging

Diffusible iodine-based contrast-enhanced computed tomography (diceCT) facilitates three-dimensional imaging of soft-tissue anatomy at high spatial resolutions, relatively rapidly, and at manageable expense. A critical preparatory step is identifying the length of time for which a specimen should stain in iodine potassium-iodide (I_2KI) to (1) ensure the contrast agent fully penetrates the deepest tissues, but (2) without over-staining the sample thus reducing inter-tissue contrast differences and/or contributing to soft-tissue distortions. Finding this balance includes accounting for confounding factors such as size and iodine concentration. Here 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 (~10 mm) sections from the bodies of adult specimens of pythons (*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 (~10, 20, 30, and 40 mm) were prepared in triplicate. Triplicates were stained with a series of exposures to I_2KI (1, 3, 5, and 10% concentrations) and at specific durations (7, 14, 21, 28, and 35 days), followed by µCT scanning to measure tissue grayscale values and total depth of staining within sections. Based on staining completeness and tissue differentiation, we generally found that longer staining durations produce the best results. However, acceptable contrasts can certainly be achieved using shorter staining periods at higher concentrations. We summarize the scope of our findings into best-practices recommendations for the diceCT community.

106-2 GILBERT, AL*; RUTSCHMANN, A; FITSCHEN-BROWN, MS; MILES, DB; CLOBERT, J; Ohio University, University of Auckland, tion of Experimental and Theoretical Ecology, Moulis, France; *anthony.gilbert09@gmail.com*

Acclimation to warmer temperatures attenuates heat-shock plasticity in high elevation populations of common lizards

As the intensity of heat waves and the occurrence of extreme weather patterns increases, ectotherms are likely to rely on heat-shock responses to counteract rapidly warming body temperatures and reduce the costs associated with heat stress. While heat shock responses tend to be conserved across taxa, the plasticity of these responses to increasing environmental temperatures is unknown. If warmer environmental temperatures reduce the strength of heat-shock responses, then the reliance on these plastic responses as a short-term mechanism of lethal temperature avoidance could dwindle as the climate warms. Here, we performed an experiment using five populations of common lizards (Zootoca vivipara) distributed along an elevational gradient to test how heat-shock responses (i.e. heat-hardening) change with acclimation to warmer environmental conditions. We measured cold tolerance (CTmin), preferred body temperatures (Tpref), heat tolerance (CTmax) and the heat-hardening response (the change in CTmax with heat shock) before and after acclimation to temperatures 2C above mean environmental conditions. We found that the strength of the hardening response was attenuated for populations at higher elevations, but not for populations at low elevations. Acclimation also shifted baseline heat and cold tolerances as well as preferred temperatures. These finding suggests that consistent and slow increases in environmental temperatures might over time reduce the ability of populations to mount short-term responses to rapid environmental changes.

P1-188 GILBERT, MC*; LEROSE, C; CONITH, A; MOYER, JK; HUSKEY, S; ALBERTSON, RC; Organismic and Evolutionary Biology, Univ. MA, Amherst, Biology Department, Univ. MA, Amherst, Biology Department, Western KY Univ.; *chaise.gilbert@live.com*

Osteology and Myology of Pterycombus petersii, with Insights into the Functional Tradeoff Between Feeding and Locomotion

The family Bramidae represents 20 species across 7 genera that inhabit oceanic waters. Despite a global distribution, they are seldom collected and therefore understudied. Of the bramids, the fanfishes (*Pteraclis* and *Pterycombus*) are especially rare and exhibit a striking anatomical exaggeration consisting of anteriorly elongated dorsal and anal fins. Changes in fin morphology are a driving force in the functional diversification of ray-finned fishes. Such diversification may be facilitated by compensatory changes to the underlying musculoskeletal system that support novel fin morphologies but impose a trade-off on other functional systems such as prey acquisition. Using µCT scans, staining methods, and morphometrics we compare the anatomy and ontogeny of *Pterycombus petersii* (Hilgendorf, 1878) to other bramid fishes to gain insights into the form, function, and evolution of their musculoskeletal architecture. In particular, we describe anatomical modifications that accommodate the exaggerated dorsal fins of the fanfishes, including a modified neurocranium with a greatly reduced supraoccipital crest (SOC). The SOC normally provides surface area for the anterior epaxial musculature, and is important for cranial elevation during feeding, especially suction-feeding. In fanfish, the dorsal aspect of the skull has been modified to serve as the attachment site for dorsal fin muscles. This modification is required to operate an elongated dorsal fin and may come at the expense of prey-capture capabilities, representing another example of an evolutionary trade off in those systems with exaggerated, naturally selected traits.

P1-191 GILBERT, MC*; LEROSE, C; CONITH, A; COX FERNANDES, C; ALBERTSON, RC; Organismic and Evolutionary Biology, Univ. MA, Amherst, Biology Department, Univ. MA, Amherst, Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil; *chaise.gilbert@live.com*

Ontogeny of Caquetaia spectabilis: Delayed Skull Development Accommodates Extreme Jaw Protrusion

Among teleost fishes, upper jaw protrusion is a key contributor to their ecological success and evolutionary diversity. This feat involves numerous functional components of the craniofacial skeleton and associated muscles. Extreme protrusion, ~ 30% of head length, has evolved in a handful of Perciform lineages, and can enhance the capture of elusive prey. Here we explore the morphological alterations to the craniofacial skeleton that underlie this radical behavior. We focus on *Caquetaia spectabilis*, a South American cichlid known for its extreme jaw protrusion. Using µCT scans and 2D morphometrics, we compare craniofacial morphology and ontogeny of *C. spectabilis* to other cichlids. We document conspicuous, and predictable shifts in anatomy, including accelerated growth of the ascending arm of the premaxilla and length of the maxilla. In addition, we find that *C. spectabilis* experience delayed suture closure between the frontal components of the neurocranium, resulting in the retention of a fissure between frontal bones well beyond the developmental stage when sutures normally close. Cranial suture closure is a critical event in vertebrate development that is orchestrated by a complex genetic pathway. Deviations in the timing of suture closure can result in severe birth defects, detrimental to organismal fitness. We suggest that this unexpected osteological adaptation has evolved to accommodate growth of the ascending arm of the premaxilla in *C. spectabilis*. If true, this would mean that a major developmental process has been altered to accommodate extreme jaw protrusion in this lineage.

P1-129 GILCHRIST, SL; New College of Florida; *gilchrist@ncf.edu*

Shell and Other Object Use by Land Hermit Crabs: Increases in Use of Anthropomorphic Objects on Cayos, Cochinos, Honduras

Hermit crabs use a variety of found objects (bamboo, shells, plastic) as housing. Humans are discarding more materials that are finding their way into our waterways. On Cayos Cochinos, land hermit crabs (*Coenobita clypeatus*) commonly incorporate plastic objects into their "shell supply" chain. Over the past 15 years, our research has shown that there is an increase in use of plastic (wine bottle plugs, PVC pieces, furniture knobs, bottles) as well as other materials (empty shotgun shells, glass fuse covers, glass bottles) into their resource pools. Larger shells on this island are not found frequently as shell accumulation sites. Hermit crabs may be using these alternative resources as a substitute for larger shells, in particular. However, we have noted that hermit crabs of all sizes have been collected using found objects from human (foh)sources into the shell pool. Despite augmenting shells on the island, we have found that 1) there has not been an significant increase in population size and 2) there has not been a decrease in use of found objects from humans. When provided shells at accumulation sites, crabs readily switch from their foh into shells, suggesting that shells remain a scarce resource for these land crabs and that shells are preferred over the fohs. Crabs in fohs do produce clutches, as noted for a few crabs over the past couple of years. However, the overall impact of using fohs is still under investigation.

121-4 GILLEN, CM*; PIERMARINI, PM; ROMERO, MF; Kenyon College, Gambier, OH, The Ohio State University, Mayo Clinic, Rochester, MN; *gillenc@kenyon.edu*

Electrogenic Sodium Transport by Insect Cation-Chloride Cotransporters?

Cation-chloride cotransporters (CCCs) regulate cell volume and intracellular chloride and contribute to transepithelial salt secretion and absorption. CCCs include the K-Cl, Na-Cl, and Na-K-Cl cotransporters, which move monovalent cations and chloride in electroneutral fashion. The *Aedes aegypti* transporter aeCCC2 belongs to an insect specific clade of transporters that group with the sodium-dependent CCCs. Transcripts of aeCCC2 are highly expressed in epithelial tissues, especially the hindgut. Surprisingly, aeCCC2 induces sodium-dependent currents when expressed in *Xenopus* oocytes. We have further characterized the transport activity of aeCCC2 and its *Drosophila melanogaster* ortholog ncc83. In voltage clamp experiments, oocytes expressing aeCCC2 and ncc83 had greater sodium currents than water-injected controls. When membrane potential was allowed to fluctuate, it was strongly dependent on external sodium in oocytes expressing aeCCC2 and ncc83, but not in water-injected oocytes. Following a 10-minute hypotonic treatment, changes in membrane potential in response to sodium replacement were 20 ± 3 mV in ncc83 and 26 ± 4 mV in aeCCC2, approximately two-fold greater than before swelling. Changes in membrane potential or current due to sodium replacement occurred in the absence of external chloride and potassium. These results lead to the hypothesis that aeCCC2 and ncc83 are electrogenic sodium transporters that contribute to transepithelial salt transport in insects. Funding: American Physiological Society RCEA, NIH F33 GM131599, and Kenyon College.

P2-205 GLASS, JR*; HARRISON, JF; Arizona State University, Tempe, AZ, USA; *jrglass@asu.edu*

Testing the limits: Physiological responses of honeybees (Apis mellifera) during flight in variable-density gases

Few studies have been able to assess maximal performance during flight, a deficiency that hampers our ability to assess animal capacities and adaptations. Graded air density has potential as a method to assess maximal performance during hovering flight but has been poorly explored. We tested the effect of graded air density on flight performance and metabolic rate of honey bees (*Apis mellifera*) at 23°C and 35°C. At 35°C, metabolic rates during flight increased linearly as air density declined, up to about 30% higher in pure heliox (0.441 $kg \cdot m^{-3}$; about one third normal air density), and most bees could not sustain hovering, suggesting this was near maximal performance. In contrast, at 23°C, metabolic rate did not increase as air density decreased, and bees could not fly in densities lower than 0.779 $kg \cdot m^{-3}$. This interactive effect of air density and air temperature resulted from different effects on thorax temperature. At 35°C, thorax temperature was statistically constant as air density declined, while at 23°C, thorax temperature declined linearly with air density, reaching the minimal thorax temperature for flight (32°C) at the lowest air density at which flight could occur. We conclude that at 23°C the high thorax-to-air gradient and the higher convective conductivity of low-density air causes thorax temperatures to decline, inhibiting flight performance in low-density air. In contrast, at 35°C, thorax temperatures are so high, and thorax-to-air temperature gradients relatively low, that graded air density functions nicely as an aerial treadmill for assessing maximal metabolic performance. Supported by USDA 2017-68004-26322.

P2-147 GLIDDEN, CA*; DEAKIN, JE; DESIMONE, JG; ELOWE, CR; GROOM, DJE; SLEZACEK, J; GERSON, AR; University of Massachusetts, Amherst, University of Western Ontario; *cglidden28@gmail.com*

Assessment of Novel Biomarkers of Kidney Function and Damage in Migratory Songbirds After Long-duration Flight

To complete their annual migrations, birds may fly over vast ecological barriers. While the primary fuel for migratory flight is fat, birds also catabolize lean mass from muscle and organs, including the kidney. It is unknown whether reductions in kidney mass that occur during flight result in decreased kidney function or damage. Creatinine and inulin are commonly used to measure kidney function, and neutrophil gelatinase-associated lipocalin (NGAL) is a protein biomarker of kidney damage in mammals that has never been studied in birds. To evaluate kidney damage and function, I measured plasma creatinine as an endogenous marker of GFR, FITC-inulin as an exogenous marker of GFR, and NGAL of Yellow-rumped Warblers before, immediately after, and 24h after flight or rest in a wind tunnel. Birds flew or rested in dry or humid conditions, which has been previously shown to alter the rate of protein breakdown in flight. NGAL levels were below detection and therefore a poor biomarker for kidney damage. Creatinine concentrations significantly increased in the 24-hour recovery rest and flight birds, and in dry conditions, indicating reduced filtration. However, inulin-measured filtration tended to be higher in dry conditions for both flight and rest birds. This study suggests that fasting and flight may impact kidney function, particularly in dry conditions. These endogenous and exogenous markers did not clearly indicate kidney damage, but future research will use molecular markers to quantify kidney atrophy and damage.

P2-2 GLOVER, AR*; BRANNOCK, PM; Rollins College ; *aglover1@rollins.edu*

Genetic analysis of invasive Pomacea sp. in Florida

Pomacea maculate and *P. canaliculata* are two apple snail species found extensively outside their native range of Central and South America. Both species have been reported within Florida (FL) ecosystems where they have caused disruptions through their voracious feeding on native plants as well as competed with native the species, *P. paludosa*, for both space and food. Due to morphological similarities among the invasive species, there is taxonomic ambiguity of the exact species present throughout FL. In addition, currently it is unknown whether FL invasive species' are mating with one another or with the native and producing hybrids. Furthermore, if hybridization is occurring, it is unclear hybridization is directional or limited in any way. In order to address these questions, apple snails were collected from a variety of FL ecosystems during the spring and summer of 2019. DNA was extracted from foot tissue. Amplification of the elongation factor 1 alpha (EF1α) nuclear gene was used to identify individuals to the species level. Cytochrome c oxidase subunit 1 (COI) mitochondrial gene was targeted to explore the potential of directionality of hybridization or determine if hybridization beyond the F1 generation was occurring. Preliminary results from 12 sample locations showed a large presence of *P. maculata* individuals throughout all sample locations and only 2 *P. canaliculata* found within among the whole sample region thus far. In addition, preliminary results indicate that hybridization and potentially hybridization beyond the F_1 generation is occurring in one southwest FL location. Future work includes continuing to sample *Pomacea* sp. from a more representative geographic range throughout FL, genotype all individuals at both EF1α and COI loci, and confirm hybridization through DNA sequencing.

44-6 GLYNN, KJ*; ZAHOR, DL; CHIPARUS, SL; CORNELIUS, JM; Eastern Michigan University, Oregon State University; *kglynn2@emich.edu*

Did the flint water crisis also harm wild birds? Examining blood lead of three urban birds in Flint, MI

Anthropogenic activities can emit metal pollutants, such as lead, into the environment and potentially elevate lead exposure in urban wildlife. Lead is toxic at relatively low concentrations and it has the potential to bioaccumulate and negatively impact the fitness of exposed organisms when introduced into an ecosystem. The route of exposure may vary across species depending on diet, excretion ability, and age. The Flint, MI water crisis introduced lead into some neighborhoods and likely into the soil via irrigation of lawns, threatening not only the health of humans, but also of urban wildlife. Avian species such as the American Robin, European Starling, and Gray Catbird commonly live within urban habitats and may be exposed differently to lead via diet preferences (i.e., initial exposure) or via physiological processes that impact the circulation or excretion of lead in the body. For example, nestlings and juveniles may be fed preferred food items that differ in quantity or type from adult diets, potentially influencing accumulation across age. Studies have also suggested that a potential pathway for excretion of lead in songbirds is through feather growth during molt or development and that lead can be stored and released as bone absorbs and releases calcium during growth processes. This study explores blood lead levels in several species of songbird in a city of known lead pollution to investigate accumulation across ages and whether or not blood lead changes across the molt. This preliminary study will provide insight into how lead moves through an ecosystem and how avian species of different age groups might be impacted by a sequestration of anthropogenic lead pollution.

P2-139 GO, M*; NOTAR, JC; JOHNSEN, S; Duke University; *mcg52@duke.edu*

Associative learning in the brittle star Ophioderma brevispinum

Associative learning can be defined as changes that an organism makes in its behavior due to associations it forms between stimuli in its environment. Research on associative learning in echinoderms is limited, though some studies suggest that it is present in sea stars. We aimed to expand this area of study by investigating associative learning in the brittle star *Ophioderma brevispinum*. Specifically, we tested whether the animal could learn to associate light and food stimuli. Brittle stars tend to hide from light, whereas they move around actively when searching for food. Thus, we expected the animal to begin moving around actively when exposed to light if it learned to associate light with food. Ten brittle stars were kept in the dark at all times except during a 15-minute trial period every 24 hours. There were a total of four trial phases. In Phase 1, brittle stars were fed four hours after the trial period, as a way of keeping food and light stimuli uncoupled. In Phase 2, brittle stars were fed at the beginning of the trial, as a way of pairing food and light stimuli. In Phase 3, brittle stars were fed immediately after the end of the trial, to test whether they had learned to associate light with food. If an animal exhibited feeding behavior in the presence of light but before the presence of food, we considered this an indication that it had learned to associate the two stimuli. Finally Phase 4 was a repeat of Phase 1, to see how long learning persisted after stimuli were fully uncoupled. During every trial, we counted the number of individuals that exhibited feeding behavior within the 15-minute trial period, and Chi-square tests were used to test the differences in the animals' responses between the different phases of the experiment. Results will be discussed.

72-4 GODOY, PL; Stony Brook University; *pedrolorenagodoy@gmail.com*

Cranial shape variation in Crocodylomorpha and the influence of ecological transitions during its evolutionary history

Today, the 27 modern crocodylian species display similar morphologies and occupy comparable ecological niches in their semi-aquatic environments. However, Crocodylomorpha, the group that includes includes the extinct relatives of living crocodylians, has an evolutionary history of more than 200 million years, which is reflected by a rich fossil record. Extinct crocodylomorphs exhibited much higher morphological disparity than extant ones, as well as remarkable ecological diversity, ranging from fully marine to completely terrestrial forms. In particular, cranial shape in crocodylomorphs seems to be integrated with ecological factors (such as feeding strategies), given the biomechanical implications of skull elongation and shortening. Nevertheless, the influence of ecological transitions on crocodylomorph cranial shape was never comprehensively investigated. I used geometric morphometric techniques and phylogenetic comparative methods to analyze cranial shape variation and disparity in crocodylomorphs and fully characterize its macroevolutionary patterns. I found a significant influence of ecological lifestyles (i.e. terrestrial, aquatic, and semi-aquatic) on cranial shape, as well as a strong size-shape relationship, indicating allometric shape changes (mainly in the snout region). Furthermore, I found that terrestrial species are more disparate in terms of cranial shape, particularly the mainly small-bodied notosuchians. I also found that aquatic and semi-aquatic forms are usually associated with regime shifts to more longirostrine crania and to larger body sizes. This suggests an intricate relationship between cranial shape, body size and ecology, and that clade-specific adaptations to different environmental conditions are determining large scale patterns of crocodylomorph cranial shape evolution.

11-6 GOEPPNER, SR*; LUTTBEG, B; Oklahoma State University; *scott.goeppner@okstate.edu*

Growth, lifespan, and reproductive investment of Physa snails exposed to predators

Past research has shown that *Physa snails* change their shell morphology, life history, and behavior based on the type of predators in their environment. The snails also exhibit transgenerational plasticity with individuals exposed to crayfish cues producing more crush resistant offspring. One explanation for this is that predator-exposed snails invest more in current offspring than control snails, at the expense of growth, life expectancy, and future reproduction. To test this hypothesis, we raised snails in one of four treatments: early-life predator exposure in which snails were exposed to crayfish cues for the first five weeks of life, late life predator exposure in which snails were exposed to crayfish cues for the second five weeks of life, continuous predator exposure in which snails were exposed to crayfish cues for both the first and second five weeks of life, or no predator exposure. We measured growth rate, age at first reproduction, egg production, and lifespan in the F1 snails. We then raised the F2 offspring of the F1 snails that produced at least 8 viable offspring at the end of the early and late life periods, and measured their size, shape, and crush resistance. In the F1 snails, we determined that early life predator exposure led to delayed reproduction, decreased egg production, and reduced lifespan, but had no effect on growth. Exposure to predator cue late in life had no effect on survival, growth, or egg production. Data analysis is ongoing for the effects of early and late life exposure on the size of eggs produced by F1 individuals and F2 phenotypes.

108-1 GOERIG, E*; DI SANTO, V; WAINWRIGHT, D K; CASTRO-SANTOS, T; AKANYETI, O; LIAO, J; LAUDER, G; Harvard University, Stockholm University, Yale University, USGS Leetown Science Center, Aberystwyth University, University of Florida; *goerig.elsa@gmail.com*

Comparative Undulatory Kinematics in Swimming Fishes: Rethinking Swimming Modes

Biologists studying fish locomotion have traditionally classified undulatory fish kinematics into categories named after exemplar species. Fishes that are thought to swim with relatively short body wavelengths that incorporate the entire body are referred to as "anguilliform" (after the eel *Anguilla*), while those swimming with progressively longer wavelengths that undulate a smaller portion of the body are termed "subcarangiform", "carangiform", and "thunniform" (after tuna, *Thunnus*). Under this scheme, lateral amplitude oscillations of the anterior body decrease progressively from eels to tuna. In order to compare undulatory swimming kinematics in fishes, we have assembled a quantitative data set of body midline kinematics across 45 species including eels, mackerel, trout, and tuna. High-speed video data were obtained from both laboratory flow tanks and a field-based high-speed flow tank where fish can exhibit volitional high-speed locomotion. We combine metrics derived from midline kinematics with measurements of body depth and width for each species. A multidimensional analysis shows that morphology captures a significant proportion of the variance in the data, while there is considerable similarity in midline kinematics among species as diverse as eels and tuna. These results question the validity of the longstanding categories used to describe the body kinematics of swimming fishes, and instead suggest that these "swimming" modes may simply represent morphological categories. In the future our multi-species kinematics database will be available for use in comparative studies of fish locomotion and for programming fish robotic systems.

63-4 GOFORTH, KM*; LOHMANN, CMF; LOHMANN, KJ; University of North Carolina at Chapel Hill; *kaylago@live.unc.edu*

The Role of Magnetic Field Detection in Foraging Site Fidelity of Sea Turtles

Foraging site fidelity describes a pattern of behavior in which animals return to the same foraging area repeatedly, in some cases after migrating to distant sites. Juvenile sea turtles of several species exhibit this behavior, with turtles reliably returning to specific foraging grounds following seasonal migrations and experimental displacements. Turtles are known to have a magnetic map sense that exploits variation in Earth's magnetic field to identify and travel to distant sites. Because of this variation, different geographic locations have slightly different magnetic fields, thus, most foraging areas have a unique "magnetic signature". In principle, turtles might learn to navigate to a specific foraging area by learning the magnetic signature of that site. To investigate this possibility, we studied whether turtles are capable of learning to associate a magnetic signature with food. Captive loggerhead turtles (*Caretta caretta*) approximately three months of age, were assigned to one of two experimental groups and conditioned to a unique magnetic field. Each group was exposed to two different magnetic signatures, on a daily alternating schedule, over the course of two months. Turtles spent equivalent amounts of time in the two magnetic signatures, but only received food in one of them. In post-conditioning trials conducted in the absence of food, turtles exhibited higher levels of food-seeking behavior when exposed to the magnetic field in which they had previously been fed, but not when exposed to the other magnetic field. These results provide the first direct evidence that sea turtles can learn to associate a magnetic field with food, a process that may underlie the development of foraging site fidelity.

P1-75 GOGEL , CA*; MULLIN, SM; LEESE, JM; DeSales University, Center Valley, PA, DeSales University, Center Valley PA; *cg3612@desales.edu*

Environmental factors influence sex roles and nest site selection in cichlids

One of the most important decisions many animals face in their lifetime is determining where to raise their offspring. For egg laying species, this involves selecting a nest site that is secure with appropriate resources. Within monogamous species, nest site selection can be decided collaboratively or one sex may have more influence over the process. For convict cichlids (*Amatitlania nigrofasciata*), our preliminary research has shown that when acclimated to equivalent nest sites, females tend to demonstrate a stronger preference for their own nest than males. In this follow-up experiment, we explored the effect of nest site quality on nest site selection. Specifically, we sought to determine if improving a male's nest site (adding artificial plants) or reducing the quality of a female's nest site (adding an intruder) would influence the nest selection process in a pair. We hypothesized that females would have less of a preference for their nest site when the quality of a male's nest is increased, or when their own nest site quality is reduced. Our results support the latter, but not the first part of our hypothesis. In the first treatment, females showed a non-significant decrease in their nest site preference and an increase in preference for the male nest site. In the second treatment, females showed a significant decrease in their nest site preference and an increase in preference for the male's nest site. These results suggest that altering environmental factors can influence the nest site selection process in monogamous animals after pair-bond formation.

11-1 GOLDBERG, DL*; BASSINGTHWAITE, TA; BEILKE, S; WARD, MP; CAPPARELLA, AP; Illinois State University, Audubon Great Lakes, Chicago, University of Illinois at Urbana-Champaign; *dlgoldb@ilstu.edu*

Never Cry Owl: Rails do not Adjust Vocal Activity Rates in Response to Predation Risk

Animal communication carries the risk of signal exploitation by predators, and thus many species will adjust their behavior to produce signals that range from more discreet messages to conspecifics, to conspicuous anti-predator cues. Although rails (Family Rallidae) are known to use the visual display of tail-flicking as a warning of vigilance towards predators, how these birds will alter their frequent and diverse vocal behavior based on perceived predation risk remains little studied. The calls of owls, which consume a variety of rallid species and can home in on acoustic cues of their prey, have been found to reduce singing in numerous other birds. We applied remotely-activated broadcasts and Autonomous Recording Units to study whether rails in the wetlands of the Lake Calumet region near Chicago would decrease vocal activity rate (VAR) following the broadcast of a known rallid predator, the Great Horned Owl (*Bubo virginianus*). In our comparison of different wetland sites that varied in the historical presence of owls, neither Soras (*Porzana carolina*) nor Virginia Rails (*Rallus limicola*), nor both species combined, showed a significant reduction in VAR in experimental relative to control trials. As the rails at Lake Calumet showed a general trend of higher VAR with the onset of the breeding season, our results indicate that these rallid species either do not recognize owl predation risk, or that they employ alternative, currently unknown behavioral strategies to mitigate this risk.

96-5 GOLOS, MR*; BAUER, U; University of Bristol; *michal.golos@bristol.ac.uk*

Wettability of Pitcher Plant Trapping Surfaces

Carnivorous plants have evolved a myriad of highly elaborate structures in order to attract, trap, and retain their prey. Notable among these are the main trapping surfaces of tropical pitcher plants (*Nepenthes* and *Heliamphora*), which exhibit highly ordered, hierarchical microstructures that confer a suite of interesting properties, including (super)hydrophilicity, water film stabilisation, and directional water spreading. These surfaces are unusual in that they are highly wettable yet lack the discontinuities in the waxy cuticle that characterise most hydrophilic plant surfaces. We explored how a glabrous, non-glandular, non-porous, primary plant surface can nonetheless exhibit these wetting properties, investigating the influence of both topography and surface chemistry in order to disentangle their relative contributions. Understanding how the form and chemistry of these structures renders them well-wettable and capable of rapid directional water transport has the potential to open new avenues for research into bioinspired technologies.

P1-165 GOMES AVERSA, M D*; HARTLEY, J G; LEESE, J M; DeSales University, Center Valley, PA; *ma8050@desales.edu*

Female Mate Preference in Convict Cichlids Influenced by Intrasexual Competition and Male Quality

Sexual selection, the ultimate mechanism driving the evolution of sexual dimorphism in animals, includes both intra and inter-sexual components. Here, the interaction between intra- and inter-sexual selection pressures was explored on female mate preference in the monogamous convict cichlid, *Amatitlania nigrofasciata*. We hypothesized that female mate preference would be influenced primarily by male quality, but also intrasexual competition. To test this, two females were allowed to compete while provided a choice of potential male mates. As a result, each female formed a time-based preference for one of two males and both females secured a male partner. In a follow-up treatment, we differed the quality (size) of the two potential male mates and found both females demonstrated a preference for the high-quality (larger) male over the low-quality (smaller) male. This resulted in one female successfully securing a partner, while the other rejected a low-quality male and remained alone. We then explored whether the decision to reject a low-quality male was due to, or independent of, female-female competition. Single females were allowed to form a preference for a large male over a small male. After preference formation, the large male was removed and behavior of the female to the rejected male was observed when given 1) no other option or 2) a similar low-quality novel male. We found that females preferred to spend time alone, or with a novel low-quality male rather than with the rejected male. Together, these data suggest that females adjust their threshold for mate preference. Furthermore, females maintain rejection of a male, despite the absence of another potential mate and independent of intrasexual competition.

P3-85 GONZALEZ, P*; SEAVER, EC; BAXEVANIS, AD; NHGRI/NIH, University of Florida; *paul.gonzalez@nih.gov*
Haplotype-Phased de novo Genome Assembly of the Marine Annelid Capitella teleta Using a Three-Generation Long-Read Binning Approach
Sequencing the genome of organisms that combine high levels of heterozygosity with small body size is challenging and, as a result, the genomic diversity of many branches of the metazoan tree remains unexplored. Heterozygosity is problematic because sequence variation between alleles must be reconciled into a single consensus sequence, often resulting in spurious "mosaic" sequences that do not actually exist in nature. In small organisms, this problem is further amplified, as many individuals must be pooled in order to obtain sufficient DNA for sequencing. This issue is widespread, particularly among marine invertebrates that typically have body sizes in the millimeter range as well as large effective population sizes, resulting in high levels of heterozygosity. Here, we present a new sequencing strategy based on the trio binning method that solves these issues, applying this method towards the sequencing and assembly of the genome of the marine annelid worm *Capitella teleta*. We have sequenced a pooled sample of siblings using long-read PacBio SMRT sequencing. We then used Illumina short-read data obtained from their four grand-parents to identify sequences that were specifically inherited from each of the four parental haplotypes present in the sibling pool sample. Finally, we assembled each of these four haplotypes separately prior to scaffolding using Hi-C data. While this method is limited to organisms where sampling of a single family over three generations is feasible, it has the potential to greatly expand the range of species for which a highly contiguous and accurate genome assembly can be obtained, a prerequisite for future comparative genomics studies.

P2-133 GONZALEZ, BD*; MARTINEZ ACOSTA, VG; Univ. of the Incarnate Word; *bdgonzal@student.uiwtx.edu*
Overexpression of Beta-catenin During Regeneration in Lumbriculus variegatus
Our overall research goal is to identify cellular and molecular events triggered following injury within the central nervous system (CNS) that promote regeneration and recovery of function versus deterioration. Studies of wound healing and regenerative processes in *Lumbriculus variegatus* provide an opportunity to identify signaling pathways triggered following wound formation in a system that is committed to successful regeneration and recovery of function. We have carried out broad screens for protein markers associated with regeneration, such as beta-catenin. Initial analysis highlights β-catenin expression within regenerating head tissue 24hrs post-amputation, diminishing after 1 week. Immunohistochemical analysis also highlights the expression of β-catenin within the ventral nerve cord with visible up regulation in the lateral giant fibers as well as in smaller intermediate giant fibers which run the length of the nerve cord. Beta-catenin intensity within the ventral nerve cord increases 24 hours post amputation in both anterior and posterior fragments and is sustained up to 1 week. Currently, we present a study where beta catenin is overexpressed through treatment with the GSK inhibitor, alsterpaullone. Preliminary data suggests a reduction in recovery of behaviors associated with anterior segments, despite regeneration of head segments. While we continue to investigate the proteomic profiles of regenerating worm fragments, it is of great interest that we determine the role β-catenin, an armadillo protein involved in activating cell-specific transcription factors in the canonical Wnt signaling pathway.

P2-80 GONZáLEZ, K*; WARKENTIN, KM; GüELL, BA; Purdue University, Biological Sciences, IN, Boston University, MA and Smithsonian Tropical Research Institute, Panamá, Boston University, Department of Biology, MA; *kgonzalez@purdue.edu*
Effects of hydration on the arboreal eggs of gliding treefrogs: even small reductions in humidity induce premature hatching, reduce hatchling size, and kill embryos
Many environmental conditions affect egg survival and hatching timing in amphibians. Variation in temperature and humidity can strongly influence terrestrial and arboreal egg clutch properties and therefore embryo fates. Despite increasingly unpredictable rainfall patterns in the tropics, how changes in egg mass properties due to climate change affect embryo behavior and survival remains poorly studied. We investigated whether gliding treefrog embryos (*Agalychnis spurrelli*) adaptively shift their hatching timing in response to desiccation risk, at the cost of smaller hatchling size. We raised embryos in more and less humid treatments and determined their hatching timing, level of egg and clutch hydration, and mortality rates. Mean relative humidity in all treatments was > 90%, however a decrease from ~98 to 96% humidity induced premature hatching and hatchlings that were small for their age. Clutches and eggs in these less humid conditions decreased in size over time and a mean humidity of 92% led to egg desiccation and death. Our results suggest that *A. spurrelli* embryos are extremely dependent on consistent precipitation and particularly vulnerable to climate change. Although we did not directly measure differences in hatchling fitness, our results and previous findings suggest that small, dehydrated *A. spurrelli* hatchlings would suffer higher mortality rates in the wild, thus creating a trade-off in hatching timing in response to dehydration. These findings add to our understanding of how anuran embryos may respond to predicted climate changes and the fitness consequences they face across life stages.

32-7 GOODCHILD, CG*; DURANT, SE; Oklahoma State University, University of Arkansas; *christopher.goodchild@okstate.edu*
Is a novel marker of oxidative damage linked to aerobic scope and flying performance in birds exposed to crude oil?
Birds externally exposed to crude oil have impaired flying performance due to crude oil damaging the microstructure of feathers. However, crude oil ingestion can also damage red blood cells (RBCs), which may reduce oxygen delivery to muscles and further limit flying performance. Although RBC damage has been previously described in birds exposed to crude oil, the effects of crude oil ingestion across levels of biological organization (e.g., RBC damage, metabolic scope for activity, and flying performance) remains unclear. In this study, we orally dosed zebra finches (Taeniopygia guttata) with 2 or 6 ml/kg of artificially weathered MC252 crude oil for 28 days and measured RBC integrity using traditional and novel endpoints, basal and maximal metabolic rates using a 'hop-flutter' chamber, and vertical flight speed and takeoff acceleration using a high-speed camera. Crude oil ingestion caused a decrease in packed cell volume (PCV) and an increase in reticulocytes, indicating regenerative anemia. Furthermore, we also detected an increase in fluorescent heme-degradation products (HDPs), a novel tool for measuring oxidative damage. Crude oil ingestion caused a reduction in resting metabolic rate, maximum metabolic rate, and aerobic scope. Interestingly, we found that birds exposed to crude oil increased vertical flight speed. Crude oil ingestion also caused a decrease in fat score, which may explain why oiled birds increased flight speed. Our results suggest that RBC damage in birds exposed to crude oil has metabolic consequences, but the metabolic effects do not impair short-range, burst flight.

P3-15 GOODCHILD, CG*; DURANT, SE; Oklahoma State University, University of Arkansas;
christopher.goodchild@okstate.edu

Avian eggs externally exposed to sublethal crude oil applications have reduced heart rate and metabolic rate.

Brooding birds externally exposed to crude oil can transfer oil from their feathers to the external surfaces of their eggs. Previous studies have documented that application of crude oil to the surface of bird eggs can cause embryotoxicity, yet the potential effects of sublethal crude oil application on avian embryo development is unknown. As has been demonstrated in other taxa, embryonic exposure can cause heart malformations. In this study, we used zebra finch (Taeniopygia guttata) eggs to examine the potential for cardiotoxicity in avian embryos after external application of crude oil to the egg shell. First, we conducted a pilot dosing experiment to determine a sublethal application. We then conducted a second experiment to measure embryonic heart rate and metabolic rate. We found that >2.5 µl of crude caused the embryo to become non-viable. Additionally, we detected a decrease in embryonic heart rate and metabolic rates. This study suggests that sublethal oiling of bird eggs may lead to post-hatch effects on cardiac function.

P3-218 GOODHEART, JA*; MINSKY, G; BRYNJEGARD-BIALIK , MN; DRUMMOND, MS; MUNOZ, JD; FALLON, TR; SCHULTZ, DT; WENG, J; TORRES, E; OAKLEY, TH; UC Santa Barbara, California State Univ. Los Angeles, Massachusetts Institute of Technology, Monterey Bay Aquarium Research Institute; *goodheart@ucsb.edu*

Laboratory culture of the California Sea Firefly Vargula tsujii: Developing a model system for the evolution of marine bioluminescence

Bioluminescence evolved many times across Metazoa. Culturing luminescent organisms from diverse metazoan groups is critical for determining the biosynthetic pathways of diverse bioluminescent substrates, which may lead to new tools for biotechnology and biomedicine. Although some previously cultured luminescent groups represent independent origins of bioluminescence, many use luminescent substrates (luciferins) obtained from their diets, and therefore are not informative for determination of the luciferin biosynthetic pathway. Terrestrial fireflies do synthesize their own luciferin, but the biosynthetic pathway for firefly luciferin remains unclear. An additional independent origin of autogenic bioluminescence is found within ostracods from the family Cypridinidae, which use their luminescence for defense and, in Caribbean species, for courtship displays. Here, we report the first complete life cycle of a luminous ostracod (*Vargula tsujii*, the California Sea Firefly) in the laboratory and discuss the embryonic and juvenile development of *Vargula tsujii*. We also find no evidence of significant population genetic structure or cryptic speciation throughout the southern California range of *V. tsujii*. Bringing a luminous ostracod into laboratory culture sets the stage for many potential avenues of study, including the biosynthetic pathway of cypridinid luciferin and genomic manipulation of an autogenic bioluminescent system.

105-8 GOODMAN, CM*; BUCKMAN, KN; HILL, JE; TUCKETT, QM; ROMAGOSA, CM; University of Florida;
colin.goodman@ufl.edu

Dispersal, performance, and Morphometry of a Novel Invader (Xenopus tropicalis) in Central Florida: Evidence of Spatial Sorting?

A primary determinant of long-term invasion success is a species' ability to colonize novel environs. Colonization success is linked to the dispersal rates of individuals within the invading population. The traits that confer increased dispersal rates are often heritable and are, therefore, open to selection pressure. This pressure can lead to spatial sorting, whereby individuals that are more effective dispersers naturally align themselves along the invasion front, hastening the spread of the invasion. Using the extant invasion of *Xenopus tropicalis* in Florida as a system, we examined individual, sex, and site-level differences in both morphometry and performance as they relate to dispersal distance and success. We predicted that individuals that disperse should have longer hind-limbs and better stamina, relative to individuals that do not disperse. Additionally, we predicted that individuals with better exertion capacity would be more likely to disperse longer distances. We found significant differences in performance, with individuals that dispersed performing for longer intervals before reaching exhaustion than individuals that did not disperse. Additionally, we found that both morphometry and performance predicted dispersal distance, with dispersal distance increasing with both hind limb length and maximal exertion capacity. These results suggest that dispersal success is nonrandom with respect to morphometric and performance traits, and may indicate the real-time progression of spatial sorting.

P3-111 GOODREAU, JL*; KRANS, JL; Western New England University; *jordan.goodreau@wne.edu*

Using STED to measure RNAi induced changes in isoform structure of the titin ortholog, sallimus.

We are interested in structural and functional changes to muscle resulting from RNAi against the sallimus gene, which encodes a giant sarcomere associated protein (gSAP). Sallimus (sls) is an ortholog of vertebrate titin and like most animal gSAPs, sls possesses both compliant (Ig) and stiffer elastic domains (PEVK). There are ten identified sls isoforms in fruit fly that express different proportions of compliant and stiff domains, potentially offering diverse mechanical tissue properties. Our previous experiments show that RNAi against sls in *Drosophila* larvae does not knock down all sls isoforms equally. Namely, the expression of isoforms most rich in PEVK domains is dramatically reduced. Additionally, sls RNAi yields a significant increase in gSAP length and in the expression of isoforms rich in compliant domains rather than those isoforms consisting of more elastic domains. Experiments described here are aimed at determining how sarcomere length increases. It's plausible that (1) post-RNAi sls has been cut during the process of alternative splicing, or (2) that the reduced expression of PEVK domains yields a more easily elongated (i.e. compliant) gSAP. We used stimulated emission depletion microscopy (STED) and dual labelling immunohistochemistry (IHC) to measure the distance between known regions of the sls protein. Commercially available anti-kettin binds ~175 nm from the Z-disk and the custom made Klg3/4 antibody (gift of B. Bullard) binds ~0.5 mm from the Z-disk in control tissue. We predict that if the sls protein is somehow cut during splicing (post-RNAi), then the distance between these two points will decrease. Alternatively, the distance between antibodies would increase if the post-RNAi sls proteins, that are rich with compliant domains, were simply elongated.

P1-215 GOODVIN, DM*; ROSENBACH, KL; WILSON, JA; University of Michigan, Ann Arbor; *goodvin@umich.edu*

A New Method of Measuring Air Space Proportion in Pneumatic Skeletal Tissue

Pneumaticity refers to the hollow space within skeletal tissue caused by the invasion of the diverticula of respiratory air sacs. Pneumatic bones are present in many archosaur groups, but postcranial skeletal pneumaticity is well developed in three of these groups: pterosaurs, sauropodomorphs, and theropods. The degree of pneumaticity can be quantified by the Air Space Proportion (ASP), which is a measure of the ratio of air space (represented in fossils by the infilling of matrix) to skeletal tissue. Initially, ASP in fossil bones was measured in places where fortuitous breaks allowed visualization of the internal bone. More recently, ASP has been measured in fossil bones using micro-computed tomography (µ-CT), which is a non-destructive means of accessing the internal structure of a bone. This method has been applied to pterosaur fossils, for which ASP was measured in a representative sample of slices, accounting for trabecular bone at the articulations and excluding struts in the shaft of the bone. We have developed a new method that calculates the volumetric proportion of air and bone (volumetric ASP, or vASP) from three-dimensional (3D) models reconstructed from µ-CT scans using the program Mimics. Here we report the application of this method to pterosaur and avian wing bones. Using this method, we estimate an average vASP of 96.8% in two pterosaur humeri and 62.1% in five hummingbird humeri (genera *Archilocus* and *Calliphlox*). The use of Mimics provides faster segmentation of fossils and modern bone than previous methods. This new method maximizes the amount of preserved skeletal tissue accounted for in ASP calculation, while still providing slice by slice information, and produces 3D models that will be used for further study of the biomechanical properties of pneumatic bones.

69-3 GORMALLY, BMG*; ESTRADA, RS; MCVEY, M; ROMERO, LM; Tufts University; *brenna.gormally@gmail.com*

Expanding the acute stress phenotype: DNA damage rapidly increases in house sparrows

Corticosterone (Cort) is the metric of choice in stress physiology studies. Despite its popularity, this hormone often does not accurately reflect how an animal copes with a stressor, likely due to its complex actions. Furthermore, changes in Cort are rarely consistent across contexts, life-history stages, and species. By focusing solely on this hormone, we reach an incomplete picture of how animals cope with unpredictable stimuli; a separate, independent measure is thus needed. In this study, we tested the hypothesis that acute increases in DNA damage could serve as an adjunct to Cort when assessing stressor exposure. Previous studies have found that DNA damage increases in response to stress-related hormones in vitro, prompting further exploration in wild animal systems. We exposed house sparrows (*Passer domesticus*) to a short (30 or 120-minute) restraint stressor and took blood samples at 0, 30, 60, and 120 minutes to measure Cort, DNA damage, and uric acid. DNA damage and Cort increased while uric acid decreased. DNA damage can thus reflect acute stressor exposure. We also tested the impacts of freezing on DNA damage in the hopes that this method will become more applicable in field-based studies. Leaving red blood cells on ice for up to 24 hours resulted in statistically significant, but likely not important, increases in DNA damage. Freezing blood samples for up to 4 weeks substantially increased DNA damage. These findings emphasize the importance of assaying samples together whenever possible. Overall, these results indicate that DNA damage can reflect whether and how an animal is coping with a stressor.

P1-249 GORMALLY, BMG*; MACY, RR; MARTIN, K; WRIGHT-LICHTER, JX; ROMERO, LM; Tufts University; *brenna.gormally@gmail.com*

Expanding the dexamethasone suppression test: assessing multiple synthetic glucocorticoids in house sparrows (Passer domesticus)

For over 50 years, dexamethasone (Dex) has been the predominant synthetic glucocorticoid used to test hypothalamic-pituitary-adrenal negative feedback strength. While Dex works in a majority of systems, it is only a single example of a much larger class of synthetic glucocorticoids used as drugs, each with unique structures. Several other drugs are now readily available and could potentially more strongly stimulate negative feedback. In this study, we tested how five different drugs, in addition to Dex and a saline control, affected the release of corticosterone (Cort) in house sparrows (*Passer domesticus*) that were restrained for 30 minutes. These additional drugs included methylprednisolone, fludrocortisone, isoflupredone, prednisolone, and hydrocortisone. Each drug was tested on 12 birds over the course of 6 weeks in a randomized order. Blood samples were taken after the initial 30-minute stressor, 45 minutes after injection, and 90 minutes after injection. All treatments, including saline, elicited a reduction in Cort release over the 90 minutes. Dex resulted in the strongest negative feedback, while hydrocortisone did not shut down the release of Cort; this is likely because hydrocortisone cross-reacts with the antibody in the radioimmunoassay used to quantify Cort. We hope that these results provide additional options for those whose study systems do not respond to Dex.

15-4 GORMAN, CE*; BOND, L; VAN KLEUNEN, M; DORKEN, M; STIFT, M; University of Konstanz, BW, Germany , Trent University, Peterborough, ON, Canada, University of Konstanz, BW, Germany and Zhejiang Provincial Key Laboratory of Plant Evolutionary Ecology and Conservation, Taizhou University, China; *cgorman22@gmail.com*

Phenological and pollinator-mediated isolation among selfing and outcrossing Arabidopsis lyrata populations

Mating system transitions from outcrossing to selfing have been a frequent evolutionary shift in plants and clearly play a role in species divergence. However, many questions remain about the initial mechanistic basis of reproductive isolation during the evolution of selfing. For instance, how important are prezygotic pre-pollination mechanisms (e.g. changes in phenology and pollinator visitation) in maintaining reproductive isolation between newly arisen selfing populations and their outcrossing ancestors? To test whether changes in phenology and pollinator visitation isolate selfing populations of *Arabidopsis lyrata* from conspecific outcrossing populations, we conducted a common garden experiment with plants from selfing and outcrossing populations as well as their F1 hybrids. Specifically, we asked whether there was reproductive isolation between outcrossing and selfing plants and their F1 hybrids through differences in 1) the timing or intensity of flowering; and/or 2) pollinator visitation. We found that phenology largely overlapped between plants from outcrossing and selfing populations. There were also no differences in pollinator preference related to mating system. Additionally, pollinators preferred to visit flowers on the same plant rather than exploring nearby plants, regardless of whether they were of an alternative mating system type or F1 hybrids, creating a large opportunity for self-fertilization. Together, this suggests that prezygotic pre-pollination mechanisms do not strongly reproductively isolate plants from selfing and outcrossing populations of *A. lyrata*.

P2-96 GOUGH, WT*; CADE, DE; POTVIN, J; KAHANE-RAPPORT, SR; GOLDBOGEN, JA; Stanford University, University of California, Santa Cruz, Saint Louis University; *wgough@stanford.edu*

Scaling of Lunge Feeding Kinematics in Baleen Whales

Although gigantic body size and obligate filter feeding mechanisms have evolved in multiple independent vertebrate lineages (mammals and fishes), intermittent ram (lunge) filter feeding is unique to a specific family of baleen whales: rorquals. Lunge feeding is a high cost, high benefit feeding mechanism that requires the integration of unsteady locomotion (i.e. acceleration and maneuvers) and the impact of scale on the biomechanics and energetics of this foraging mode remains poorly understood. The goal of our study was to use a combination of multi-sensor tags paired with drone footage to determine the impact of morphometrics such as body size on kinematic lunging parameters such as fluking duration and timing, maximum lunging speed, and deceleration during the engulfment period. Our preliminary results show that, regardless of size, animals tend to time the cessation of fluking to coincide with both the maximum lunging speed and the point of mouth opening. Given the ability of the rorquals to engulf large volumes of water using their momentum, rather than requiring constant thrust production from the flukes throughout the lunge, we predicted the optimal speed of lunging across scale. In order to minimize the energetic cost of lunge feeding, hydrodynamic theory predicts lower lunge feeding speeds at intermediate body sizes but much higher speeds at the extremes of rorqual body size. We used empirical data to test this theory and to determine how and when rorquals depart from optimal predictions given ecological factors such as differences in prey type and prey distribution. Broadly our results indicate a scale-dependent energetic trade-off between lunge feeding kinematics (cost) and engulfment capacity (gain) that has important implications for the evolution and ecology of gigantic filter feeders.

85-6 GOULD, FDH*; LAMMERS, A; MAYERL, CJ; GERMAN, RZ; Rowan University School of Osteopathic Medicine, Stratford NJ, Cleveland State University, Cleveland OH, Northeast Ohio Medical University, Rootstown, OH, Northeast Ohio Medical University, Rootstown, OH; *gouldf@rowan.edu*

Differential Effect of Superior and Recurrent Laryngeal Nerve Lesion on Kinematics and Performance in Mammalian Swallowing

Mammalian swallowing is complex at anatomical, functional, and neurological levels. The complexity of swallowing physiology means that multiple points may lead to similar failure in performance, specifically failure to protect the airway. The superior laryngeal nerve (SLN) and the recurrent laryngeal nerve (RLN) are branches of the Vagus that innervate different structures involved in swallowing. Although they have distinct sensory and motor fields, lesion of either nerve leads to a decrease in airway protection. We tested the hypothesis that despite similar outcomes in terms of airway protection, SLN and RLN lesion would impact oropharyngeal kinematics differently. To test the effect of lesion of either nerve on kinematics, we recorded 11 infant pigs swallowing milk using high speed videofluoroscopy before and after either unilateral SLN or RLN lesion. Because of the repeated measures design each animal acted as its own control. We measured oropharyngeal kinematics from the videofluoroscopic recordings. Posterior tongue kinematics during swallowing respond differently to RLN lesion and SLN lesion ($p=0.007$). Furthermore the relationship between tongue kinematics and airway protection outcome differs in SLN and RLN lesion ($p=0.045$). Thus, although SLN and RLN lesion lead to the same performance failure, the effect on tongue kinematics and their relationship to airway protection failure are different. The complex connections that exist in mammalian feeding systems result in a many-to-one relationship between function and performance, and has significant implications for understanding how complex systems are functionally integrated in ontogeny and evolution.

129-6 GOULD, A*; FRITTS-PENNIMAN, A; California Academy of Sciences; *agould@calacademy.org*

Shedding light on specificity: the phylogeography of a bioluminescent symbiosis

All organisms depend on symbiotic interactions with bacteria for their success, yet little is known of the evolutionary processes that shape the specificity of these associations. Coral reef fish in the genus *Siphamia* form symbiotic associations with luminous bacteria, which they provision in a gut-associated light organ. There are 25 described *Siphamia* species that are distributed throughout the Indo-Pacific, however, the light organ symbionts of only a single host species, *S. tubifer*, from a small region in the Okinawan Islands, Japan have been described to date. Using Siphamia specimens archived in natural history collections and applying whole genome shotgun sequencing methods, the luminous symbionts of 15 host species were identified. Additionally, the light organ symbionts of *S. tubifer* specimens from locations representing their broad biogeographic distribution, ranging from eastern Africa to French Polynesia were described. Using targeted sequence capture methods, the phylogenetic relationships across the host genus were also inferred and compared to that of their luminous symbionts to test for evidence of co-divergence of host and symbiont. Results indicate that the bioluminescent symbiosis is highly conserved across the host genus; the light organ symbionts of all Siphamia species examined were identified as Clade II of *Photobacterium mandapamensis*, the luminous symbiont of *S. tubifer* that was previously identified. Furthermore, the association between *S. tubifer* and *P. mandapamensis* is highly conserved throughout the host's broad Indo-Pacific distribution and through time. This high degree of specificity observed for this bioluminescent symbiosis suggests that the association could be genetically constrained at the genus level and presents the opportunity to investigate the genetic mechanisms regulating the specificity of host-microbe associations.

125-5 GRACE, JK*; ANGELIER, F; Texas A&M University, Centre d'Etudes Biologiques de Chize, CNRS; *jkgrace@tamu.edu*

Post-natal Glucocorticoids Negatively Affect Adult Anti-predator Behavior in House Sparrows

Short-term behavioral effects of early-life stressor experience and/or elevated glucocorticoids are widely documented across vertebrates. However, the persistence and severity of these effects are largely unknown, especially through the adult stage and in wild species. We investigated long-term effects of experimental post-natal increases in circulating corticosterone on antipredator behavior in house sparrows (*Passer domesticus*). We manipulated circulating corticosterone concentration in wild, free-living nestlings, transferred fledglings to captivity, and tested juveniles and adults for two measures of antipredator behavior: evasiveness during a direct human encounter, and propensity to escape from a risky environment. We found no effect of treatment on escape behavior, but a delayed effect on evasive behavior: treatment lowered evasive behavior in adults but not juveniles, and this effect was moderated by current body condition. These results highlight the importance of state-behavior interactions and life stage in assessing long-term effects of early-life stress, and provide rare evidence for delayed effects of early-life stress to adulthood.

123-8 GRAHAM, Z/G*; GARDE, E; HEIDE-JøRGENSEN, M/P; PALAORO, A/V; Arizona State University, Greenland Institute of Natural Resources, Universidade Federal de São Paulo; *zgraham1@asu.edu*

What is the Function of the Narwhal's Tusk? Insights from Morphology

The narwhal tusk is undoubtedly one of the most charismatic structures in all of biology, protruding from the head of male narwhals and reaching lengths of up to 3-m. Recent evidence has arisen that proposes that narwhals may use their tusk to stun prey or sense changes in water quality. By contrast, because all males and only a small percentage of females develop a tusk; this suggests that the tusk may function as a weapon during male-male aggression or as a signal during female-mate choice. Hence, clear inconsistencies arise when attempting to distinguish between these functions. Because direct observations of narwhal behavior are nearly impossible, we studied morphological scaling and variation in adult narwhals. With our analyses, we demonstrate that the size of the narwhal tusk scales steeply with body size. Additionally, substantial variation in tusk size for a given body size supports the hypothesis that the tusk is sexually selected. Overall, we propose that the narwhal tusk is an exaggerated weapon used during male-male competition but may also serve additional functions.

P1-39 GRAHAM, Z/G*; PALORO, A/V; VARGAS, C; ANGILLETTA, M/J; Arizona State University, Universidade Federal de Sao Paulo; *zgraham1@asu.edu*

The Offense and Defense of a Regenerated Weapon

Animals possess a variety of weapons that can displace and intimidate opponents during aggressive interactions. In many cases, severe injuries and damage can occur during these fights. In some species, such as a crustaceans and leaf-footed bugs, weapons are autotomized to escape predators or flee from a stronger opponent. In crayfish specifically, an autotomized claw can be regenerated and return to a similar size, but differently morphology when compared to a normal claw. Despite crayfish being model organisms for communication and aggression, it is unknown whether there are functional and structural consequences to wielding regenerated weapons. Thus, we investigated the offense performance (claw strength) and defensive capacity (cuticle thickness) of regenerated and non-regenerated claws of virile crayfish (Faxonius virilis). We found that despite regenerated claws being capable of growing to a same size as a normal claw, they produce on average 5 newtons weaker of force. Surprisingly, despite the reduction in maximum pinching force of a regenerated claw, we did not detect any impact of regeneration in pinching stamina trials. Furthermore, we found that the cuticle thickness of regenerated claws was like that of a normal claw.

90-2 GRANATOSKY, MC*; LAURENCE-CHASEN, JD; GARTNER, SM; WHITLOW, KR; WESTNEAT, MW; NYAKATURA, JA; New York Institute of Technology, University of Chicago, Humboldt-Universität zu Berlin; *Michael.Granatosky@nyit.edu*

An XROMM and kinetic analysis of underwater walking in the West African lungfish (Protopterus annectens) with implications for the role of quadrupedal gaits during the fin-to-limb transition

The integration of experimental data and modelling techniques have generated novel hypotheses about the fin-to-limb transition. One such hypothesis suggests that early tetrapods were incapable of salamander-like walking gaits. However, some dipnoans are well-known for their propensity for underwater walking. As such, it is possible that the neuromuscular substrates for quadrupedal gaits did not evolve during the invasion onto land, but instead for movement on benthic substrates. If true, living salamanders may be too anatomically derived to be particularly informative about the locomotor patterns of early tetrapodomorphs. In this study, we collect limb-loading data and three-dimensional femoral kinematics using X-ray Reconstruction of Moving Morphology from the West African lungfish (*Protopterus annectens*) during underwater walking. These data are compared to patterns of terrestrial locomotion in three species of salamander. Limb-loading in lungfish is dramatically lower than predicted based on their body mass, presumably due to the lungs providing additional buoyancy. However, when scaled to the underwater mass of the animal, limb-loading patterns and magnitudes are comparable to salamanders. Movements and overall excursion of femoral protraction/retraction and abduction/adduction are similar between walking lungfish and salamanders. However, long-axis rotation of the femur is substantially lower during quadrupedal walking in lungfish. These findings suggest that despite limited long-axis rotation of the femur, as has been posited for some stem tetrapods, quadrupedal gaits and tetrapod-like limb loading patterns can be achieved.

28-2 GRAND PRE, CA*; HEDRICK, BP; SCHACHNER, ER; Louisiana State University Health Science Center, New Orleans; *cgran9@lsuhsc.edu*

Movement and Function of the Hepatic-Piston Pulmonary Apparatus During Various Modes of Respiration in the American Alligator (Alligator mississippiensis)

Investigating the evolution of the respiratory system of crocodilians requires a thorough understanding of functional pulmonary anatomy and the associated osteological correlates in extant crocodilians. Previous work suggests that the hepatic-piston pump in extant crocodilians is correlated with a smooth thoracodorsal ceiling, which allows for the free movement and displacement of the lung and pleura during hepatically-driven ventilation, which has been suggested to only engage after vigorous exercise. However, this free movement and displacement of the pleura has neither been confirmed nor measured in living crocodilians. We present our initial results of ultrasound data of the pleura of two juvenile specimens of *Alligator mississippiensis*. Ultrasound was used to record the hepatic-piston driven ventilation and pleural displacement under three different conditions: 1) the alligators were measured in a calm, natural state, with typical shallow breathing; 2) the alligators inspired a 5% CO_2 fixed N_2 gas to invoke deep breathing; and, 3) the alligators were measured after exercise (breathing freely without CO_2 gas). These preliminary data demonstrate that hepatic-piston pump ventilation and pleural displacement occurred craniocaudally under all three conditions. The amount of pleural and hepatic displacement increased dramatically after CO_2/N_2 delivery. Our data demonstrate that the hepatic-piston ventilation system is functional both during shallow breathing and induced large breaths, and confirms that the smooth thoracodorsal ceiling allows for the free displacement of pleura and lung tissue.

113-3 GRANGER, J*; WALKOWICZ, L; FITAK, R; JOHNSEN, S; Duke University, Adler Planetarium; *jngranger@email.wm.edu*

Gray Whales Strand More Often on Days With Increased Levels of Atmospheric Radio Frequency Noise

Relatively little is known about how large marine mammals, such as whales, accomplish their impressive long-distance migrations. An underexplored sensory modality is magnetoreception: the ability to derive positional and directional information from the earth's magnetic field. Baleen whales are a candidate group for investigating magnetoreception in mammals due to their long migrations and the unique navigational challenges they face in the featureless open ocean. In this environment, it could be advantageous to derive navigational cues from the geomagnetic field because it is relatively constant and ubiquitous. While it is difficult to perform behavioral experiments on whales, it may be possible to use live stranding data (strandings in which the whale may have made a navigational error, rather than those in which a whale died at sea and washed ashore) as a tool for investigating their navigational senses. We used gray whale (*Eschrichtius robustus*) stranding data from the US west coast (n=186). We found that gray whales strand more often on days with high levels of solar radio flux (RF, $p<0.0001$) than on random calendar days. RF is strongly correlated with solar storms – sudden releases of high-energy particles from the sun that interact with parts of the earth's magnetosphere. One hypothesized mechanism for magnetoreception, the radical-pair mechanism, predicts that magnetoreception can be disrupted by radio-frequency radiation, and RF noise has been shown to disrupt magnetic orientation in certain species. These results indicate a magnetic sense in whales, which may be mediated by a radical-pair mechanism.

Moore-1 GRASLIE, EG; Field Museum, Chicago IL; *egraslie@fieldmuseum.org*

Prehistoric Road Trip: Crafting a Story 2 Billion Years in the Making

If you were to tell a story about your science, what narratives or examples would you highlight? Where would you start? Who would you include? Paleontology is a field of science that relies on collaborations spanning organizations, institutions, cultures, and generations. In this presentation, I will address some of these questions and share insights gained from my time in production on "Prehistoric Road Trip," an upcoming three-hour series for PBS about the study of geology and the fossil record in the Northern Great Plains of the United States. The overall goal is to share experiences that can help others communicate their science to a broad array of audiences, no matter the platform or medium.

42-5 GRAY, JA*; SHERRATT, E; HUTCHINSON, MN; JONES, MEH; Oklahoma State University Center for Health Sciences, University of Adelaide, South Australian Museum, University College London; *grayjaimi@gmail.com*

Dragons of the trees, the rocks, and the ground: the evolution of cranial shape in a continental-scale evolutionary radiation of lizards (Lepidosauria: Agamidae)

Morphological disparity can be generated during adaptive radiations in response to factors such as new resources, freedom from competition, and an absence of predators and pathogens. The oldest ancestor of the extant Australian radiation of agamid lizards (Amphibolurinae) arrived in Australia from Southeast Asia approximately 30 million years ago. Since then, Australian agamids have become a species-rich and ecologically diverse clade. Today, they are comprised of around 120 species distributed among every Australian habitat, and are particularly successful in arid environments. We have relatively sound knowledge of their taxonomic diversity and phylogenetic relationships, but their morphological diversity remains largely unexplored. Despite being such a taxonomically and ecologically diverse clade, their adaptive character has not been explicitly tested. Here, we use three-dimensional geometric morphometrics to characterise skull shape in Australian agamids and their Asian agamid relatives (Draconinae), and investigate the association between skull shape and ecological life habit. We find that in addition to phylogenetic affinity and evolutionary allometry, ecological factors play a major role in skull shape evolution of this clade, confirming their adaptive character. Through our evaluation of the cranial morphospace we find common themes of ecomorphology, where tree-dwelling species have long skulls and snouts, terrestrial species have short, blunt skulls, and saxicolous species have dorsoventrally flat skulls. These characteristics likely result from trade-offs to optimise functional capabilities, which often play a role in the evolution of skull shape.

123-6 GREEN, TL*; GIGNAC, PM; Oklahoma State University Center for Health Sciences, Tulsa; *todd.green@okstate.edu*

Cassowary Casques are Lightning Rods for Speculation: Anatomical Development and Phenotypic Variation Clarifies Potential Biological Roles

The cranial casques (i.e., bony and keratinous dorsal skull projections) of extant cassowaries (*Casuarius*) have been of interest to researchers since the 17th century due to their conspicuousness. Casque biological roles, however, remain poorly understood, limiting our understanding of the life history of these unique birds as well as the selective conditions under which cranial elaborations appear in archosaurs. A strict focus on adult ornaments has left surprisingly few links to ontogeny, life history, and function. Moreover, the handful of osteological interpretations of casques are contradictory, illustrating the difficulty by which full documentation of this anatomy has proceeded. Four primary hypotheses for casque function have been proposed: (1) ramming, (2) vocalization, (3) thermoregulation, and (4) display. To address these roles, we undertook µCT analyses of cranial anatomy in a developmental series of southern cassowaries (*C. casuarius*), capturing details of external and internal structures as well as timings of sutural fusions and inflations of casque elements. We compared the developmental timing of casques to physical, behavioral, and reproductive maturity to determine the plausibility of each function. Our sample ($n = 110$) indicates the majority of casque growth occurs prior to sexual maturity; however, casque morphology continues to change substantially throughout adulthood. In *C. casuarius* casque deviation from midline is common, and such asymmetries appear to be primarily dextral. Form does not support functions for physical ramming or vocalization. Thermoregulation and display are not refuted by developmental anatomy and adult phenotype, necessitating more focused study.

P3-191 GREENE, MJ*; RENNER, K; SWALLOW, JG; GREENE, Mic; University of Colorado Denver, University of South Dakota; *michael.greene@ucdenver.edu*

Mechanisms of Pavement Ant Aggression.

Ant colonies are distributed systems that are regulated in a non-hierarchical manner. Without a central authority, individuals inform their behavioral decisions by comparing information in local cues to a set of inherent behavioral rules. Collectively, many individual behavioral decisions lead to changes in colony behavior including the decision to be aggressive with neighboring colonies. Pavement ants (*Tetramorium immigrans*) form conspicuous wars with neighboring colonies in which thousands of ants participate. Wars last for many hours and few workers die in the process as because fighting is ritualized. A worker is likely to decide to fight if 1) it has had a recent history of interactions with nestmates and 2) detects a mismatch in nestmate recognition cues, coded in cuticular hydrocarbon profiles, on the cuticle of a non-nestmate ant. We present evidence showing how tactile and chemical cues and social context – isolation, nestmate interaction, or fighting non-nestmates – affect levels of the brain monoamines serotonin (5-HT), octopamine (OA), and dopamine (DA) and how serotenergic neurons are distributed in pavement ant brains.

P2-68 GREIVES, T*; ESHLEMAN, M; GALANTE, H; DEIMEL, C; HAU, M; North Dakota State University, Max Planck Institute for Ornithology; *timothy.greives@ndsu.edu*

Testosterone peaks in the early evening and GnRH-induced testosterone is correlated with this peak

Experimental manipulation of testosterone has established it as a potent pleiotropic regulator coordinating morphology, physiology and behavior. However, the relationship of field-sampled, unmanipulated testosterone with traits of interest is often equivocal. Circulating testosterone varies over the course of the day. Reports indicate that testosterone peaks during the night in birds, yet most field studies sample testosterone during the morning. Sampling at times when levels are low may be one reason relationships are not always observed. Testosterone is regulated by the hypothalamic-pituitary-gonadal axis, with gonadotropin-releasing hormone (GnRH) initiating the endocrine cascade. Researchers have begun to examine GnRH-induced testosterone levels with traits of interest, yet the relevance of these induced levels are not fully clear. Using photostimulated male great tits (*Parus major*) we test the hypotheses that testosterone levels peak during the night and that GnRH-induced testosterone is related to nightly testosterone peaks. Blood was sampled during the first, middle or last third of night. One week later, baseline and GnRH-induced levels were sampled during mid-morning. Morning baseline testosterone levels were low compared with night-sampled levels that peaked during the first third of the night. Further, GnRH-induced testosterone was strongly correlated with levels observed during the first third of the night. These data suggest that morning testosterone samples likely do not reflect an individual's endogenous peak, and GnRH-induced levels approximate an individual's nightly peak and may be an alternative for birds that cannot easily be sampled at night in the field.

125-7 GREVILLE, LJ*; POLLOCK, T; DECATANZARO, D; FAURE, PA; McMaster University, Hamilton, ON; *grevillj@mcmaster.ca*

Seasonal Variation in Estradiol Transfer Among Male and Female Big Brown Bats

Current research suggests that unconjugated steroids excreted in the urine of male mice alter the reproductive behaviour and physiology of female conspecifics. These observations support the notion that steroids can act as pheromones in mammals. Using tritium (^{3}H)-labelled estradiol (E_2) as a radioactive tracer, we have shown that female big brown bats (*Eptesicus fuscus*) readily absorb exogenous ^{3}H-E_2 applied via cutaneous and intranasal exposure, with radioactivity measured throughout neural, peripheral, and reproductive tissues 1 hour after exposure. Additional experiments with ^{3}H-E_2 have shown the reliable transfer of estradiol from male *E. fuscus* to cohabitating female conspecifics during the Autumn mating season. Here we explore seasonal variation in estradiol transfer between male and female *E. fuscus* at three relevant time points: Autumn (mating season), Spring (female ovulation, ovum fertilization, and implantation), and Summer (maternity colony formation, parturition, and maternal care). We found substantial seasonal variation in the amount of ^{3}H-E_2 transferred from males to a variety of female tissues, including the frontal cortex, heart, liver, uterus, and blood serum, with a number of other tissues approaching statistically significant differences among seasons. We present data demonstrating the presence of unconjugated and bioactive estradiol in male urine across the mating cycle, with the peak concentration occurring during reproductively relevant times. We concluded that estradiol is a likely vector for steroid transfer between individuals. Seasonal variation in estradiol transfer could influence sexual behaviour and reproductive physiology of female bats during critical reproductive periods, as transferred steroids were found in both neural and reproductive tissues.

23-6 GRIFFITHS, JS*; JOHNSON, KM; KELLY, MW; Louisiana State University; *jgrif61@lsu.edu*

Evolutionary Change in the Oyster, Crassostrea virginica, Following an Experimental Low Salinity Event

The eastern oyster, *Crassostrea virginica*, is known for its tolerance to 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.

43-3 GRIMES, CJ*; PAIVA, PC; PETERSEN, L; SCHULZE, A; Texas A&M University at Galveston, Universidade Federal do Rio de Janeiro; *cg1478@tamu.edu*

How fireworms, Hermodice carunculata, react to hypoxia: morphological, physiological and gene expression responses

The bearded fireworm, *Hermodice carunculata*, is a resilient amphinomid annelid, found throughout the Atlantic Ocean under a wide range of environmental conditions. Due to the species' ease of capture, culture, widespread, and abundant nature, it is very suitable for experimental studies of environmental tolerance. Here, we have subjected *H. carunculata* to intermittent (< 18 hours) and chronic (> 18 hours) hypoxia to investigate the species' molecular and morphological responses to such stressful situations. For chronic hypoxia, five bearded fireworms were exposed to one of three levels of dissolved oxygen (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). To investigate intermittent hypoxia responses, 16 worms were subjected to intermittent hypoxia (6 hours of hypoxia and 18 hours of normoxia) for 2 days and sampled for tissues at 6, 18, 24, and 42 hours. The morphological comparisons before and after hypoxia exposure show an increase in the surface area of branchial tufts. Differential gene expression analyses suggest up-regulation of stress response genes, metabolic depression, and an increase in efficiency of oxygen transport molecules under hypoxic conditions. This study allows us to infer the threshold DO level for hypoxic response in this abundant coral reef inhabitant, predict downstream responses to this stressful condition, and potentially predict the historical DO levels for an area where the worms are found.

P1-271 GRIMES, CJ*; LABONTÈ, J; LOPEZ, JV; SCHULZE, A; Texas A&M University at Galveston, Nova Southeastern University ; *cg1478@tamu.edu*

Microbiomes of a corallivore (Hermodice carunculata): where in the worm are the coral microbes?

The bearded fireworm, *Hermodice carunculata*, is a widespread annelid generally considered a nuisance species in reef environments and in aquaria alike as it feeds preferentially on members of the Phylum Cnidaria. As *H. carunculata* is a mobile corallivore, it has the potential to spread microbes by transporting them on its body surfaces and in its digestive tract. Here, we sequenced the V3-V4 16S ribosomal RNA region from four worm tissue types (anterior end, pharynx, posterior end with excrement, and middle body segments). We also characterized whole worms, substrates, diseased and healthy colonies of Montastrea cavernosa, in order to characterize the microbiome of the worm and its prey. Preliminary analyses suggest distinct microbial communities between the different tissue types and sections of the bearded fireworm as well as between the disease and healthy coral colonies. These initial results also indicate a higher number of pathogenic bacteria (e.g. *Vibrio* spp.) on the diseased coral and higher bacterial diversity in the substrate. The pharynx communities were primarily dominated by members of the Pseudomonadales and Flavobacteriales orders, while the middle and posterior ends contained higher proportions of Desulfobacterales. Since these annelids move between healthy and diseased coral colonies, determining the method and location of microbial abundance and exchange will lead to improved understanding of marine disease dynamics and mitigation efforts.

P1-192 GRINER, JG*; DIAMOND, KM; BLOB, RW; Clemson Univ.; *jggrine@g.clemson.edu*

Comparative body shapes of amphidromous goby fishes living in different predator regimes

The evolution of morphological specializations across prey species might be driven by differences in the predators that species encounter. Species that are separated geographically often experience different predator regimes which might also require different predator-avoidance strategies. Amphidromous goby fishes provide a system that experiences a spectrum of predator regimes across their different habitats, making them an excellent system for studying how such regimes relate to prey morphology and behavior. For example, on the islands of Hawai'i and La Réunion, goby species that cannot climb live consistently with predators throughout their life. However, some goby species can climb waterfalls, which allows them to either live in predator-free (Hawai'i) or diminished-predator (La Réunion) environments as adults. We expected to find distinct body shapes across the adults from each regime, depending on the type of anti-predator strategy that each species prey used. Fish using a morphological strategy should have traits that physically hinder consumption by predators., whereas those using a kinematic strategy should have traits that assist in the production of thrust. To test these predictions, we used geometric morphometrics to quantify differences in body shape across six goby species that experience different predator regimes. We found that fish living consistently with predators have deeper bodies that would be harder to consume than those that can climb. Among climbing gobies, those that face diminished predation have longer posterior bodies, possibly allowing for a greater output of thrust compared to species from predator-free environments. These results support our prediction that morphology, and consequently the predator-avoidance strategy it facilitates, varies between predator regimes.

11-4 GRIPSHOVER, ND*; JAYNE, BC; University of Cincinnati; *gripshnd@mail.uc.edu*

Feeding of Crayfish Snakes: A Model System for Testing the Roles of Predator Anatomy and Behavior on Foraging Ecology

Snakes are a classic example of a gape-limited predator, but ironically gape has been quantified directly in fewer than 10 of more than 3,500 extant species. Besides an anatomy specialized for large gape, snakes seem likely to require additional specializations for unusual types prey, such as crustaceans. In this study, we quantified maximum gape and its scaling relationships for two natricine snake species (*Regina septemvittata*, *Liodytes alleni*) that primarily prey upon freshly molted (soft) or hard-shell crayfish, respectively. We also quantified the relative area (RelA) of prey consumed in the field and in the lab as a percentage of the maximal cross-sectional area of snake gape. For snakes with equal snout-vent length, the maximal gape of *L. alleni* (N=26) was significantly larger than that of *R. septemvittata* (N=21). In the field, *R. septemvittata* (N=148) consumed large prey (RelA>50%) more often than *L. alleni* (N=17) (38% vs. 22% of stomach contents). For equal RelA during laboratory trials, *L. alleni* consumed soft-shell prey significantly faster than hard-shelled prey. However, presumably as a result of its coiling behavior, *L. alleni* consumed soft-shell crayfish significantly faster than *R. septemvittata*. In laboratory trials of *L. alleni*, when prey exceeded 50% RelA the success rates of attacks were 11% and 48% for hard-shelled (N=19) and soft-shelled (N=42) crayfish, respectively. Similar to the two natricine study species, the Southeast Asian snake that eats hard-shell crabs has larger gape but eats prey with smaller relative size than its sister species that eats only soft-shell crabs. Hence, the primary constraints of snakes for the maximal prey size when eating hard-shell and soft-shell crustaceans are probably the ability to capture prey and maximal gape, respectively.

45-3 GROBER, M S*; PRADHAN, D S; Georgia State University, Idaho State University; *mgrober@gsu.edu*

Rosemary Knapp: scientist, colleague, mentor, friend

I will spend my 15 minutes talking about how Rosemary Knapp helped Devaleena Pradhan (my graduate student) to better develop a great piece of science that was a significant part of her dissertation. She essentially co-mentored Devaleena by giving excellent feedback at her SICB poster AND, after we improved the study as a result of her feedback, via her excellent service as an editor at Proceedings of the Royal Society, London. The story is a testament to what a great scientist, mentor and colleague Rosemary was and also what a great friend she was to me. While the story will be about Rosemary, some neat data about how brain derived androgens regulate paternal care in the Bluebanded Goby will make an appearance, since this is the study that Devaleena was presenting at SICB when Rosemary dropped by and made everything better.

P2-180 GROOM, DJE*; ELOWE, CE; SLEZACEK, J; GERSON, AR; University of Massachusetts, Amherst, University of Western Ontario; *dgroom@umass.edu*

Whole-animal Metabolic Phenotype Before and After a Migratory Flight in the Yellow-rumped Warbler (Setophaga coronata)

The pace of avian migration is heavily determined by the time required to recover from long duration flights in order to prepare for the next. Long duration flight results in significant losses of both lean (ie. protein) mass and fat mass, which are recovered in a bi-phasic pattern where lean mass is recovered before fat can be deposited. While the recovery of metabolically active lean mass can improve physiological function such as digestion, which is necessary for refueling, lean mass recovery may also increase already high mass-specific resting metabolism, impeding fat deposition rates. Few studies have examined the dynamics of metabolism following long duration flight and how it relates to lean mass gain and total energy balance. Here, we use whole-animal metabolic phenotyping, food consumption, digestive physiology, and real-time body mass measurements to determine the dynamics of metabolism and energy balance for 72-hours before and after a 6-hour wind tunnel flight in the yellow-rumped warbler (*Setophaga coronata*). We predicted that yellow-rumped warblers would have lower metabolic rates following flight due to the loss of lean mass associated with flight, but would also depress mass-specific metabolic rates to accelerate the rate of mass gain. The metabolic phenotyping system captured diurnal patterns in metabolic rate and fuel mixture with high time resolution, enabling precise quantification of metabolism and its relation to food intake and mass change before and after long duration flight.

27-7 GUERNSEY, MW*; VAN KRUISTUM, H; REZNICK, DN; POLLUX, BJA; BAKER, JC; Stanford University School of Medicine, Wageningen University, University of California, Riverside; *michael.w.guernsey@gmail.com*

Poeciliopsis maternal follicle transcriptomes reveal importance of placenta and secretory genes in the emergence of live-birth

Placentation evolved many times independently in vertebrates, and while the core functions of all placentas are similar we know less about how this similarity extends to the molecular level. Here we study *Poeciliopsis*, a unique genus of live-bearing fish that have evolved placental structures at least three times independently. The maternal follicle is a key component of these structures; it envelops yolk rich eggs and is morphologically simple in non-placental species, but has elaborate villous structures in placental species. Through sequencing the follicle transcriptome of a placental, *P. retropinna*, and non-placental, *P. turrubarensis*, species we found genes known to be critical for placenta function expressed in both species despite their difference in complexity. Additionally, when we compare the transcriptome of different river populations of *P. retropinna*, known to vary in maternal provisioning, we find differential expression of secretory genes expressed specifically in the top layer of villi cells in the maternal follicle. This provides some of the first evidence that the placental structures of *Poeciliopsis* function using a secretory mechanism rather than direct exchange between maternal-fetal circulation. Finally, when we look at the expression of placenta proteins at the maternal-fetal interface of a larger sampling of *Poeciliopsis* species we find expression of key maternal and fetal placenta proteins in their cognate tissue types of all species, but follicle expression of Prolactin is restricted to only placental species. Taken together, we suggest that all *Poeciliopsis* follicles are poised for placenta function, but require expression of key genes to form secretory villi.

54-7 GUERRA CANEDO, VI*; HART, MW; KOEPFLI, KP; Simon Fraser University, Burnaby, BC and Smithsonian Conservation Biology Institute, Washington, DC, Simon Fraser University, Burnaby, BC, Smithsonian Conservation Biology Institute, Washington, DC; *vguerracanedo@gmail.com*

Evidence of positive selection in genes known to regulate fertilization in Mustelids

Gamete-recognition proteins (GRG), expressed on the surface of gametes, mitigate the initiation of sperm hyperactivation, acrosome reaction, gamete binding and fusion. Few genetic changes in these proteins can lead to reproductive incompatibility. GRG are poorly described in mustelids and other mammals. This is in part due to duplication events, diversifying selection, loss of function, and convergence. Conservation breeding efforts of endangered species are encountering an increased number of fertilization problems linked to gamete health. For example, since the onset of the captive breeding program, the percentage of structurally-normal spermatozoa in the black-footed ferret has decreased from 50% to 20%, coincident with a decline in testes size. These features are indicative of inbreeding depression. To better understand fertilization in mustelids, we used whole genome data comparison to find and characterize genes linked to fertilization. In particular, we focused on finding orthologous GRG in mustelids and related taxa of the Carnivora. We characterized eight potential GRG and tested these for signatures of positive selection within a phylogenetic and machine learning framework using the software toolkit HyPhy. We identified regions of these genes under positive selection in mustelids, which have also been previously identified to be under selection in mice and humans. Our findings can help inform functional analyses to confirm the patterns of expression and function of these orthologous GRG in mustelids and other carnivores. Furthermore, these genes can be used in combination with additional fertilization genes to identify healthy gametes for ex situ and in situ population breeding efforts of endangered species.

P2-81 GUEVARA MOLINA, SC; RIBEIRO GOMES, F; WARKENTIN, KM*; University of São Paulo, Brazil, University of S Paulo, Brazil, Boston University, MA and Smithsonian Tropical Research Institute, Panamá; *scarolinemolina@usp.br*

The VTMax of embryos: interacting effects of warming and dehydration on hatching behavior in red-eyed treefrogs, Agalychnis callidryas (Anura: Phyllomedusidae)

Climate change is increasing environmental temperatures and droughts around the world. Many tropical anurans lay terrestrial eggs, relying on environmental moisture for embryonic development. These eggs are vulnerable to dehydration, which may alter development or cause mortality. However, in some species, embryos can hatch prematurely to escape from drying eggs. Although warm temperatures can accelerate hatching by speeding development, it is unknown if embryos also respond behaviorally to warming, showing a voluntary thermal maximum (VTMax) at which they leave the egg. Further, it is unknown if embryo VTMax depends on hydration. We used a warming experiment to evaluate if *Agalychnis callidryas* embryos hatch early as an immediate behavioral response to high temperatures. We discovered that these embryos make a behavioral escape-hatching decision to avoid excess warming, showing a VTMax. Second, we examined if hydration level of eggs and egg-clutch jelly influence the response of embryos to warming. We found the hatching response varies with hydration state. Fully hydrated eggs and clutches warmed substantially slower than dehydrated ones, suggesting hydration buffers embryos from environmental warming via evaporative cooling. Moreover, embryos tolerated higher temperatures before hatching if they were initially well-hydrated. Our results demonstrate a convenient behavioral assay for thermal tolerance of terrestrial anuran embryos and reveal interacting effects of dehydration and high temperatures at an early life stage.

8-3 GUIDRY, ME*; REIGEL, AM; KELLY, MW; Louisiana State University ; *mguid73@lsu.edu*

Variation in the Microbiome of the Eastern Oyster: Environmental Influences and Effects on Oyster Health

Crassostrea virginica (eastern oysters) are ecologically and economically valuable organisms in coastal Louisiana. Understanding the nuanced relationships between *C. virginica* hosts and associated microbiota could be the key to maintaining healthy populations along a dynamic coastline. This study utilizes the natural salinity gradient along the Louisiana Gulf coast to analyze the effect of variable environmental conditions and disease on the *C. virginica* microbiota. Oysters were collected from two parent sites in Louisiana: Lake Calcasieu (19.4 ± 2.5ppt) and Vermillion Bay (3.9 ± 1.9ppt). Oyster stocks were spawned at the Louisiana Sea Grant Grand Isle Hatchery, and offspring were outplanted to Grand Isle (19.9 ± 4.2ppt) and LUMCON (8.0 ± 3.5ppt) for 14 months. Oyster gill tissue and pallial fluid samples were collected from both sites in July and October of 2018. Microbial DNA was extracted from gill tissue and pallial fluid samples and sequenced for 16S rRNA (V4 region) using Illumina HiSeq for 2x250bp reads. The progression of Dermo infection, caused by parasitic protozoan *Perkinsus marinus*, was measured and recorded for all individuals. By comparing microbiomes from gill tissue and pallial fluid and different environmental conditions, we were able to gain an initial understanding of the diversity of the *C. virginica* microbiota. Data suggest signature microbial communities for gill tissue and pallial fluid, as well as outplant-site specific community structure. Similar patterns are expected for seasonal differences and disease states. These fundamental differences in microbial communities could be associated with host responses to changing environmental conditions and could influence oyster fitness and overall population health.

80-6 GUINDRE-PARKER, S; Kennesaw State University; *sguindre@kennesaw.edu*

Revisiting glucocorticoid plasticity

Endocrine systems are by definition dynamic and flexible, characterized by carefully regulated circulating ligands that control changes in physiology, development, and behavior across altered intrinsic or extrinsic conditions. Glucocorticoids are thought to be an important coping mechanism for vertebrates facing changes in their environments, as these hormones promote adaptive responses following both predictable and unpredictable environmental perturbations. Glucocorticoid plasticity – the ability of one individual to alter circulating glucocorticoids or other components of the hypothalamic-pituitary-adrenal-axis (HPA-axis) across a gradient of environmental conditions – is thought to be central to the ability of organisms to cope with rapid changes in our dynamic world. The HPA-axis and circulating glucocorticoid concentrations represent complex traits, however, and this complexity needs to be explicitly incorporated into future work on glucocorticoid plasticity. I will outline different types of glucocorticoid plasticity and review previous work on the topic. I will discuss statistical tools which can enable us to quantify individual variation in glucocorticoid plasticity as well as explore the fitness consequences of this variation. Finally, I will discuss the implications of variation in endocrine plasticity for predicting coping ability within and across populations and species.

137-3 GUMM, JM*; STANTON, M; FEUERBACHER, OG; Ash Meadows Fish Conservation Facility, USFWS; *jennifer_gumm@fws.gov*

Refuge Populations as Research Populations: Morphology, Reproduction and Ecology in a Captive Population of Devils Hole Pupfish

Captive populations are critical to the recovery and maintenance of biodiversity of many species. These populations can also provide opportunities for research that bridge gaps between academics and agencies. The Ash Meadows Fish Conservation Facility (AMFCF) houses a refuge population of the endangered Devils Hole pupfish (*Cyprinodon diabolis*) in a 100,000-gallon refuge tank designed to mimic the extreme desert habitat and ecosystem of Devils Hole. One challenge in previous captive populations is exact matching of environmental parameters, which is thought to have altered morphology and behavior of C. diabolis in captivity. The habitat at the AMFCF represents a change in approach to captive environment design, providing increased control and monitoring of biotic and abiotic variables and allowing us to examine the relationships between these variables and fish morphology, behavior and ecology. Herein, we present findings of studies comparing morphology, reproduction and ecology between the captive and wild populations. Specifically, we evaluate larval and early life stage growth rates, reproductive outputs, and report a novel predator-prey relationship that may be mediated by temperature. Taken together, our studies support the integration of research and management as conservation actions often require an understanding of organismal form and function to be successful.

P3-177 GUO, Y*; SHAMPAY, J; RENN, SCP; Reed College; *mifguo@reed.edu*

Effects of Social Stress on Telomere Length and Telomerase Activity in Astatotilapia burtoni

Telomeres, the end regions of eukaryotic chromosomes, preserve integrity. Short telomeres will lead to cellular senescence, thus telomeres must be maintained and elongated by the telomerase enzyme. Chronic stress correlates with heightened oxidative stress and DNA damage. Our subjects, *Astatotilapia burtoni* cichlid males, form a strict primarily size-based social hierarchy. We maintained the social status of individual *A. burtoni* males for the first 6 months of life. Then by manipulating the relative size of tank mates, they were either forced to switch social status or allowed to maintain it for 4 more weeks. Brain, liver and gut tissues were then assayed for absolute telomere length and telomerase activity. This design allows us to assess both the chronic and acute effects of stress on telomeres. It's hypothesized that always dominant males will have higher telomerase activity due to constant growth, while always subordinate males will have lower telomerase activity due to limited growth. For those that descend social status, telomerase activity will decrease; for those that ascend social status, telomerase activity will increase with resumed growth. Within 4 weeks, no dramatic change in telomere lengths is expected even with changes in telomerase activity. However, it is difficult to predict the chronic effects of stress on telomere length in fish because they have indeterminate growth, meaning they can delay growth when necessary. Due to growth suppression, always subordinate fish may not suffer a reduction in telomere length that would otherwise be predicted for reduced telomerase activity; likewise, due to increased growth and cell division, always dominant fish may suffer reduced telomere length despite elevated telomerase activity. All possible results will provide further insights into the mechanism of cellular aging and how social stress influences organisms on a molecular level.

60-5 GURGIS, GP*; DAZA, JD; BRENNAN, IG; HUTCHINSON , M; BAUER , AM; OLORI, JC; SUNY Oswego, Sam Houston State University, The Australian National University, South Australian Museum, Villanova University; *ggurgis@oswego.edu*

Using your head! Finite Element Analysis of head-first burrowing Pygopodids (Gekkota)

Pygopodids are limb-reduced, miniaturized geckos found across Australia and New Guinea. Pygopodids are mainly terrestrial; however, Aprasia species are highly fossorial and further miniaturized, converging on similar ecology and morphology to typhlopid snakes. Additionally, Aprasia from eastern/central and western Australia exhibit distinct skull shapes, possibly due to the functional demands of burrowing in different soil types. Another pygopodid genus, Ophidiocephalus, also was described as fossorial with morphology most similar to eastern Aprasia species, and thus may experience a similar pattern of cranial stress when digging. The burrowing mechanics of pygopodids have never been studied; however, we propose that mechanical stress is distributed outwardly as a shell across the expanded nasals, rather than along an anterior-posterior central column as suggested for other head-first burrowing squamates. To test how differences in morphology may be related to differing functional demands, Finite Element Analysis was implemented by applying and comparing both face loads and point loads of 20N onto 3D solid meshes of the skulls of one eastern/central and one western Aprasia, and one Ophidiocephalus. The resulting stress and strain were low in all taxa and appeared to be evenly spread out across each axis; however, Ophidiocephalus experienced slightly higher average stress than either Aprasia. Although anatomically divergent, each lineage appears to have independently converged on a similar level of biomechanical performance.

S7-10 GUST, KA; US Army, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS; *kurt.a.gust@usace.army.mil*

Omics in Non-Model Species: Closing the Loop Among Genes, Molecular Systems, and Phenotypes to predict Adverse Outcomes to Environmental Stress

Omics technologies have been instrumental in characterizing the impacts of environmental stressors and stressor combinations in non-model species of concern to the US Army. The use of omics investigations has provided mechanistic and systems-level understanding of stressor impacts for species ranging from birds, lizards and amphibians to fish and coral. Recent results include functional transcriptomics expression correlations with clinical toxicological phenotypes in Western fence lizards which demonstrated the remarkable robustness of immune responses to lizard malaria infection under combined stressor exposures to food limitation and trinitrotoluene exposures. Additionally, meta-transcriptomics investigations among coal and commensal algal zooxanthellae coupled with histochemical analyses indicated heightened sensitivity to 1,3,5-trinitro-1,3,5 triazine (RDX) exposure in the zooxanthellae compromising energy production within the coral holobiont. As a final example, transcriptomics, proteomics, lipidomics and *in vitro* assays conducted across non-model species (birds and fish) and model species (rodent and human) were integrated to establish a robust Adverse Outcome Pathway (AOP) connecting molecular initiating events, key metabolic, cellular and physiological events to the adverse outcomes of lethargy and weight loss caused by nitrotoluene exposure; the mechanisms of which had remained elusive for over 100 years prior. Overall, omics-based experimental investigations have accelerated expression-to-phenotype discoveries in stressor biology providing unprecedented robustness in systems-level screening for non-model organisms.

138-4 GUSTISON, ML*; PHELPS, SM; University of Texas at Austin, Austin, TX; *gustison@utexas.edu*

Vocal activity is coupled to partner proximity and mating during pair-bonding in a monogamous rodent

Prairie voles (*Microtus ochrogaster*) are one of the few mammalian species to form stable attachments, or pair bonds, between mating partners. A great deal is known about the function of vole tactile social behaviors (e.g., mating, huddling) in establishing pair bonds, but the role of conspicuous behaviors like ultrasonic vocalizations (USVs) remains a mystery. Here, we quantify the temporal dynamics of vocal activity during pair-bond formation and map these dynamics onto other measures of affiliation like partner proximity and mating. Following 4-5 days of social isolation, subjects were paired with either a familiar same-sex sibling or a novel opposite-sex mating partner for up to 22h while we continuously tracked their movements and vocalizations. For both sibling and mating pairs, time courses of vocal activity and partner distance were strongly correlated in that higher USV rates occurred when pairs were separated. Moreover, mating pairs produced higher USV rates than sibling pairs, with peaks in vocal activity linked to the male initiation of mating. Preliminary results reveal that USVs associated with mating are acoustically distinct from USVs that occur when isolated, suggesting that USVs can function both as courtship signals and contact calls. Taken together, our results suggest that prairie vole USVs function to re-establish contact with social partners and promote mating interactions that are critical for pair-bond formation.

P3-71 GUTIERREZ-ANDRADE, D*; MIDDLEBROOKS, ML; University of Tampa, Tampa FL; *d.gutierrezandrade@spartans.ut.edu*
Effectiveness of ceratal autotomy as a defense mechanism for the sacoglossan sea slug Placida kingstoni
Relatively little is known about the interactions between sacoglossan sea slugs and potential predators. *Placida kingstoni* is a small sacoglossan that conducts ceratal autotomy, deliberately casting off body structures due to danger or stress. Although the ability of some sacoglossan species to conduct autotomy has been reported, very few studies have assessed its effectiveness as a defense mechanism against predation. The purpose of this investigation was to evaluate *P. kingstoni's* autotomy in the presence of a potential predator and the effect that autotomy has on survival. The caridean shrimp *Lysmata wurdemanni* was selected as a potential predator due to its habitat overlap with *P. kingstoni*, generalist diet, and aggressive behavior. Each shrimp was individually isolated, underwent a period of starvation, and was then exposed to a sea slug for a ten-minute observation. In most interactions *P. kingstoni* was attacked by *L. wurdemanni*, suggesting that the slug is palatable and that the shrimp is in fact a plausible predator of the sea slug. Although they were attacked, and some slugs were eaten, most slugs autotomized cerata and survived the encounter. *L. wurdemanni* often directed its attention to the autotomized cerata clusters and consumed them, which allowed the slugs to survive. This demonstrates that in *P. kingostoni* ceratal autotomy can be an effective defense mechanism against certain predators. However, autotomy might not be effective against other organisms that exhibit different modes of attack, requiring slugs to use other defenses such as crypsis or chemical secretions. Although autotomy increased survival in *P. kingstoni*, its effectiveness for other sacoglossans is still mostly unresolved.

P1-49 GUZMAN, A*; KOLONIN, A; ASPBURY, A; GABOR, C; Texas State University, San Marcos, TX; *avg32@txstate.edu*
Land Use Conversion Affects Stress Physiology and Life-History of Western Mosquitofish
Land use conversion can lead to decreased biodiversity and organismal health in freshwater habitats. Run-off from urbanized environments introduces pollutants and alters water temperature, chemistry, and hydrology in streams. The resulting "urban stream syndrome" affects the stress response of resident fishes by elevating or dysregulating the stress hormone, cortisol. We explored the consequences of land use conversion on baseline cortisol release rates, stress response (to agitation), resilience, and life-history plasticity of the Western Mosquitofish, *Gambusia affinis*, an abundant species which persists in urbanized habitats. We hypothesized that increasing urbanization, defined by the percent developed land within a 2.2 km radius of each site, will alter cortisol levels and affect life-history traits of female mosquitofish. We sampled fish from streams varying in levels of urbanization and measured water quality covariates in 2018 and 2019. In both years the dry brood mass of female mosquitofish increased with increasing urbanization. Cortisol release rates increased with increasing urbanization in 2018, but not in 2019. All streams showed stress response to agitation in both years. In 2019 none of the mosquitofish populations showed resilience indicating that they did not recover in one hour from a stressor. In urban populations as the magnitude of resilience decreases, dry brood mass increases but there is no such trade-off for the more rural populations. Further, we found that cortisol response was highly repeatable indicating an ability to respond to selection. Our findings suggest that mosquitofish are urban adaptors and modulate reproductive output in lower quality streams.

P3-215 HAGEN, OL*; CERVENY, KL; Reed College; *hageno@reed.edu*
How does cell proliferation in the optic tectum change when fish see?
Unlike mammals, many anamniotes exhibit lifelong growth of the retina and its target brain tissue, the optic tectum. In zebrafish, retinal ganglion cells (RGCs) project from the inner layer of the retina and form synapses with the contralateral optic tectum. In a variety of animals, tectal cell proliferation and cell death are influenced by innervation from the retina, indicating that RGC axons provide key information to control stem and progenitor cell behaviors. However, the nature of this information, trophic or synaptic, remains unknown. In this study we investigated how the loss of visual input that occurs through rearing fish in constant darkness alters stem and progenitor cell behaviors in the optic tectum relative to the presence or absence of a functional optic nerve. We demonstrate that while non-innervated lobes of fish raised in the typical light-dark cycle had significantly less proliferation than their innervated counterparts, there was not a significant difference between the innervated and non-innervated lobes of fish raised in complete darkness. These findings provide preliminary evidence that the cue supplied by RGC axons to tectal stem and progenitor cells arises from synaptic, visually-evoked activity.

P3-141 HAGOOD, ME*; PORTER, ME; Florida Atlantic University; *mhagood2018@fau.edu*
Anisotropic Mechanical Properties of Shark Skin
The surface of shark skin is covered with dermal denticles that reduce drag and are hypothesized to increase swimming speeds. Denticle morphology and skin material properties have been shown to vary regionally along the body and denticle density has been correlated with skin material properties like stiffness and toughness. The stratum compactum, an interior layer of the dermis, is composed of sheets of collagen fibers wound in two distinct orientations that vary regionally and between species. Our goal was to assess the anisotropic mechanical and structural properties of shark skin among species. We determined the following mechanical properties in two directions of uniaxial stress (longitudinal and circumferential): ultimate tensile strength (MPa), strain at maximum load (%), toughness (MPa), and Young's Modulus (MPa). From each shark, we dissected a section of skin from between the two dorsal fins, and we divided this section into a grid. For each cell of the grid, denticle density and fiber angle were assessed under a microscope and quantified using NIH ImageJ. Four dog-bone shaped samples, 2 at each orientation, were tested in tension until failure at a 2 mm/s strain rate on an Instron E1000. A stress-strain curve was generated for each sample and tensile properties were calculated. We found significant differences among species and testing orientation; skin is strongest in the circumferential orientation. Skin mechanical properties also correlated with denticle density. These data support the hypothesis that shark skin may act as an exotendon modulating body stiffness during swimming.

S7-11 HAHN, DA; HAHN, Daniel; University of Florida; *dahahn@ufl.edu*
Combining 'omics Approaches to Pick Apart the Genetic and Physiological Architectures of Seasonal Adaptation
The ability of ectotherms to perform under seasonally relevant thermal stress has been a major and active sub-field within biology for >50 years, providing much insight into subjects ranging from adaptation and diversification to risk of establishment of invasive species and predicting winners and losers in the face of climate change. Given the importance of ectotherm thermal biology, there have been many efforts to build bridges between genotypes and seasonal phenotypes. We have learned many seasonal traits are the product of genotype x environment interactions, with strong layers of reversible plasticity for each trait. Yet, there are a wide diversity of results with respect to how selection shapes the genetic and physiological architectures of ectotherm seasonal responses. Even within a single population the genetic architecture and physiological traits implicated in seasonal adaptation vary substantially based on the context in which whole-organism phenotypes are studied. This wide diversity of results, often with discordant conclusions, currently hampers the development of general rules for ectotherm thermal and seasonal adaptation. Here I argue that an integrative biology perspective, with specific focus on carefully defining whole organism performance traits at a sub-organismal level is needed to ensure that equivalent seasonal traits are being considered, so genotype-phenotype mapping efforts across laboratories and systems are in fact comparing apples to apples to bridge the gap between genotypes and phenotypes.

P1-175 HAHN, TP*; DINGLE, H; RAMENOFSKY, M; CUSSEN, VA; CORNELIUS, JM; Univ. of California, Davis, Oregon State Univ.; *tphahn@ucdavis.edu*
Strategies for use of unpredictable dynamic resources
Most animals experience resources that vary in space and time. When resource variation is pulsed (the resource spikes dramatically and transiently), special strategies can facilitate coping with / exploiting the pulse. We examine several pulse types that vary in spatial and temporal predictability, and identify different strategies used to exploit them. Organisms that maintain reproduction at base resource levels in generally favorable habitats such as savannas and forests, but take advantage of pulses when they occur, are employing a Resource Pulse Opportunist (RPO) strategy. RPO strategists need not move long distances to reach and exploit resource pulses. Organisms that occupy marginal or unfavorable habitats such as deserts and ephemeral saltpan lakes and exploit irregular and widely distributed pulses for reproduction and survival employ either of two other strategies. Those with limited ability or opportunity to move are Obligate Opportunists (OBO), and those with the ability to travel long distances to reach pulses are Rich Patch Exploiters (RPE). RPE species are dependent on widely separated and ephemeral resources (the rich patches) that they can exploit through extraordinary abilities to locate them. RPE species experience low variance in quality and availability of resources in high variance landscapes by averaging over both space and time. We present examples from large birds to small insects that exploit various types of resource pulses, illustrating the differences among OBO, RPO and RPE strategies. We discuss implications of these strategies for migration, conservation, concepts of ecological communities, and behavioral and physiological adaptations to unpredictable conditions.

P3-56 HAIN, TJA*; CHURCHMAN, EKL; KNAPP, R; NEFF, BD; University of Western Ontario, London, ON, University of Oklahoma, Norman OK; *tjhain@uwo.ca*
Nest size and 11-ketotestosterone in bluegill sunfish (Lepomis macrochirus)
In some species, males congregate on breeding grounds (leks) to attract females, mate with them, and provide only genes to their offspring. In such breeding systems, a small number of dominant males acquire the vast majority of matings by virtue of their size and superior genes. Bluegill (*Lepomis macrochirus*) offer an interesting variation on the lek mating system. In bluegill, males form colonies of nests and attract females, spawn with those females, then provide care to the developing young. In mating systems with direct benefits such as in bluegill, females are expected to choose mates who can provide high-quality care. However, the cues that females use to choose mates are largely unknown. In this study, we measured nest size in a bluegill colony and examined if the depth or area of nests could reliably inform females about a male's body size or 11-ketotestosterone (11-KT) levels, which are important characteristics in nest defence. We found that the colony had 4-fold variation in nest area and 3-fold variation in nest depth and that the nest depth was strongly correlated with nest area. However, neither depth nor area was correlated with body size or 11-KT. We suggest that nest size is not a reliable indicator of body size or 11-KT and that females either use other, more reliable signals of male quality, or assess quality directly.

19-1 HALANYCH, KM*; LI, Y; TASSIA, MG; WAITS, DS; BOGANTES, VE; DAVID, KT; Auburn University; *ken@auburn.edu*
The Genome of Deep-Sea Seep-Dwelling Lamellibrachia luymesi (Siboglinidae) and Clues on Chemosynthetic Symbiosis
The long-lived gutless tubeworm *Lamellibrachia luymesi* (Siboglinidae) is found at deep-sea cold seeps in the Gulf of Mexico and has served as model to study chemosynthetic symbiosis and adaptation to extreme environments. However, the evolution of genomic and molecular mechanisms involved in such symbiosis is poorly understood. Here, we present and characterize the genome of *Lamellibrachia luymesi*. In relation to chemoautotrophy, we found evidence that symbionts compensate for the host's deficiency in amino acid biosynthesis and found a large expansion of hemoglobin B1 genes (these genes may function in sulfide-binding to help feed the endosymbionts). Comparative analyses suggest the Toll-like receptor pathway may be essential to host immunity and tolerance/sensitivity to symbionts and pathogens. Last, we identified genes that potentially play an important role in organismal longevity.

40-1 HALE, ME*; GOOLSBEE, AW; University of Chicago, Chicago IL; *mhale@uchicago.edu*

Substrate-based locomotion in young octopuses.

Young *Octopus bimaculoides* (less than 60 days post-hatching) have well developed arms and arm-based locomotor movements. Using high-speed imaging and kinematic analyses we describe substrate associated locomotor movements in 20 young octopuses striding across a glass tank bottom. A variety of patterns of arm movement were observed for both straight movement and change in locomotor trajectory. Several key findings are that: 1. Through use of different arm combinations hatchling octopuses change movement direction without changing the orientation of the body. This has been described previously in mature *O. vulgaris* (Levy et al. 2015. *Current Biology*, 25:1195). 2. Leading arms were most likely to drive locomotion while trailing arms were regularly, but not uniformly, held above the tank floor. 3. The animals used a range of patterns of arm coordination but several were particularly prevalent. Frequently three or four arms positioned on the side of the body in the direction of movement appeared to power locomotion. We recorded several different patterns of arm coordination during locomotion. When three arms were predominantly used, we observed the central arm to alternate extension cycles with the arm to each side. We also observed cases in which the three arms moved in sequence, without synchronous placement of two arms. When four arms were used, at times the center two were observed to move synchronously and alternate with the arm to each side of the central pair while we also saw sequencing of the four arms without synchronous movement of any subset of the arms. We did not observe rhythmic bipedal locomotion, which has been described in other octopus species.
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P2-130 HALE, ME*; MENELAOU, E; VASQUEZ, E; University of Chicago; *mhale@uchicago.edu*

Median fin innervation of the zebrafish, Danio rerio, and implications for function

Fishes use median and paired fins to control their body movements. Although fin kinematics are being studied in a variety of species, little is known of the sensorimotor control of fins. Fish fins are equipped with a neural organization that allows for coordination of two pairs of fins (pectoral and pelvic) and multiple median fins, which offers a rich opportunity to address how the brain and spinal cord control and modulate motor patterns. Here, we combine genetic tools with imaging in larval and juvenile zebrafish to examine the sensory architecture of the fin fold and the sensory and motor innervation of the later developing dorsal and anal fins. The larval fin fold is innervated by the mechanosensory Rohon Beard (RB) neurons, which exhibit diverse arborization patterns. RB somata are often located several segments anterior to the innervated tissue. While all RB cells innervate the trunk body wall, some cells also arborize into the dorsal, ventral or both fin folds. In juvenile zebrafish, sensory innervation of the dorsal and anal fins is provided by dorsal root ganglion (DRG) neurons. Each fin ray is innervated by multiple DRG cells whose somata are located in body segments adjacent to the innervated area. Spinal motor neurons arborize extensively in the serially organized median fin muscles with dense innervation mainly along the base of the fin. Unlike axial motor innervation, fin motor axons appear to extend to multiple fin muscles along the anteroposterior axis of the fin. Investigating patterns of sensorimotor innervation of the median fins will help us understand sensorimotor strategies for fin actuation and multifin coordination.
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98-4 HALE, HJ*; POKORNY, L; GARDNER, EM; SLIMP, M; JOHNSON, MG; Texas Tech University, Center for Biotechnology and Genomics, Madrid, Case Western University; *haley.hale@ttu.edu*

Developing a cost-effective workflow for high-throughput targeted sequencing of herbarium specimens using Angiosperms353

The reduced cost of high-throughput targeted sequencing, along with new "universal" probe sets like Angiosperms353, means genomic-scale data is no longer limited to heavily funded laboratories. However, the feasibility of targeted sequencing for population genetics has not been fully explored. Here, we look at the costs and challenges of producing target-capture datasets from herbarium specimens to answer within-species questions in a variety of flowering plants. We describe best practices for choosing methods for DNA extraction, use of enzymatic fragmentation, high-throughput library preparation, and sequencing platform using the Angiosperms353 probe set for enrichment of hundreds of nuclear genes. Our dataset includes herbarium specimens from 24 angiosperm species collected during a survey of Guadalupe Mountains National Park between 1971 and 1974. The variety and age of the specimens brings their own challenges to large scale processing, especially DNA extraction due to the presence of different foliar or floral compounds as well as the diverse tissue composition used. Using Angiosperms353, we observed a 15-20% median enrichment efficiency and that 25000 reads on target was enough to recover over 200 genes. We also consistently recovered the same genes within species. In addition to the targeted genes, we successfully captured flanking noncoding regions, effectively doubling the amount of variable characters that have potential use for population level studies. By optimizing and generating a detailed protocol and cost calculator for sample processing, we offer a strategy for wide adoption of target capture sequencing for both phylogenetics and population genetics.

88-5 HALL, R P*; MUTUMI, G L; HEDRICK, B P; YOHE, L R; SADIER, A; DAVIES, KTJ; DáVALOS, L M; ROSSITER, S J; SEARS, K; DUMONT, E R; University of California, Merced, Louisiana State University, Yale University, University of California, Los Angeles, Queen Mary University of London, Stony Brook University; *rhall8@ucmerced.edu*

Ancestral Generalization as a Potential Gateway to Rapid Dietary Divergence in Neotropical Leaf-Nosed Bats

Neotropical leaf-nosed bats (Phyllostomidae), as a result of adaptive radiation, are a prime example for studying the evolution of sensory morphology. They exhibit diverse and unique feeding strategies among bats. Using diceCT scans of 79 specimens, representing 35 species of phyllostomids and 10 outgroup species, within the superfamily Noctilionoidea, we analyzed the link between volumes of three sensory structures (olfactory bulb, orbits, and cochleae) and diet. We hypothesized that frugivory and nectarivory are associated with enlarged olfactory bulbs and orbits. We predicted that the sensory profile of modern plant-eating bats first appeared in the ancestral phyllostomid. We found that only frugivory is linked to large olfactory bulbs and orbits. The phyllostomid ancestor had larger olfactory bulbs and orbits than its ancestor and outgroups. This study shows that an ancestral shift in sensory morphology associated with diet predated, and possibly enabled, the diversification seen in Phyllostomidae.

P1-46 HALL, KC*; KOLMANN, MA; WILSON, GP; HUNDT, PJ; University of Washington, George Washington University, University of Minnesota; *kchall8@uw.edu*

Chimaeras, sharks, skates and rays, oh my! Ecological structuring and evolutionary life-history traits of Chondrichthyes

Chondrichthyes (chimaeras, sharks, skates and rays) are a lineage of vertebrates with skeletons composed entirely of cartilage, that have been around for over 400 million years. This long evolutionary history has led them to exhibit a diverse range in life-history traits, ecology, and biogeography as they are found throughout the world's marine and freshwater waterways. Chondrichthyans exhibit most forms of sexual reproduction, from egg-laying to live birth: oviparity, multiple types of aplacental viviparity, and placental viviparity. They have also evolved many modes of locomotion, from axial-swimming (tail undulations), undulating or oscillating pectoral fins, to walking (or ‘punting') along the substrate with pelvic fins. Some species even use a combination of these methods to locomote, depending on their habitat. We described the ecological structuring of chondrichthyan communities over time, with the aim of exploring potential correlates and mechanisms that have shaped modern assemblages. We used reproduction, dietary preference, and locomotor mode to establish the ecospace occupation of extant species from all aquatic ecosystems. By gathering these data from the literature we were able to view the ecosystem and community structures of cartilaginous fishes in 3D morphospace and quantify the functional ecological roles across species. The relevant space these communities fill is limited compared to the theoretical ecospace available throughout the world's waterways, specifically in the deep-sea. Considering extant taxa in this new framework illuminates which factors have shaped the cartilaginous fish communities of today and how these aquatic ecological assemblages have changed throughout time.

17-2 HALL, BE*; BIGMAN, JS; BEDORE, CN; Georgia Southern University, Simon Fraser University; *bh06426@georgiasouthern.edu*

Allometric relationships in the visual ecology of sharks

Adaptations of visual systems, such as acuity, sensitivity, and eye size (e.g., eye diameter) can be used to infer the relative importance of vision to an organism. The high metabolic cost of visual system development and maintenance suggests that large relative eye size (as it relates to body length) may have a significant ecological or evolutionary role. Elasmobranchs are morphologically diverse and inhabit a wide range of marine and freshwater niches. As energetic and ecological demands shift over time, several species occupy different predatory niches across their lifetime, yielding a large array of visual habitats. Additionally, eye size changes with body length ontogenetically, thus elasmobranchs represent an ideal group for examining scaling relationships (i.e., eye growth rate and eye size at a given body length) with respect to specific ecological lifestyle traits. Here we quantified the relationship of eye size and body length in 16 shark species and compared this scaling across species that differ in ecological lifestyle (i.e., activity level, habitat, and maximum size). Relative eye size at a given size varied across species and habitat, but not activity level or maximum size. Deep-sea species had the largest relative eye size, followed by oceanic then coastal species. In contrast, the rate at which eye size scaled with body length was the same across 13 of the 16 species and did not differ with ecological lifestyle trait. These results suggest that ecology may influence relative eye size and not the rate at which eye size scales with body length. As habitat had the greatest influence on relative eye size, future investigations should focus on ecological lifestyle traits involving visual habitat characteristics such as light level, turbidity, and migratory patterns.

P1-173 HALL, LM*; ENRIQUEZ, MS; MENSINGER, AF; University of Minnesota Duluth; *hall1722@d.umn.edu*

The Effects of Intensive Trapping on the Population Dynamics of the Invasive Round Goby (Neogobius melanostomus)

The round goby (*Neogobius melanostomus*) is an invasive benthic fish first introduced to the Laurentian Great Lakes in 1990. The round goby has negatively impacted native fishes through high fecundity, aggressive interactions, and egg predation. The latter effect may be leading to a decline in the reproductive success of a newly established breeding population of lake sturgeon (*Acipenser fulvescens*). While complete eradication of the round goby is not currently possible, intensive trapping in designated areas during spawning seasons could lead to reduced egg predation. A 100 meter stretch of shoreline within the Duluth Superior Harbor was selected for trapping over the duration of the round goby breeding period (June to October). Minnow traps were baited with 400 g of fresh fish, and round gobies were removed from the experimental area every 48 hours. Control traps were deployed once a week, with captured gobies tagged with alphanumeric tags before release. Consistent removal reduced the catch per unit effort of round gobies by 38% compared to control areas outside the collection area. Perhaps more importantly, there were extended periods with no round gobies caught in the experimental traps. However, there was no difference in the size or gender of round gobies caught in the two areas. In addition, 69% of tagged gobies (n=23) were recaptured at the initial release site in the control areas, suggesting high site affinity. Therefore, it is unclear where the repopulating round gobies originated. Future experiments will examine different bait to increase trapping efficacy and look into how often trapping should be conducted to maximize population reduction.

105-1 HALL, MI*; PLOCHOCKI, JH; SOSA, JRR; VOEGELE, GM; Midwestern University, AZ, University of Central Florida, Dartmouth College, NH; *mhallx1@midwestern.edu*

The evolution of cutaneous muscles in placental mammals

Four ventrolateral muscular layers consistently support the thorax and abdomen of most tetrapods, while only two muscular layers support the perineum. However, many, if not all, placental mammals have four ventrolateral muscular layers supporting the perineum, that function to allow precise muscular control of the structures that develop as part of full septation of the cloaca into urogenital and anorectal portions, including the rectum, anal canal, urethra, vagina, vulva, and paired vascular erectile tissues. The organization and function of muscular layers of the thorax and abdomen are conserved across taxa, with the muscular layers of the perineum serving a diverse set of functions and are more varied in structure. From superficial to deep, the perineal subcutaneous layer usually regulates orifice closure; the external layer usually supplements erectile and micturition function; the internal layer usually provides primary micturition and defecation regulation, and the transversus layer provides structural support for pelvic organs. However, we observe that some well-known muscles that are present across many mammals may derive from alternative muscle layers. In carnivorans, the retractor penis/clitoris muscle is derived from the external layer, but in ungulates, retractor penis is derived from the transversus muscle. In dogs, constrictor vulvae and constrictor vestibulae are both derived from the external layer, whereas in horses it is derives from the subcutaneous layer and constrictor vestibulae is derived from the external layer. We identify perineal muscular homologies and analogies in a variety of placental mammals, and suggest variations in perineal muscle layering taxa likely represent independent evolutionary adaptations that serve specific reproductive and excretory functions.

98-2 HALSEY, MK*; STUHLER, JD; BRADLEY, RD; STEVENS, RD; RAY, DA; Texas Tech University, Texas Tech University and Museum of Texas Tech, Texas Tech University and Museum of Texas Tech, Texas Tech University ; *michaela.k.halsey@gmail.com*

Temporal and Spatial Genetic Assessment of a Natural Metapopulation

Metapopulation theory is concerned with local population dynamics, especially migration, and the relationship between population colonization and extinction. It is hypothesized that isolated subpopulations with low immigration rates display reduced genetic variation, likely a result of genetic drift. Fortunately, researchers can use genomic sequence data to rigorously examine the population biology and ecology of natural metapopulations in a conservation context. Here, we analyze the genetic variation of 65 samples of a threatened kangaroo rat, *Dipodomys elator*, using 3RAD, a modified restriction site associated sequencing approach amenable to low initial DNA input, such as those sampled from minimally invasive techniques or degraded samples. We demonstrate that there are at least two *D. elator* subpopulations, which are grouped into eastern and western demes. An area where no samples were drawn, called a "sampling hole," separates these two. In addition, this metapopulation exhibits an excess of heterozygotes, which is symptomatic of small, isolated populations experiencing coalescence. Because of these results, we classify the *D. elator* population as a classic two-population metapopulation whose persistence is dependent on deme location. Since subpopulations can vanish very rapidly, it is vital for conservation managers to monitor spatial population dynamics and genetic variability of this species for long-term population viability.

P1-24 HAMILTON, N*; RODRIGUEZ, E; IZUMI, T; YAP, N; DALY, M; Texas A&M University, The American Museum of Natural History, The University of Tokyo, National University of Singapore, The Ohio State University; *nhamilton@tamu.edu*

Phylogenetic relationships among burrowing sea anemones in the family Haloclavidae (Cnidaria: Anthozoa: Actiniaria)

Sea anemones (order Actiniaria) are a diverse group of subclass Hexacorallia. Burrowing sea anemones have been historically grouped into the infraorder Athenaria (Carlgren 1899; Fautin 2013). Athenaria was revealed as polyphyletic (Daly et al. 2003, 2008, 2017; Rodríguez et al. 2014; Gusmão 2016). Haloclavidae is a family of burrowing sea anemones now grouped within the superfamily Actinioidea (Rafinesque 1815). This family includes 10 genera containing 30 species (Daly & Fautin 2019 – WORMS). Characters given for this family by Carlgren (1949) have a high range of variability, with numerous exceptions to the diagnoses of the family (Rodríguez and López-González 2002). Previous phylogenetic analyses have shown that Haloclavidae is potentially a polyphyletic group (Rodriguez et al. 2012; Rodríguez et al. 2014; Daly et al. 2017), but resolution of relationships of the few representatives of Haloclavidae have been problematic. Using mitochondrial and nuclear markers, we explore the systematics of Haloclavidae using three mitochondrial (COIII, 12S, 16S) and two nuclear markers (18S, 28S). We assess the monophyly of Haloclavidae by building a tree of this family within the superfamily Actinioidea. Additionally, we used parsimony-based character optimization to interpret the distribution of key traits in the superfamily. We find that Haloclavidae is not a monophyletic group. Based on the results of our analyses and taxonomic considerations, we propose two new families.

P3-220 HAMMOND, TA*; KOVACS, J; WERREN, J; Spelman College , Spelman College, University of Rochester ; *thammon5@scmail.spelman.edu*

Evidence of Horizontal Gene Transfer in the Kissing Bug, Rhodnius prolixus

Horizontally transferred genes (HGTs) are a result of transferred genetic material across species and is not a result of direct descent. HGTs are common in prokaryotes but typically rare in multi-cellular eukaryotes however, rapid accumulation of genomic info has recently identified increased amounts of exogenous DNA inserts within insect genomes. The majority of the horizontally transferred material is non-functional however evidence shows some genes are being expressed and functional in some eukaryotes. In this study we used publically available sequence data and a newly designed bioinformatics pipeline to identify expressed HGTs in the genome of the kissing bug *Rhodnius prolixus*. We were particularly interested in identifying HGTs that were functional and associated with blood-feeding in arthropods. Therefore, our pipeline was designed to specifically target HGTs that are shared with other blood-feeding arthropods such as the bedbug *Cimex lectularis* and the mosquito *Aedes aegytpti*, but are absent in more closely related non-blood-feeding arthropods such as the pea aphid. We will discuss several of the candidate HGTs identified using this methodology in this poster.

61-1 HAMMOND, KA*; DOLAN, JE; SAWAYA, M; University of California Riverside; *khammond@ucr.edu*

Deer Mouse Lungs as Flexible Environmental Interfaces

Because of the flexible and fast growing tissues in their digestive tracts, many animal species are able to respond to increases in metabolic demands by increasing the surface area available to increase absorption of nutrients in their gut. They can also reduce energy expenditure by reducing tissue amount in times when food availability decreases. In this way the intestinal tracts of animals are highly flexible and responsive interface to the outside world. My lab has been investigating whether or not the respiratory interfaces in mammalian lungs have an ability for a plastic response that is driven by demand that is similar to mammalian guts. In this case, rather than changes in caloric density, we have been examining the effect of low oxygen tensions on the respiratory membranes and daily energy expenditure of deer mice (*Peromyscus maniculatus*) living at high altitude. Deer mice are interesting because they live at and move between altitudinal extremes during their life time and are, thus, exposed to a variety of oxygen tensions. In recent work we have found: 1. high altitude acclimated deer mice display an increase in oxygen transport tissue and alveolar septal tissue relative to the low altitude acclimated mice. 2. Likewise, in a different set of experiments we have learned that the bulk amount of oxygen that is transported across the alveoli to the blood increases in the lungs of high altitude mice relative to low altitude mice. 3. Finally, we have learned that, upon acclimation to high altitude, mice given running wheels are able to substantially increase their daily energy expenditure relative to the same expenditure with running wheels before acclimation. Taken together these several experiments have demonstrated that the lungs of deer mice are somewhat flexible and are able to support change metabolic demands in very harsh environments.

P2-136 HAN, JW*; FRIESEN, CN; YOUNG, RL; HOFMANN, HA; UT Austin; *jiaweihan96@gmail.com*

Social Regulation of Neural Transcriptomes

Social status can affect numerous aspects of individual behavior, but the mechanisms by which social cues exert their effects on physiological processes are poorly understood. Here we use the highly social cichlid fish, *Astatotilapia burtoni*, to examine the effects of social status on the transcriptomes of three key nodes of the evolutionarily conserved Social Decision-Making Network (SDMN) that is critical for evaluating the valence and salience of social and other stimuli. Males of this species transition between two social phenotypes - dominant males (DOMs) defend a territory and are reproductively active while subordinate males (SUBs) lack a territory and are reproductively suppressed. We monitored the behavior of 8 mixed sex communities (n=8 per sex) over six weeks. We then linked behavioral variation with levels of stress and sex hormones as well as the transcriptomes of the preoptic area (POA, critical for social behavior), area Dl (putative hippocampus homolog: spatial cognition, learning, and memory), and area Dm (medial amygdala complex: social cognition, aggressive and sexual behavior) of 51 DOMs and 68 SUBs. Our results show distinct expression profiles for different SDMN nodes, with numerous genes significantly varying between DOMs and SUBs. When we examined the behavioral, physiological, and molecular co-variance structure across individuals and brain regions, we discovered co-regulated clusters of these variables that provide insight into the mechanisms that generate individual variation within highly dynamic social groups, with consequences for individual well-being and reproductive success.

P3-154 HANDY, SD*; FARINA, SC; California State University San Bernardino, Howard University; *sarahhandy96@gmail.com*

Gill Position Affects Ventilatory Pressure Amplitudes in Pacific Spiny Dogfish

Elasmobranch ventilation is a two-pump system driven by the generation of a pressure differential between the oral (mouth) and branchial (gill) chambers. Early work conducted in *Squalus acanthias* evaluated the pressures generated in each of five gill chambers and found there to be a phase-shift in timing but no difference in pressures generated by each gill. Therefore, work on ventilation in a variety of elasmobranch species has since assumed that each chamber generated equal pressures. We reevaluated this idea by implanting pressure transducers into gill chambers two, three, and five (numbered anterior to posterior) of *Squalus suckleyii* (n=5) across a range of sizes, and found there to be a significant difference in the amplitudes of pressure generated between gills ($p<0.0001$). A Tukey test indicated that gill two was higher than gill three ($p<0.0001$) and gill five ($p<0.0001$), and gill three was higher than gill five ($p<0.0001$). Size of the individual (body length) was also found to have a significant effect on the amplitudes generated in each gill slit ($p<0.0001$). Linear regressions of amplitude relative to size for each gill chamber showed that pressure in gill two and three scales with size, but gill five does not ($p=0.249$). Differences in our findings from studies previously conducted may be a result of updated technology, or as a consequence of *Squalus suckleyii* having multiple ventilatory modes in which the gill chambers are used differentially, as has been observed in species such as the hedgehog skate. This observed attenuation of pressure can potentially shed light on the pattern of a reduction in the number of gill slits over evolutionary time.

P2-250 HANES, S/D*; HUBBUCH, J; Martin Methodist College, 1979; *shanes@martinmethodist.edu*

Descriptive analysis of cellular organization in the Aiptasia-Symbiodinium model system

Coral bleaching involves the loss of essential, photosynthetic dinoflagellates (*Symbiodinium* sp.) from host gastrodermal cells and occurs as a stress response of both members of the symbiosis. Although a variety of cellular bleaching mechanisms have been proposed, the histological organization of healthy symbiotic cnidarian tissues remains largely undescribed. Thus, a detailed ultrastructural analysis of a commonly used model symbiotic cnidarian is critical in order to provide essential baseline information for future bleaching investigations to assess cellular changes in response to stress conditions. In this study, both transmission electron microscopy (TEM) and fluorescence microscopy (FM) were used to examine and characterize multiple regions throughout the tentacles of both symbiotic and aposymbiotic *A. pallida.* This study represents the first detailed and systematic histological analysis of the *Aiptasia-Symbiodinium* model system or that of any other symbiotic cnidarian. Moreover, the ultrastructural information gained from this analysis can be used as an informative health assessment tool as they are manipulated in the lab or during field-mediated conditions.

1-7 HANEY, WA*; STROTHER, JA; University of Florida; *haneyaustin@gmail.com*

Time to Panic? Stressors modulate exploratory behavior in larval zebrafish

The stress response of vertebrates can be initiated by many different environmental stimuli including extreme temperatures, noxious chemicals, mechanical disturbance, visual stimuli 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, the mechanisms by which stress modulates CNS activity and alters behavioral responses are not well understood. 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 (electric shock, noxious chemicals) on responses. Our results suggest that stressors produce characteristic changes in light preference and exploratory behavior. We then used multiphoton *in vivo* calcium imaging to identify neuronal populations in the hindbrain associated with stressful stimuli, and small-molecule blockade to identify neuron types necessary for stress-induced changes in behavior. Our results suggest a simple pathway for stress-induced modulation of exploratory pathway.

P2-10 HANNON, MC*; HILLIARD, J; GARBUGLIO DE OLIVEIRA, A; SCHULZE, A; Texas A&M University, Galveston, University of São Paulo, Brazil; *MCHannon23@tamu.edu*
Annelid Bioluminescence: The Search for Luciferases in Annelid Trancriptomes
There are 13 known bioluminescent families in the phylum Annelida, including polychaetes and clitellates. Light emission through bioluminescence appears multiple times within the clade and is likely a convergent trait. In all instances, bioluminescence is produced through a chemical reaction involving the release of chemical energy in the form of light, following the oxidation of a substrate (small organic molecule generically called luciferin) catalyzed by an enzyme (luciferase). Luciferins are highly conserved whilst their associated luciferases are more variable. Luciferases isolated from bioluminescent organisms such as bacteria, coelenterates, and crustaceans have been commercialized for use in medicine, biotechnology, and environmental surveying. Some of these systems have limitations which could be ameliorated through the discovery of novel bioluminescent systems. The ever-increasing publicly available data set of annelid transcriptomes is an essential database for mining novel luciferases. Through a series of standardized bioinformatic approaches, a dataset of nearly 70 annelid transcriptomes have been assembled. This dataset is being mined for previously identified luciferases or their conserved domains to potentially identify novel bioluminescent systems. Parallel to the bioinformatic search tools, direct field observations are conducted to confirm bioluminescence in some annelid groups and potentially discover it in others. These results will shed light on the diversity of bioluminescent pathways as well as their evolutionary histories.

P2-230 HANSEN, AK; LENT, DD; MULLER, UK*; MULLER, Ulrike; California State University Fresno; *umuller@csufresno.edu*
How bio-inspiration teaches us: Digital fabrication and modeling in STEM education and outreach
Science education is most effective when it provides authentic experiences that reflect professional practices and approaches and that address issues relevant to students' communities. Such educational experiences at the interface of biology, engineering, and physics can be provided by bio-inspiration and biomechanics projects that use digital fabrication. Digital fabrication is the process of designing objects for the purposes of fabricating with machinery such as 3D-printers, laser cutters, and CNC machines. Historically, these types of tools have been exceptionally costly and difficult to access, however recent advancements in technological design have been accompanied by decreasing prices. In the context of higher education, many institutions are creating maker spaces (or fabrication labs) that allow students to gain hands-on design experience using cutting-edge technology. Evidence from the learning sciences suggests that when students are actively creating an artifact for the public, something with a larger purpose, motivation and engagement increase. This talk will describe one example of a fabrication project in the context of an undergraduate comparative morphology class. Students were tasked with using their conceptual understanding of biomechanics to fabricate objects for use as K-12 outreach materials. The associated paper will provide a comprehensive literature review across both biology and science education journals to share the current state of the field, as well as outline best practices for integrating digital fabrication into K-16+ biological education.

S2-1 HANSON, H; MARTIN, LB; STEVENSON, TJ*; University of South Florida, University of Glasgow; *tyler.stevenson@glasgow.ac.uk*
Introduction to Epigenetic Variation in Endocrine Systems
Predictable variation in environmental cues provide reliable information that animals can use to time life-history transitions. Endocrine systems have evolved in part, to maintain a consistent internal milieu and coordinate organism-wide physiological responses to environmental changes. An emerging body of evidence reveals that epigenetic modifications are central to timing genome plasticity that underlies adaptive and maladaptive endocrine responses. The symposium includes a series of presentations that will discuss the latest findings on epigenomic plasticity with a focus on range expansions, ecology and life-history transitions. This introductory presentation will provide an overview of developmental, transgenerational and rhythmic epigenetic modifications with an emphasis on DNA methylation and histone modifications. Then a brief introduction of the symposium speakers and their research programs will be provided. Overall, the aim of the presentation is to ensure that the topics covered in the symposium will be accessible to all attendees regardless of their experience with epigenetic modifications.

S2-2 HANSON, HE*; WANG, C; SCHREY, AW; JIANG, RHY; MARTIN, LB; University of South Florida, Global and Planetary Health, Georgia Southern Armstrong Campus, Department of Biology; *haleyhanson@mail.usf.edu*
Epigenetic Potential and DNA Methylation Across an Ongoing Avian Range Expansion
During range expansions, epigenetic mechanisms may mediate phenotypic responses to environmental cues, enabling organisms to adjust to conditions at novel sites. In particular, we expect that the number of CpG sites within the genome, one genetic mechanism underlying epigenetic potential, may be important for success at range edges because methylation could titrate gene expression contingent on environmental conditions. Previously we found that this form of epigenetic potential was higher in introduced compared to native populations of house sparrows (*Passer domesticus*) for two immune genes (Toll-like receptors *2A* and *4*). Here, we took a next-generation sequencing approach (ddRadSeq and EpiRadSeq) to investigate how this same form of epigenetic potential, as well as resultant DNA methylation, varied across five sites in the ~60 year-old Kenyan house sparrow range expansion. We found that CpG sites increased towards the edge of the invasion, even when accounting for genetic diversity among sites. This pattern was driven by more losses of CpG sites in birds from the core. Additionally, DNA methylation levels towards the range edge, when we considered only sequences proximal to CpG sites that were lost to mutation in core birds. This pattern is significant because DNA methylation across the whole genome decreased towards the range-edge. These results provide further evidence that epigenetic potential influences house sparrow range expansions, perhaps providing greater phenotypic plasticity later to be assimilated genetically in as populations adapt to new conditions.

P1-157 HARDT, B*; BENEDICT, L; University of Northern Colorado; *braelei.hardt@gmail.com*

Assessing the Influences of Habitat Structure on Bird Song Propagation

Many taxa produce long-range acoustics signals for the purpose of communication with conspecifics. These signals play an important role in mate attraction and retention as well as territory defense, which are key behaviors for reproductive success. The *Acoustic Adaptation Hypothesis (AAH)* posits that long-range acoustic signals are adapted for minimized signal degradation in the environment in which they are produced, leading to optimized communication within a species' preferred habitat. While some playback experiments have found evidence for the AAH in structurally 'open' vs. 'closed' habitats, support for the AAH remains unclear when considering finer-scale differences in habitat structure and when assessing effects of habitat structure on multiple species' signals. This study is the first comprehensive test of the AAH, which assess acoustic signal quality in a more diverse set of spatial and temporal habitats across a set of songbird species which exhibit large variability in both song structure and habitat preference. We used PCA on several habitat characteristics in multiple distinct habitats, both during and after the breeding season, and determined that breeding territories for these species are most differentiated by their vegetation density and topographical properties. We then quantified signal degradation and found that the three different measures of quality, which quantify changes in signal strength and shape over distance, are associated with separate and sometimes conflicting environmental aspects. This indicates that birds may not be able to optimize all three measures of signal quality for one specific environment, and may face trade-offs between producing songs that are either loud, clear, or separate from noise in their preferred habitat.

P3-157 HARDY, DJ*; SALCEDO, MK; KENNY, MC; PULLIAM, JN; PENDAR, H; SOCHA, JJ; Morehouse College, Atlanta, GA, Virginia Tech, Blacksburg, VA, Wake Forest University, Winston-Salem, NC; *donovan.hardy@morehouse.edu*

Shot through the heart: a non-invasive IR technique to measure dorsal heart pumping in insects

The insect circulatory system is "open", with flow of hemolymph produced by the dorsal vessel, a long tubular heart that pumps fluid from posterior to anterior. Tubular pumps are found throughout the animal kingdom, yet specific mechanisms of flow production in many taxa are not well understood. The insect heart pumps in wave-like contractions by helically-wound muscles around the tubes circumference. In addition, fan-like alary muscles may function to provide tension or aid in expansion of the heart lumen. Flow in the heart may also be aided by pressure differences resulting from internal compartmentalization or abdominal contractions. In the context of these complex factors, our aim is to understand the kinematics of heart contraction for biomechanical models of hemolymph flow production. We developed a non-invasive technique using infrared (IR) sensors to observe and record pumping movements in the heart of the tenebrionid beetle *Zophobas morio*. To measure the propagation of contraction waves of the dorsal vessel, the beetle was first gently restrained with wings splayed and pinned to either side. Two IR sensors positioned above the abdomen captured dorsal vessel movement by sending and receiving IR light using two fiber-optic cables. Because changes in IR signals result from any change in light reflectance, specific patterns of IR signals were interpreted by comparison with synchronized video recordings of the abdominal surface. The use of IR to measure heart kinematics is a new non-invasive technique that can be used to quantify how tubular pumps in insects contribute to overall internal hemolymph flow.

P2-120 HARDY, AR*; HALE, ME; University of Chicago; *arhardy7@uchicago.edu*

A new sensory ending in the paired fins of damselfish

The fins of fishes are innervated with sensory nerves and specialized endings capable of providing feedback on the environment. Here we describe the morphology and distribution of a newly identified sensory ending in the pectoral and pelvic fins of two distantly related damselfish (*Pomacentrus coelestis* and *Chromis viridis*) that vary in their substrate association (rubble vs live coral specialist). Immunolabeling with a general neuronal marker revealed an extensive and precisely organized network of sensory fibers, a subset of which terminate in these newly identified bulbous endings. Although the physiology of these endings has yet to be determined, their anatomy suggests that they may be involved in taste perception. Located at or in close proximity to the epidermal surface, these receptors are small (~15 µm diameter) and are found primarily in the distal half of the fin. Despite differences in habitat and fin function, the general innervation patterns between the pectoral and pelvic fins were similar in both species. Along a given ray, endings exhibit stereotypical branching patterns with receptors linearly orientated to one another along the proximodistal axis of the fin. The leading and trailing edges of the paired fins exhibit the highest receptor densities with the distance between receptors ranging from 50 - 100 µm. As receptor density influences sensitivity and the ability to discriminate separate stimuli, the increased density observed along the edges of the paired fins suggests their importance as focal points for stimulus detection as the fins move through the water. In addition to further examining the function of these receptors, we aim to compare variation in the distributions of these receptors among fins and to other species known to exhibit chemosensory abilities via fins.

P2-91 HARMAN, AR*; SJOBLOM, NP; RENN, SCP; Reed College; *harmaran@reed.edu*

Behavioral Conditioning of Astatotilapia burtoni Without Overtraining

The modern field of Animal Behavior was born through collaboration between behaviorists and ethologists. Today we can still learn a lot about the natural behavior of animals using the controlled and quantifiable approaches pioneered by behaviorism. In order to study the neural mechanisms that have allowed the evolution of the behaviorally fascinating mouth-brooding form of parental care, the Renn lab needs to quantify hunger without actually feeding the fish. We use the emerging model for social behavior, *A. burtoni*, an east African cichlid fish, and have constructed an Arduino robot to train and measure behavior. While our previous research presented at SICB demonstrated successful training of feeding behavior in response to an LED light, those fish became overtrained, in that they ceased to exhibit normal swimming and social behaviors. In our current research we have introduced a Variable Schedule program which offers randomized food reinforcement, unlike the previous protocol that distributed the food every time the sensor was tripped. The Variable Schedule program was introduced after initial training on a Fixed Schedule program for two weeks. We use behavioral observations with JWatcher to quantify normal swimming and social behavior, allowing the Arduino Robot to then quantify feeding behavior as latency to approach the LED. This protocol will allow us to collect brain samples for gene expression studies of hunger and satiety cues from animals of a known hunger level without corrupting brain chemistry by feeding the animals.

P1-31 HARPER, FM*; CLARKE, DG; Rollins College, Winter Park, FL; *fharper@rollins.edu*

Very low genetic diversity in two species of North Atlantic sea stars

Following the retreat of the Last Glacial Maximum in the North Atlantic about 20,000 years ago, two sibling species of sea stars, *Asterias rubens* and *A. forbesi* , expanded their ranges from glacial refuges in Europe and the southeastern United States, respectively. To examine the effects of post-glacial migration on species population genetics and gene flow, *Asterias rubens* was sampled from 15 populations across the North Atlantic, from northeastern Canada to Russia. Endemic to North America, *Asterias forbesi* , was sampled from 9 populations from Prince Edward Island to North Carolina. Mitochondrial DNA sequences of the cytochrome oxidase I gene (586 bp) were obtained following PCR reactions with extracted genomic DNA, and analyzed together with sequences available on GenBank. In *A. rubens* populations, while we found 19 different haplotypes from 107 individuals across the species' range, most individuals (71%) had the same haplotype. Similarly, in *A. forbesi* populations, we found 16 different haplotypes from 87 individuals, with most individuals (80%) having one of only two main haplotypes. In phylogenetic analysis with both species, haplotypes did not form monophyletic groups with respect to sampling location, as many geographically separate populations shared identical haplotypes. No significant genetic structure or genetic discontinuity was found across either species' range, which is indicative of recent population expansions in both species.

91-6 HARRIS, BN*; PRATER, CM; LOCKWOOD, R; KENNEDY, A; CARR, JA; Texas Tech University, Texas Tech University ; *breanna.n.harris@ttu.edu*

Now You See It, Now You Don't: Role of Tectal CRF Administration on Visually Guided Feeding Behavior

Navigation of feed vs. flee trade-offs is crucial for survival and fitness. To do this animals must integrate sensory and somatic information. The optic tectum (OT) integrates visual and lateral line information and sends projections to the brain stem and spinal cord, thus it may link sensory cues with motor output. The precise cues and neuromodulators of this trade-off are not entirely known, but neuropeptides associated with the physiological stress response may play a role. CRF, well known for its role in the hypothalamic-pituitary-interrenal axis, is abundant in the OT. In the South African clawed frog (Xenopus laevis) stressor or predator exposure decreases feeding and increases OT CRF, and elevated OT CRF decreases feeding; blocking CRFR1 reverses outcomes. The CRFR1 may be acting on visual, lateral line, and/or multiple sensory modalities. In the visual system, CRF may alter the way food items are perceived. Here, we test the prediction that OT CRF injection will decrease the response to visual stimuli. We initially tested multiple releasing stimuli previously used in adult frogs before finding a purely visual stimulus (iPad) that repeatedly elicited behavioral responses in juveniles. Frogs were injected with one of 4 doses of CRF, saline, or left unmanipulated; 1 h later they were exposed to visual prey cues (iPad movie) and then to a live worm (positive control). After 72 h, behavioral tests were repeated. All trials were video recorded. Analysis of discrete behaviors is underway. Preliminary analyses suggest CRF decreases the response to visual stimuli, and to live prey, but does not completely abolish responses. Our data will aid in understanding the neuroendocrine mechanisms governing feed/flee trade-offs. Funded by the NSF (Grant No. 1656734).

P1-95 HARRIS, OK*; MOREHOUSE, NI; University of Cincinnati; *harrisok@mail.uc.edu*

Predator-mimicking sensory exploitation in the courtship display of Maratus jumping spiders.

Many organisms benefit from innate anti-predator responses. Innate response behaviors can save precious processing time that may mean the difference between capture and escape. Such behaviors are often under strong natural selection to be retained. However, this creates an opportunity for others to exploit such responses. Male courtship displays in jumping spiders provide an exciting opportunity for studying how predator-mimicking traits might induce anti-predatory responses in female receivers. Inducing female anti-predator responses might advantage males through reduced female pre-copulatory sexual cannibalism and/or via reductions in female movement, a typical anti-predatory response. Here, we investigate whether the abdominal fan displays of Australian peacock spiders (genus *Maratus*) mimic the faces of local invertebrate predators. To investigate this, we digitally characterized the abdominal patterns males use in courtship. We then compared these patterns to the facial patterning of co-occurring predators using principal component and machine learning analyses. We find broad overlap in the principal components of *Maratus* fans, mantid faces and wasp faces, as compared to various controls, such as foliage, background substrates, and other insects. Machine learning classification (MLC) results in higher false discovery rates for *Maratus* than any other group. MLC also struggled to parse *Maratus* fans from native wasp faces. However, MLC readily discriminated between *Maratus* fans and invasive wasp species, suggesting that the *Maratus* fan features responsible for predator resemblance are the result of shared evolutionary history within their native communities, rather than generic predator-like facial features. We discuss how the 'ecology of fear' may play a role in the evolution of courtship.

17-1 HARRIS, OK; KINGSTON, ACN; STEICHMANN, NR; JOHNSEN, S; SPEISER, DI*; University of Cincinnati, University of South Carolina, Duke University; *dispeiser@gmail.com*

How and why are the blue eyes of scallops blue?

Many animals produce structural colors, but taxa vary in how and why they do so. Scallops, for example, have dozens of mirror-based eyes and, in some species, these eyes are a bright iridescent blue. In other species, the eyes are a non-iridescent brown or black. We hypothesized that the blue eyes of scallops obtain their color, at least in part, from the scattering of short-wavelength light by photonic nanostructures. Using transmission electron microscopy, we found the epithelial cells surrounding the blue eyes of the bay scallop *Argopecten irradians* contain close-packed nanospheres that are absent from the black eyes of the sea scallop *Placopecten magellanicus*. The nanospheres in the eyes of *A. irradians* are ~ 180 nm in diameter and consist of electron-dense cores ~ 140 nm in diameter surrounded by less electron-dense shells 20 nm thick. These core-shell nanospheres are packed at a volume density of ~ 60% and energy-dispersive X-ray spectroscopy indicates they are not mineralized. Using optical modeling, we calculated that the nanospheres in the eyes of *A. irradians* are an ideal size for producing angle-weighted scattering that is bright and blue. From these results, we have learned how scallops make their eyes blue, but we have yet to learn why they do so. We hypothesize that light-scattering nanospheres help prevent UV wavelengths from damaging the internal structures of the eyes of blue-eyed scallops. If we are correct, we would expect to see a correlation between eye color and habitat depth across scallops, with blue-eyed species tending to live in shallower, more UV-rich environments than black-eyed species. To test our hypothesis, we used comparative phylogenetic methods to ask if eye color in scallops correlates with environmental features related to light conditions, such as depth.

79-1 HARRIS, RM*; AUSTIN, SH; LANGCALISI, A; MACMANES, M; CALISI, RM; NPB, UC Davis, MCB, UNH, MCB, UNH; *rmharris@ucdavis.edu*

Peaks and valleys of prolactin-related gene expression during the pigeon parental care stage

Parental care of offspring is essential to maximize fitness in many species throughout the animal kingdom. New parents undergo major changes in physiology and behavior to promote offspring survival in predictable and unpredictable conditions. While much is known about neuroendocrine mechanisms modulating these changes, we know less about genomic mechanisms driving these changes in male and female parents. To fill this gap, our team characterized gene expression states of the hypothalamus, pituitary, and gonads of mothers and fathers of the socially monogamous, bi-parental rock dove (*Columba livia*) at multiple stages of parenting. Next, we manipulated the timeline of the offspring development to distinguish genomic signatures that are driven by external cues from the offspring from internal cues from within the parent. We developed an R workflow for rapid and reproducible hypothesis testing related to specific tissues, sexes, and timepoints from our dataset of 1000 samples. Data and analyses are available at https://github.com/macmanes-lab/DoveParentsRNAseq. Preliminary findings suggest that gene expression of hundreds of genes in the pituitary mirrors that of circulating prolactin levels in the blood. Removal of offspring around the time of chicks hatching causes circulating prolactin to plummet and gene expression patterns shift to a non-parental state; however, prolonging incubation or delaying hatch has a much more subtle effect on gene expression. By characterizing and manipulating parental care and measuring the effects on hormones and gene expression in both male and female parents over time, we provide a more complete picture of how the hypothalamic-pituitary-gonadal axis responds to predictable and unpredictable changes during offspring development.

P2-151 HARRIS, JC*; REES, BB; University of New Orleans; *jcharris@my.uno.edu*

HIF-1α Protein Levels in Tissues of Fundulus grandis During Hypoxia

The hypoxia-inducible transcription factor (HIF) is the master regulator of gene expression underlying compensatory mechanisms that contribute to the ability of mammalian cells and tissues to withstand exposure to low oxygen. Less is known about the tissue-, time-, and oxygen-dependence of HIF in non-mammalian vertebrates. Because aquatic hypoxia is a prevalent and challenging environmental issue, it is relevant to ask whether HIF plays a similar role in hypoxia-tolerant fishes. This study used *Fundulus grandis*, a hypoxia-tolerant estuarine fish, to evaluate tissue-dependence and investigate the time course of HIF-1α protein levels during hypoxic exposure. Female fish were exposed to either normoxia (>7mg/L dissolved oxygen) or hypoxia (1mg/L) for 6h or 24 h and dissected. Then, HIF-1α protein levels in gills, liver, ovaries, and skeletal muscle were detected by immunoprecipitation and western blotting. Hypoxic exposure significantly increased HIF-1α protein levels in ovary and muscle, and the increase in liver approached statistical significance. There was no difference between HIF-1α levels at 6 and 24 h of low oxygen exposure. There was considerable variation in HIF-1α levels in tissues from hypoxic fish, which may be related to other behavioral and physiological responses to hypoxia.

77-7 HARRISON, J.F*; AIVAZIAN, V.; WEED, M.; MUNOZ, E; VANDENBROOKS, J.M; Arizona State University, Midwestern University; *j.harrison@asu.edu*

Hypermetric scaling of the leg tracheal system in cockroaches

Understanding the causes and consequences of evolution of larger or smaller body sizes in a lineage remains one of the important challenges of evolutionary biology. Insects have an unusual (for animals) respiratory system, transporting oxygen in the gas phase via air-filled tracheae. How is the morphology of the tracheal system adjusted as insects vary in size? Based on comparisons with vertebrates, we expect either isometric scaling (as found for lungs) or hypometric scaling (as found for vertebrate capillaries), with the latter matching the hypometric scaling of metabolic rate. We tested these expectations using one-to-three individuals of ten species of cockroach, ranging in mass from 0.5 to 4 g. Animals were imaged at Argonne National Laboratories using x-ray synchrotron imaging, all with the same resolution (0.65 microns/pixel). Composite images were created by tiling, and we measured tracheal diameters and the fraction of body volume by point-counting using ImageJ. Tracheal diameters generally scaled isometrically, as did the percent of body volume occupied by the tracheal system within the head, thorax and abdomen. However, within the leg, tracheal volume scaled strongly hypermetrically, due to an increase in the number of tracheae with size. The length of meta- and meso-, but not prothoracic legs scaled hypometrically. These data indicate that evolution of larger species size in cockroaches requires specific modification of the tracheal system structure of the legs, perhaps to overcome the challenges of long-distance transport through these long, blind-ended structures. The increased tracheal content of legs in larger roaches will also reduce leg density, likely reducing cost of transport and risk of damage. Supported by NSF IOS 1122157 and IOS 1558052.

14-6 HARRISON, JS*; PORTER, ML; PATEK, SN; Duke University, University of Hawai'i, Manoa; *jacob.harrison@duke.edu*

Scaling and development of elastic mechanisms: the tiny strikes of larval mantis shrimp

Mantis shrimp use a latch-mediated spring actuation (LaMSA) mechanism in their raptorial appendages to produce powerful strikes for resource acquisition and defense. Previous research on the mantis shrimp strike, including kinematics and appendage morphology, has focused exclusively on the adults (3-30 cm total length). However, mantis shrimp first exhibit striking behavior during their larval stages (~3 mm total length). At this size, mathematical models suggest that spring driven motion may not be an effective way of actuating the mantis shrimp strike. Understanding the larval mantis shrimp strike allows us to address major questions regarding the scaling and development of LaMSA systems. Here we describe the larval mantis shrimp strike in *Gonodactylaceus falcatus*, including raptorial appendage development, morphology, and kinematics. We raised *G. falcatus* collected as eggs in Honolulu, Hawaii to their seventh larval stage. Using light and scanning electron microscopy we show that larval *G. falcatus* possess the saddle and meral-v as early as their fourth larval stage. Using a custom designed apparatus, we captured high speed video of strikes from fourth and fifth stage larvae. Larval mantis shrimp achieved, on average, rotational accelerations of $6.5 \times 10^5 \pm 5.1 \times 10^5$ rad/s^2 with an angular velocity of 350.1±159 rad/s (12 animals, 26 strikes). When comparing strike kinematics from larvae to various adult mantis shrimp species, we find larvae achieve similar angular accelerations as adult mantis shrimp. Establishing the development of the raptorial appendage and strike kinematics in larval mantis shrimp offers insights on the development of LaMSA morphology, and how size may limit LaMSA mechanisms.

P2-156 HARTER, LN*; STAHLSCHMIDT, ZR; U Pacific; *l_harter@u.pacific.edu*
Does reproductive investment trade off with hardening or cross-tolerance related to heat and desiccation?
Animals exhibit physiological adjustments to many different environmental stressors, including heat waves and droughts (water limitation). For example, prior exposure to a given stressor (e.g., heat) can improve an animal's performance in a subsequent exposure to the same stressor, which is known as heat hardening or acclimation. Animals may also exhibit cross-tolerance where prior exposure to one stressor (e.g., heat) improves an animal's performance in response to a different stressor (e.g., desiccation). Although important for survival, hardening and/or cross-tolerance may tradeoff with other important processes, such as reproductive investment. Therefore, we tested for heat and desiccation hardening and cross-tolerance in short-winged female variable field crickets, *Gryllus lineaticeps*. Newly emerged adults were isolated, and they were weighed 5 d later because body mass at this age strongly correlates with reproductive investment (dry ovary mass). Then, each animal had its food removed and was subjected to pre-treatments for heat (42°C for 100 min.), desiccation (silica-dried air for 24 h), or control (normal rearing temperature [28°C] and access to water). After recovery from their pre-treatments, animals' performance for heat tolerance (critical thermal maximum) or desiccation resistance (duration of life without wa-ter) were assessed and body size (femur length) was determined. Thus, we tested for heat and desiccation hardening or cross-tolerance, and tested whether investment into reproduction traded off with hardening or cross-tolerance. The co-occurrence of heat waves and drought are expected to increase with climate change, and our results will provide insight into fitness-related costs as-sociated with physiological adaptations to these two stressors.

P3-194 HASTINGS, BT*; JACKSON, BE; Longwood University; *brandon.hastings@live.longwood.edu*
Analyzing the Flight Patterns and Behavior of Dragonflies Engaged in Aerial Territory Battles
It has previously been determined that male dragonflies occupying the most suitable territory within a habitat have a higher flight muscle ratio (FMR) than those occupying poor territories, but it is unknown how this increased FMR relates to their flight patterns. This study examined the flight patterns of dragonflies engaged in aerial territory battles to investigate differences in maneuverability. 3D video data of dragonflies interacting in a natural habitat was analyzed for interacting (<0.5 m apart) and non-interacting flights. Non-interacting dragonflies showed higher linear velocities and accelerations, while interacting dragonflies showed higher angular velocities. With further data collection, we can categorize the winners and losers of these territory battles and provide a link between flight maneuverability and FMR in dragonflies.

P2-208 HATCHER, M*; FLORENDO, J; MAIA, A; Rhode Island College, University of Rhode Island; *mhatcher_1915@email.ric.edu*
Rising Ocean Temperatures Affect Red and White Muscle Recruitment in Fish Species
We evaluated the recruitment of red and white muscles of four Narragansett Bay fish species - summer flounder, winter flounder, black sea bass and scup - at 18, 20, 22 and 24° C to determine how temperatures affect muscle mechanics. We expect fish species including, black sea bass, scup, winter and summer flounder will recruit more red muscle when exposed to higher temperature waters in order to complete simple movements. Sedentary species like the flounder will likely demonstrate less of a physiological adjustment than the more active pelagic species. We placed electromyography electrodes into red and white muscle at 50 (mid body) and 75% (caudal region) of the fish's total length. In winter flounder, all muscles showed higher magnitude of contraction at higher temperatures, while duration was not affected. However, in summer flounder, red caudal had higher magnitude at higher temperatures, while mid white had the reversed pattern. White caudal was the only muscle with decreased duration at higher temperatures. In scup, all muscles but red caudal showed changes in magnitude of contraction with temperature, however magnitude was higher for white muscles at lower temperatures while the opposite was true for red muscles. In black sea bass, all muscles but mid white had higher magnitude of contraction at the higher temperature and red caudal also had higher duration of contraction at higher temperatures. These results confirm that red muscles were recruited more at higher temperatures. This seems to indicate that at higher temperatures most fish are increasing recruitment of red muscle and oxygen demands are expected to be higher. Studying the muscle function in light of a changing environment of fish species will help determine fitness of the populations in the coming years and how local stakeholders must also adapt in order to achieve long-term fishery sustainability.

P2-141 HAVENS, LT*; LOHMANN, KJ; University of North Carolina, Chapel Hill; *lukethavens@gmail.com*
A model for directional magnetic field processing in the Caribbean spiny lobster Panulirus argus
Many animals use Earth's magnetic field to acquire positional or directional information for use during directed travel. However, despite its widespread occurrence across phylogeny, magnetoreception remains poorly understood. Biological tissues are generally transparent to magnetic information, so magnetoreceptors are not necessarily limited to particular areas of the body and thus have been difficult to localize. By necessity, studies of magnetoreception mechanism largely rely on indirect, transduction-specific methods to disrupt magnetoreception. One such method is the application of a strong magnetic pulse: if the transduction method utilized by the animal is based on ferromagnetic particles, a strong magnetic pulse can realign their magnetization, disrupting normal magnetic field transduction. Studies utilizing magnetic pulse-based disruption of magnetoreception have determined whether a pulse affects animal orientation, but the directional nature of magnetic pulses suggests that these experiments could also be used to perform directional ablations. That is, the effects of directionality of the pulse—and thus ferromagnetic particle realignment—could help us deduce how the magnetic field might be processed. For instance, if there is a consistent orientation effect dependent on pulse direction, that might suggest how signals from multiple receptors could be combined. Here, we use existing multidirectional pulse data collected from the Caribbean spiny lobster *Panulirus argus* to develop a conceptual receptor array and neural circuit model for processing directional information. By constructing a model which responds similarly to magnetic pulse disruptions, we hope to more closely approximate processing of the magnetic field in *Panulirus argus.*

S7-5 HAVIRD, JC; The University of Texas, Austin, TX; *jhavird@utexas.edu*

Building Bridges from the Mitogenome to the Mitophenome to the Organismal Phenome

Phenotypes do not emerge solely as a result of variation at a single locus, but can be altered by genetic variation at other loci (epistasis), environmental variation (plasticity), and epigenetic modifications. Complicating matters further, most studies only consider the nuclear genome when examining genotype-to-phenotype relationships. However, emerging evidence suggests mitonuclear epistasis is rampant – different phenotypes arise when the same nuclear genome is placed against different mitochondrial genotypes. The environment can further modify mitonuclear epistasis (G x G x E interactions). "Phenotype" can also be defined across biological scales, from the expression of genes to whole-organism fitness. In this talk I will discuss a series of studies linking mitochondrial genotype to mitochondrial and whole-organism phenotypes. First, we ask whether extreme variation seen in mitochondrial genomes of the angiosperm genus *Silene* affects mitochondrial function, despite having little noticeable effects at the organismal level. Next, we explore whether placing different mitochondrial genotypes against a common nuclear genome affects mitochondrial function and organismal phenotypes in *Silene*. Finally, we present a meta-analysis of mitochondrial and whole-animal oxygen consumption in response to temperature to ask how similarly phenotypes at different scales vary in response to environment. Taken together, our results suggest that phenotypic variation should be explored in response to genetic variation at both mito- and nuclear loci, across environments, and across biological scales.

S4-11 HAWKES, K; University of Utah; *hawkes@anthro.utah.edu*

The centrality of grandmothers in human evolution

When RA Fisher, PB Medawar, GC Williams, and WD Hamilton laid the foundations of evolutionary life history theory, they recognized elements of what became a grandmother hypothesis for the evolution of human longevity. Only subsequent study of modern hunter-gatherers, great apes, and the wider mammalian radiation revealed strong regularities in development and behavior that identify additional unexpected effects that grandmothering likely had on human evolution. Now ancestral grandmothering is a serious contender to help explain not only, 1) the large fraction of post-fertile years women live, but also 2) the pair bonding habits that distinguish humans from our closest living evolutionary cousins, the great apes (and most other mammals), 3) our big human brain and large neocortex, 4) our socially precocious babies' active engagement with others, and 5) our preoccupation with reputations, shared intentionality and persistent cultural learning, which 6) underpin the diversity of our cultural lives, and even 7) that particular human distinction: language. Ancestral grandmothers' contribution to the ancestry of subsequent generations likely contributed to an astonishing array of features that make us human.

65-4 HAWKINS, RK*; STOCKER, MR; METZGAR, JS; Virginia Tech; *rehawk@vt.edu*

The Importance of Natural History Collection Clubs in Preserving and Using University Collections

Natural history collections have an essential place in universities for education, research, and outreach. For example, collection specimens are used in taxonomy courses, biodiversity studies, and scientific communication. However, despite these valuable and well-established uses, many university collections are neglected from a lack of funds and attention, sometimes even to the point of ruin. The Natural History Collections Club Network (NHCCN) was founded in 2013 to save and advocate for collections like these through the establishment of Natural History Collections Clubs (NHCCs) at their universities. Currently, NHCCs have been formed at Arkansas State University, University of California at Santa Barbara, University of California at Riverside, Virginia Tech, University of New Mexico, Georgia Southern University, and UNC Wilmington. NHCCs have been successful in bringing student attention to university collections, which in turn has provided collection volunteers; increased specimen use in education, research, and outreach; and even led to much-needed funding opportunities. At Arkansas State University, NHCC members raised funding and worked to revitalize forgotten teaching collections by rehousing specimens, improving collection spaces, and hiring student workers. At Virginia Tech, student interest in natural history grew after a NHCC was founded, leading to the creation of a museum studies course. These accomplishments and many more from other NHCCs illustrate their power to bring funding and attention back to university collections, allowing them to continue serving students, researchers, and the community.

P3-211 HAWKINS, TM*; SHORT, RA; DAVIS, JE; Radford University ; *thawkins18@radford.edu*

Exploring the Impacts of Royal Jelly, Juvenile Hormone, and Nutritional State on Immune Response of Gromphadorhina portentosa

Hormone modulation of immune response in vertebrates is relatively well understood, however the immune system of invertebrates is complex, non-adaptive, and poorly explored. Royal jelly (RJ), a modulator of reproduction and growth in honeybees, and juvenile growth hormone (JH), which maintains adolescent morphology and physiology across diverse invertebrate taxa and aids in reproductive ability after maturation, were used as endocrine treatments to better understand the immune response of Madagascar hissing cockroaches (*Gromphadorhina portentosa*) in various treatment conditions. Zone of inhibition tests were performed to observe bacteria growth in relationship to hormonal modulation using hemolymph from Madagascar hissing cockroaches reared in each of the respective treatment groups: RJ, JH, and RJ + JH. In addition to exogenous hormone treatments, prior experiments suggest that nutritional state also impacts immune response. For this reason, starvation testing was also observed to determine immune response 24 hours post feeding and one-week post feeding.

19-3 HAYNES, L; BEVERIDGE, J; FISH, O; GIAMBRONE, SA; REED, L; SCOTT CHIALVO, C*; University of Alabama, Appalachian State University; *chialvoch@appstate.edu*
Characterizing the Impact of a Complex Mix of Toxins on Survival in Drosophila Species
To defend against herbivory, plants and fungi produce a variety of secondary metabolites. While understanding the biological effects of these host secondary metabolites on plant-insect interactions remains an active area of research, many studies focus on a single metabolite or a subset of the compounds. However, the potent bioactivity of some compounds is due to their synergistic/antagonistic interactions with other metabolites in their natural matrix. Thus, there is a need to characterize plant-insect interactions using complex mixtures that more closely resemble the chemical matrix found in the host. In this study, we examine this question by assessing how the survival of mushroom-feeding *Drosophila* in the *immigrans-tripunctata* radiation is impacted by the natural suite of toxins found in a small proportion of their hosts. Previous work examining toxin tolerance in these flies focused only on the effect of α-amanitin; however, the toxic mushrooms contain over 14 known toxins. To assess the impact of a natural toxin mix on survival, we reared the larvae of three tolerant and six susceptible species from the radiation and the distantly related *D. melanogaster* on diets containing differing concentrations of a toxin mix extracted from the host *Amantia phalloides*. To quantify the effect of the natural toxin mix, we measured several fitness phenotypes, including survival to adult and thorax length. Our results demonstrated that tolerant species exhibit similar patterns of survival to a diet containing a single toxin. We also found that the susceptible species could develop on low levels of the natural toxin mix that are lethal to most other Eukaryotes, including *D. melanogaster*. Thus, this study provides context for future research examining the evolution of toxin tolerance.

S4-2 HAYSSEN, V; Smith College, Northampton, MA; *vhayssen@smith.edu*
Misconceptions about Conception and Other Fallacies: Historical Bias in Reproductive Biology
The #meToo movement is a current social meme whose tendrils have not quite crept into our understanding of organismal physiology, behavior, and evolution. But the time has come to do so. For instance, although most consider polar bears solitary, female polar bears live nearly all their lives in the company of their offspring. Female polar bears have constant social interactions with their cubs and their interactions with their environment are as a social group not as an individual. How they hunt, how far they roam, how they thermoregulate, how much they are exposed to pathogens, how much they need to scan the environment for predators, all these aspects of their lives differ from those of a solitary individual. So, why are polar bears usually considered solitary? Why do we devalue the importance of reproduction in our assessment of the biology and ecology of animals? I will provide a brief review of the historical bias in reproductive science, the consequences of that bias, and, more importantly, ways to ameliorate that bias going forward.

55-4 HE, L; SHIN, SHJ; WANG, Z; YUAN, I; WESCHLER, R; KOYAMA, T; NIJHOUT, HF; SUZUKI, Y*; Wellesley College, Wellesley, MA, University of Copenhagen, Copenhagen, Denmark, Duke University, Durham, NC; *ysuzuki@wellesley.edu*
Body size sensing in the tobacco hornworm, Manduca sexta: the role of TGF-beta/Activin signaling in metamorphic timing
How organisms sense their size remains poorly understood. In insects, the final larval instar is specified if they have attained the threshold size; if they have not, they will undergo additional larval molts and continue to grow. In this study, the nature of threshold size determination was investigated using the tobacco hornworm, *Manduca sexta*. Hypoxia treatment caused larvae to have a lower threshold size than those reared on low nutrient diet. Measurements of relative sizes of muscles and fat body showed that the size of the muscles/integuments was correlated with the attainment of threshold size. In addition, we found that the expression of the TGF-beta/Activin signaling gene, *myoglianin (myo)*, was associated with the attainment of threshold size and that its knockdown led to supernumerary molts and prevented metamorphosis. We will present a model for how larvae sense their size.

S11-7 HEALY, SD; University of St Andrews; *susan.healy@st-andrews.ac.uk*
Using Neural Activation to Understand Nest Building in Birds
Nest building is fundamental to successful reproduction for most birds. In spite of its importance, however, rather little is known about the decision making that is involved in building. Indeed, it is still commonly assumed that the nest that is built is the product of an innate template. But there are increasing data to show that learning and memory play a role in a variety of decisions that birds make (including associations between material properties, environmental conditions and reproductive success, and who to copy) when building and there are now also data to indicate which parts of the brain might be activated when birds build. Together the behavioural and neural activation data provide a model for examining the mechanistic bases of physical cognition, including the roles of perception, motor output and a variety of cognitive processes.

S10-1 HEBDON, N*; RITTERBUSH, KA; University of Utah, Salt Lake City; *nicholas.hebdon@gmail.com*

Seeing Spirals: Evaluating the hydrodynamic effect of changes in spiraling morphology of ammonoids

Ammonoid cephalopods are an extinct group that are notable for their 300 million year history dominated by recurrent cycles of diversity boom and bust. Throughout these biodiversity cycles they repeatedly evolve distinct coiling shell shapes. These coiled ammonoids have shown very pronounced morphological shifts during their recovery following bust periods. Paleoecological research into these enigmatic animals, which have no strong modern analogue, has long featured discussions of how these changing shell morphologies influenced swimming ability. Experimental and computational approaches have attempted to quantify the hydrodynamic costs, or benefits, of shell shape, with success distinguishing most relevant first-order parameters. We advance this work by using computational fluid dynamics to investigate the hydrodynamics of theoretical ammonoid morphotypes. We use 3D modeling to create synthetic ammonoid shells that model variation in two key morphological parameters: Whorl expansion (the rate at which an individual coil increases in diameter) and umbilical exposure (the amount of central coiling exposed to flow). We use Ansys FLUENT to resolve the flow fields around each shell and the drag they incur. These drag values are then compared against a control morphotype that represents the centerpoint of each parameter variation. Our results show that the magnitude of change in drag is non-linearly sensitive to both the direction and magnitude of change within a parameter. We also recover a distinct hierarchy of effect between morphological parameters. We present new gradients of these animals swimming potential that, at larger scales, can provide the groundwork for testable hypotheses on the structure of paleozoic and mesozoic marine systems through time.

P3-232 HEBERT, AK*; MINEO, PM; BENNETT, KF; KSIAZEK-MIKENAS, K; MARSH , TM; MELLGREN, EM; RAIMONDI, SL; Elmhurst College, IL; *amy.hebert@elmhurst.edu*

Incorporating Vision and Change at Elmhurst College: a Departmental Approach

The Biology Department at Elmhurst College has made a commitment to incorporate the recommendations of *Vision and Change in Undergraduate Biology Education: A Call to Action* (AAAS 2011). Careful planning and implementation have allowed for changes, or planning for those changes, at every level of our biology curriculum, including a new mission statement and learning outcomes for our major. Complete re-design of courses began with the introductory sequence for biology majors, incorporating core concepts and competencies, as well as student-centered learning and authentic research experiences (Guenther et al., 2019). As we assess our success and challenges at the introductory level, we are beginning to move our re-design into upper-level courses of the major, as well as courses taught by the biology department for non-major students. Here we will share assessment of implemented changes and lessons learned on the path to a departmental overhaul incorporating Vision and Change.

72-5 HEDRICK, BP*; BROCKLEHURST, N; MITCHELL, JS; BENSON, RBJ; Louisiana State University Health Sciences Center, New Orleans, USA, University of Oxford, Oxford, UK, West Virginia University, Beckley, USA; *bhedri@lsuhsc.edu*

Functional Constraints and Disparity in Bird Limb Proportion Evolution

Birds have wide variation in flight capability, from flightless kiwi birds to hyper-aerial swifts. Their dinosaurian ancestors also show tremendous disparity in limb proportions and locomotor modes, spanning massive quadrupedal sauropods, carnivorous bipeds, and small bipedal herbivores. Key questions about locomotor macroevolution in dinosaurs include whether locomotor innovations were pulsed or gradual, and to what extent increases in locomotor disparity correlate with changes in patterns of integration both between and within limbs. We conducted disparity-through-time and integration analyses on a limb proportion database of 822 species of non-avian dinosaurs, fossil birds, and extant birds spanning 230 million years of evolutionary history. We found a pulse-like pattern with an early increase in relative subclade disparity of limb proportions coincident with the origin of major non-avian dinosaur clades during the Triassic and with the Early Cretaceous radiation of birds. There was a subsequent increase in disparity concurrent with the origin of crown Aves, followed by a large drop in disparity just prior to the end-Cretaceous extinction. Further, we found that shifts between locomotor modes were accompanied by a restructuring of within and between limb integration patterns. Flightless bipeds had moderate integration between limbs and high integration within limbs. In contrast, volant species had high integration within both limbs, but low between-limb integration. These results suggest that dinosaur and bird limb innovations evolved in pulses and that these pulses were strongly correlated with changes in limb integration regimes.

P1-201 HEERDEGEN, I*; PARKER, L; RUDDY, B; INGLE, D; PORTER, ME; Florida Atlantic University, Boca Raton, FL, Florida Atlantic University, Boca Raton, Fl; *bruddy2018@fau.edu*

Interspecific and regional variation in shark vertebral mineral structure and content

The mechanical behavior of mineralized cartilaginous shark vertebrae varies among body regions and species and these variations may be partially influenced by vertebral mineral architecture. We quantify mineral arrangements (radiating lamellae number and angles, and number of nodes) and calculate bone mineral densities (BMD) of vertebrae belonging to two orders of sharks (Carcharhiniformes and Lamniformes). Previous work has shown that shark vertebrae from the posterior column are the toughest and stiffest; therefore we hypothesized that the posterior region of lamniform species will have the most radiating lamellae with the smallest angles and the greatest node density. We also expected that carcharhiniform sharks will have larger BMD values due to the block-like calcification within their vertebral bodies. We dissected vertebrae from six species of sharks (three per order) along the anterior, mid, and posterior body regions. After measuring length and diameter with calipers, we scanned each vertebra using a BrukerSkyScan 1173 µCT scanner. We then obtained BMD values with Bruker CTAn software and measured the morphological variables using ImageJ. Our preliminary data show that the posterior region of lamniform sharks had a greater number of lamellae with overall smaller angles, and increased node density. The posterior region of all individuals showed significantly higher BMD values, though carcharhiniform species had greater mineralization overall when compared to lamniform individuals. We hypothesize that increased mineral density and morphological architecture may aid in thrust production and energy storage, as lateral body displacement is concentrated in the posterior region during swimming.

70-6 HEESY, CP; Midwestern University, AZ;
cheesy@midwestern.edu

On the Laws of Haller and Leuckart OR Does visual resolution scale with velocity and size in animals?

Vertebrate eyes, even with differences due to ecology, (generally) scale hypometrically with body size – as a result of a relationship called Haller's Law. Isometric eye size scaling is, however, predicted for faster-moving animals, in a relationship known as Leuckart's Law. Increased eye size within this context is often interpreted or assumed to be a proxy for higher visual acuity or resolution. Although the axial length of the eye does correlate with visual acuity, studies of birds and mammals conflict in supporting the eye-size-to-velocity relationship, in that it is currently unclear whether faster locomoting animals require higher visual resolution, or if variability in eye size is primarily explained by overall body size. I analyzed data on visual acuity, linear dimensions of the eye, maximum linear velocity, body length, and mass for multiple orders of running and flying insects, mammals, and birds to broadly evaluate the resolution-to-speed relationship. Whereas eye size and velocity do both scale with body-size variables, neither eye size nor acuity scale with speed in any phylogenetic group or locomotor type. Additionally, neither acuity nor eye size matches the empirically observed ‘U'-shaped curvilinear relationship between animal body size and speed. This study does not support Leuckart's Law, and I suggest that high visual resolution is not necessarily required for high-speed locomotion.

P3-112 HEFELE, KR*; JORGENSEN, DD; Roanoke College, Virginia; *krhefele@mail.roanoke.edu*

Ventricular function in American lobsters and Atlantic blue crabs: does contractility change with increasing metabolic demand?

Lobsters and blue crabs use a single pumping chamber, the heart or ventricle, to push hemolymph into an arterial network in a dynamic way. We are interested in characterizing how the ventricle fills and empties over a cardiac cycle in these animals. Part of this work has entailed estimating contractility of the ventricle employing a commonly-used method: analyzing the time-course of pressure change during ventricular systole. We measured pulsatile intraventricular pressure using both fluid-filled catheters connected to strain gauge pressure transducers and catheter-tip transducers, both in resting and walking (metabolically-challenged) lobsters and crabs. In some animals, we measured hemolymph velocity in the dorsal abdominal artery concurrently in an attempt to define the isovolumetric contraction portion of the ventricular pressure pulse. We analyzed the pressure data to determine the first derivative of pressure with respect to time (dP/dt) over the cardiac cycle, focusing on maximum, positive dP/dt during ventricular systole. We found mean values of 20.5 (+/- 5.6 SE; n=5) kPa/sec in resting lobsters and 32.6 (+/- 5.7) kPa/sec when they were walking steadily on a submerged treadmill (a 50% increase in contractility as measured by our method). Preliminarily, and interestingly, ventricular contractility in resting and exercising blue crabs is substantially higher than that for lobsters. Our data suggest that there is a relationship between heart rate and ventricular contractility in both animal types, although this relationship is not clearly-defined at this time.

109-4 HEINE, KB*; JUSTYN, NM; HILL, GE; TUCKER, VL; JUNG, D; POLLOCK, B; HOOD, WR; Auburn University;
kbh0039@tigermail.auburn.edu

Modeling Mitochondrial Behavior and Morphology from TEM Micrographs of Copepod Myocytes Following Ultraviolet Irradiation

The ability of animals to produce energy is determined largely by the function and structure of mitochondria. To meet the energetic demands of survival and reproduction, an organism must produce energy efficiently in the face of endogenous and environmental stressors. These stressors include exposure to reactive oxygen species that are produced both directly via oxidative phosphorylation and indirectly by environmental factors such as ultraviolet radiation. Such stressors can have negative impacts on mitochondrial function, but they may also increase mitochondrial performance at low levels by acting as cellular signals. Moreover, previous work has shown that ultraviolet radiation not only has negative impacts on the longevity of aquatic organisms but also conveys beneficial reproductive performance early in life. Further work is needed to determine the beneficial and detrimental effects that environmental stressors impose on mitochondrial structure and, therefore, organism performance. This study aims to determine how ultraviolet irradiation affects mitochondrial behavior and morphology in myocytes of the copepod *Tigriopus californicus*, in addition to whole-organism respiratory function. Using transmission electron microscopy and corresponding respiration assays, we address the impact of both moderate- and high-dose ultraviolet-A/B irradiation on the proportion of inter-mitochondrial junctions and density of the inner mitochondrial membrane, as well as mitochondrial density and aspect ratio.

S1-2 HEISER, S*; SHILLING, AJ; AMSLER, CD; MCCLINTOCK, JB; BAKER, BJ; University of Alabama at Birmingham, University of South Florida ; *heiser@uab.edu*

Allies, Cheaters and Thieves: Macroalgal-Mesograzer Interactions on the Western Antarctic Peninsula

Macroalgae dominate the hard benthos along the Western Antarctic Peninsula to depths of up to 40 m or more. Most of the macroalgae are chemically defended from a variety of macro- and mesograzers but harbor very high densities of amphipods. The amphipods benefit from living on the large, chemically-defended macroalgae because they gain refuge from fish which are their primary predators. A majority amphipod species do not consume most of the macroalgal species, but are of benefit to the macroalgae by keeping them relatively clean of epiphytic microalgae and filamentous macroalgae. One amphipod species, however, does consume some of the chemically defended red algal species and is able to sequester algal metabolites for its own use as defenses against fish. A combined genetic and chemical analysis of the alga from different collection sites revealed that it divides into two closely related haplotypes (‘phylogroups'), not distinct enough to be considered separate species, each of which is further divided into one of 14 groups (‘chemogroups') with distinct mixtures of defensive, halogenated secondary metabolites. The amphipods feed on some of the chemogroups at significantly slower rates than others. Different sites are dominated by different chemogroups but experiments indicate that most individual algae retain their chemogroup for at least a year after transplantation between sites. Patterns of gene flow are being investigated as a potential source of the spatial variation in chemogroups.

P1-272 HEITZMAN, N/S*; LOWER, S/E; Bucknell University, Lewisburg, Pennsylvania ; *nskh001@bucknell.edu*
Relationship between sex, life stage, and gut microbial communities in Photuris fireflies
Insect microbial communities have been studied as a contributing factor to aspects of insect life including insect immunity, metabolic, and vectoring efficiency. The relationships between microbial communities and factors, such as distinct sex differences and larval-adult disparities, remain unknown in many insect species. Through investigating with the non-model *Photuris* fireflies, we allow for distinct behaviors and influencing factors between sexes and life stages of the same species. We hypothesize that there will be a significant difference in relative bacterial abundance between male and female *Photuris*, because males are not predatory as adults and, therefore, are expected to present with fewer bacteria involved with diet and predatory behaviors. We further hypothesize that there will be a similar trend in the analysis of life stages, as there is a notable shift between the diet of predatory larvae and non-predatory adult males. In this experiment, we analyzed the gut microbiome of *Photuris* fireflies using Illumina 16S rRNA sequencing to answer two questions- 1) How do environmental factors affect the microbiome and 2) How do life stages affect the microbiome? Through the use of metagenomic analyses, we generated tables of relative abundance by bacterial operational taxonomic units (OTUs) and analyzed the table relationships with ANOVAs to develop principal component analyses (PCA) based on the relative abundance of bacterial genera in *Photuris* gut microbiomes. Our results can inform studies in firefly conservation, insect-microbiome evolution and wider studies investigating the relationship between gut microbiomes and behavioral variation.

128-2 HELLMANN, JK*; BENSKY, M; ZIELINSKI, C; ANDERSON, S; BELL, A; University of Illinois, Urbana-Champaign; *hellmann@illinois.edu*
The Evolution of Sex-Specific Paternal Effects in Threespined Sticklebacks
Sex-specific selection pressures can generate different phenotypic optima for males and females in response to changing environments (sex differences in phenotypic plasticity). However, there is growing evidence that the ways in which parental environments alter offspring phenotypes (transgenerational plasticity) can also depend on sex. Sex-specific transgenerational plasticity is potentially of great evolutionary significance, as it is a mechanism by which potentially adaptive traits can persist selectively across generations via only daughters or sons. In previous work, I found that there were sex-specific sperm-mediated paternal effects in response to predation risk in threespined sticklebacks (*Gasterosteus aculeatus*). Here, I explore whether these sex-specific patterns might have evolved during the stickleback radiation. I compared replicate populations of ancestral (marine) and derived (freshwater) sticklebacks that were reared in a common garden. There was population-level variation in the direction of sperm-mediated paternal effects, and evidence for parallel evolution of sex-specific paternal effects during the stickleback radiation. In ancestral populations, sons and daughters responded similarly to paternal cues of predation risk, but in derived populations, sons and daughters responded differently. These phenotypic differences emerged well before offspring were reproductively mature, suggesting that these differences organize in early development. These results suggest that current work seeking to understand the evolution of transgenerational plasticity needs to also consider the conditions which favor the evolution of sex-specific transgenerational plasticity.

P1-153 HELLMICH, DL*; WRIGHT, TF; New Mexico State University; *dlh263@nmsu.edu*
Mapping the Contact Call Variation of Urban Invasive Parrots as a Model for Understanding Vocal Dialect Formation.
Understanding the function of vocal dialects is a key interest of researchers interested in the evolution of culturally transmitted traits. However, the question of how these mosaic-like patterns of vocal variation become established in the first place has received less attention. One approach to addressing this gap is using recently established or actively expanding species as models of vocal dialect formation. The rosy-faced lovebird (*Agapornis roseicollis*) is a small parrot native to Namibia that began establishing feral populations in the Phoenix metropolitan area in the late 1980s. Since then, their total population has grown to an estimated 3,000 birds occupying 10 municipal areas. Their rapid growth and relatively recent invasion history make these populations an ideal model for understanding the conditions under which vocal dialects may evolve. The aim of our study is to identify whether geographically distinct populations of lovebirds display evidence of vocal dialects in their socially-learned contact calls. Over a 2-year period we collected contact calls from birds at 9 locations across a 2000 km2 area. Call similarity was assessed using spectrographic cross correlation followed by Mantel tests, and one-way ANOVAs performed using the results from a principle components analyses of 22 different acoustic parameters. ANOVA results indicate that some populations of lovebirds do differ significantly in their acoustic parameters with a pattern of increasing call similarity with geographic distance. Although further study is needed to understand the conditions that favor the differentiation of contact call structure in these populations, our results support the use of the invasive lovebirds as a model of vocal dialect formation and evolution.

33-5 HELMS CAHAN, S*; FRIETZE, SE; GERRARD, DL; BORA, K; KAPLAN, I; PEREZ, M; LOCKWOOD, BL; TEETS, NM; WATERS, JK; AXEN, HJ; University of Vermont, LeTourneau University, University of Kentucky, Providence College, Salve Regina University; *scahan@uvm.edu*
Developmental temperature alters brain gene expression in adult Drosophila melanogaster
The physiology of ectotherms must be able to function across a wide range of environmental temperatures, particularly in thermally variable habitats. When external temperatures are temporally correlated, earlier thermal experiences can lead to a beneficial acclimation response that enhances robustness to future thermal conditions. In *Drosophila melanogaster*, temperatures experienced during larval development can lead to shifts in critical thermal minima (CTmin) of ~1.5°C, and critical thermal maxima (CTmax) of ~0.5°C. Although these whole-body effects are well-described, it is unclear how developmental acclimation produces enhanced thermal tolerance, particularly in the central nervous system, whose failure operationally defines critical thermal limits. We investigated the effect of developmental acclimation on brain gene expression by comparing brain transcriptomic profiles of *D. melanogaster* that were reared from egg through pupation at 18°C, 25°C, or 30°C and then held at 25°C for two days as adults. Developmental temperature impacted a small proportion of genes, with a larger number showing a response to cool rearing temperatures (23) than warm temperatures (2) when each were compared to the control of 25°C. Among these, several were associated with thermal protective functions, including the heat shock response, calcium ion regulation, and phospholipid metabolism. These results suggest that the adult brain may be primed by gene-regulatory changes that are set during development to prophylactically protect against thermally-induced neuronal failure as an adult.

P1-90 HENDERSON, KW*; ROCHE, AS; HALE, ME; HENDERSON, Kat; University of Chicago; *kwh@uchicago.edu*
Hindbrain and spinal cord sensory neuron innervate of the pectoral fin
Sensory input from the limbs to the central nervous system provides important feedback during motor behaviors. Here we investigate the sensory structure of the larval pectoral fins, which have been shown to beat rhythmically and contribute to respiratory fluid flow during early post-hatching life stages. Sensory input from the larval zebrafish pectoral fins comes from two populations of neurons: hindbrain neurons (HBs) and spinal Rohon Beard neurons (RBs). HBs are believed to persist through ontogeny while RBs die off in later juvenile stages. Using islet2b transgenic lines, we found that an individual pectoral fin is innervated by three to five sensory HBs located in the caudal hindbrain. The extensive arborization of RB dendrites made single cell tracing difficult in transgenic lines, however the Gal4/UAS system allowed single cell labeling and precise 3D reconstructions of individual cells. In a sample of 21 fish with labeling of individual pectoral fin sensory neurons, only four cells were RBs. This information, in combination with broader imaging of the RB pool, suggests that between zero and two RBs innervate the fin at this stage of development. We analyzed a range of morphological parameters encompassing neuronal features from soma location to branching angles. There is high morphological variability among cells innervating the pectoral fins, regardless of soma location. Unexpectedly, all of the cells that innervate the pectoral fin had substantial innervation of the axial body wall as well, indicating that the CNS may not receive spatially precise sensory input from the pectoral fin. Future work will examine the possible chemosensory and mechanosensory functions of these neurons and investigate how this sensory innervation changes through ontogeny.

P3-246 HENNESSEY , P J*; STREICHER, J W; COX, C L; Georgia Southern University , Natural History Museum London , Florida International University; *ph06710@georgiasouthern.edu*
Evolution of skull morphology during diversification in specialist snakes
Evolutionary specialisation to the environment has produced vast phenotypic diversity of across the tree of live. In particular, feeding is crucial for both survival and reproduction and therefore many animals are morphologically adapted to their diet. One of the most important feeding structures for vertebrates is the skull, which can have morphology closely adapted to diet. However, how skull morphology evolves during evolutionary diversification and repeated evolution of dietary specialization is not well known. We studied the evolution of skull morphology in snakes of the genus *Tantilla. Snakes in general are ideal for studying evolution of trophic morphology because they are limbless and most specialization of the feeding apparatus involves the skull. The genus of Tantilla is particularly interesting because they have repeatedly evolved dietary specialization on well-defended arthropod prey such as scorpions and centipedes. We collected micro CT scans of skull morphology, assembled dietary data from the literature, and constructed a phylogeny for the genus using molecular data. We then use these data to study the pattern and tempo of the evolution of feeding and skull morphology. Ultimately, our study will reveal how osteological change and dietary specialization can contribute to the evolution of phenotypic diversity.*

89-6 HENSCHEN, AE*; HAWLEY, DM; ADELMAN, JS; University of Memphis, Virginia Tech; *henschen@memphis.edu*
Oxidative damage resistance as a potential mechanism of disease tolerance in a wild host
Hosts have two main ways to combat parasitic infections: resistance, which lowers pathogen load directly, and tolerance, which decreases the fitness costs of infections at a given pathogen load. Among animals, the mechanisms underlying variation in tolerance are not well understood. Early immune defenses against infection often include the release of free-radicals, which help kill pathogens, but also result in oxidative damage to host cells and tissues, potentially reducing host fitness. As such, minimizing this oxidative damage may be an important mechanism of tolerance in animals. We tested this hypothesis in house finches (*Haemorhous mexicanus*) infected with an emerging bacterial pathogen, *Mycoplasma gallisepticum* (MG). MG spilled over to house finches in the early 1990's in the eastern United States and has since spread to most house finch populations. Previous work in this system suggests that tolerance may be evolving to MG in populations with the longest history of MG endemism, and that more tolerant populations have dampened inflammatory responses. As inflammation and free radical production are intricately linked, oxidative damage may play an important role in producing tolerant phenotypes in this system. In this study, we compared levels of oxidative damage both before and during experimental MG infections among house finches from populations that differ in their tolerance to MG. These populations span the temporal scale of MG endemism, including a population near the original spill-over and a population still naïve to MG. We predicted that individuals from populations that are more tolerant to MG would have a lower amount of oxidative damage than individuals from less tolerant populations following experimental infection with MG. This work represents one of the first investigations into the mechanisms of tolerance in a wild animal host.

P1-158 HENSLEY, NM*; GERRISH, GA; SAHA, R; OAKLEY, TH; RIVERS, TJ; University of California, Santa Barbara, Trout Lake Station, University of Wisconsin, Madison, Bates College, University of Kansas; *nikohensley@gmail.com*
Does ecological overlap drive the evolution of mating display discrimination in female sea fireflies?
Mating displays contribute heavily to diversity, being implicated in speciation as well as providing stunning examples of phenotypic disparity. These displays are critical for reproduction, as improper mate choice can have costly repercussions, such as loss of direct benefits or mating opportunities, increased harassment, or even inviable offspring. Using the bioluminescent displays of Caribbean sea fireflies (Ostracoda), we investigate if ecological overlap drives the evolution of discrimination behaviors in receiving females of four species. Varying ecology, like sympatry with heterospecifics, can influence both how strong selection should be on receivers to recognize mates, and on senders to develop informationally-rich signals on which to choose. We used artificial playback with experimentally altered bioluminescent displays to test how well females from sympatric and allopatric species discriminate their conspecific display, and if certain display characters like pulse duration or interpulse interval produced more accurate discrimination. Our preliminary analyses indicate that females are responsive to our artificial displays, altering their levels of activity. We observed females frequently switch from slow swimming to rapid diving or back-and-forth turns, which we interpret as evidence of mate-seeking behaviors. Ongoing work using automated tracking will allow us to pair specific behavioral changes to the timing of stimulus onset. These results will allow us to assess the importance of pre-copulatory behaviors during speciation in bioluminescent ostracods.

P3-29 HEPPNER, JJ*; OUYANG, JQ; University of Nevada, Reno; *jheppner@nevada.unr.edu*

Urbanization and parental investment in a free-living songbird

As urbanization continues to expand, it is vital to understand how animals cope with increasing environmental changes. The physiological stress response, which results in the secretion of corticosterone (cort), may be one way that animals adapt to these urban challenges. In particular, direct pre-natal hormonal transfer into the egg and parental care behaviors can have permissive effects on the offspring. We sampled from a population of house wrens (*Troglodytes aedon*) at two sites differing in degrees of urbanization. We measured incubation behavior and parental provisioning rates in addition to cort levels in eggs and developing young. We present results on the effects of urbanization on offspring growth. Results will reveal transgenerational effects of hormones due to environmental differences and lead to a better understanding of how maternal investment may promote adaptive offspring phenotypes in urban environments.

135-7 HERBERT, AM*; WILGA, CD; University of Alaska Anchorage; *aherbert3@alaska.edu*

Varied tooth plate shape, varied diet: Morphology of Spotted Ratfish Tooth Plates

Teeth are a critical aspect of feeding in most vertebrates and vary greatly in shape and size among taxa. A tooth can perform multiple functions or be specialized for a specific prey type. The tooth plates of *Hydrolagus colliei*, spotted ratfish (Holocephali), have a narrow occlusal surface and the overall shape of the tooth plate varies within an individual and among species. The occlusal edge varies in the presence and number of sharp points or bumps. Spotted ratfish feed on a variety of hard and soft prey, yet lack the molariform or pavement tooth plates typical of durophagous (feed on hard prey) fish. This study investigated the morphology of the tooth plates of spotted ratfish to quantify the shape variation and describe the material arrangement. Geometric morphometric outline analyses were performed on the tooth plates to evaluate the factors that contribute to shape variation. The principal components that described the majority of shape variation in the tooth plates were the dimension (height or width) and the occlusal edge (smooth vs. pointed). Polarized light microscopy was used to visualize the arrangement of the two materials that form holocephalan tooth plates: hypermineralized dentine arranged as columns of spheres within trabecular dentine. Hypermineralized dentine has a slower wear rate than trabecular dentine, therefore as the relatively softer trabecular dentine wears, leaving the relatively harder spheres as points on the occlusal edge. The spheres eventually wear forming a smooth occlusal edge, after which the cycle starts again. This process is responsible for the variation in tooth plate shape among contralateral elements as well as among individuals and is similar to the self-sharpening teeth of rodents and sea urchins.

26-7 HERNANDEZ, E*; VáZQUEZ, O; TORRUCO, A; RAHMAN, MD; School of Earth, Environmental, and Marine Sciences, University of Texas Rio Grande Valley; *eleazar.hernandez02@utrgv.edu*

Histological evidence of annual and lunar reproductive rhythms of Atlantic sea urchin, Arbacia punctulata in the southern Gulf of Mexico: changes in nutritive phagocytes in relation to gametogenesis

Environmental phenomena such as temperature, photoperiod, tidal cycle and lunar rhythm act as external cues that stimulate the reproductive activity of marine organisms. In this study, we report the annual and lunar reproductive cycles, and changes in nutritive phagocytes (NPs) in relation to gonadal maturation of Atlantic sea urchin (*Arbacia punctulata*, a primeval species). Monthly and weekly changes in gonadal development/maturation were observed histologically. In male, the testicular lobules were densely packed with sperm from June to August. In female, on the other hand, mature eggs first appeared in some ovaries in May, numerically increased from June to July, and decreased in August. During gametogenesis, NPs in both sexes were depleted from June to August. Histological observations revealed that the gonad developed synchronously around the new moon. Collectively, our results suggest that *A. punctulata* spawns several times during the summer months according to lunar cycle in the Gulf of Mexico. This is the first report, to the best of our knowledge, on annual and lunar reproductive rhythms of *Arbacia* species in the Gulf of Mexico, a marginal sea in the Atlantic Ocean surrounded by the North American continent.

P1-141 HERNANDEZ, AM*; WAINWRIGHT, DK; FARRELL, BD; Harvard University, Yale University; *ahernandez@g.harvard.edu*

Locomotion on a Leaf: Measuring the Microtopography of a Leaf Surface

For phytophagous insects, life on plants poses three fundamental challenges: nutrition, exposure, and attachment. Of these three challenges, the adaptations required for attachment and locomotion on plants is poorly studied, especially regarding the plant surfaces that these insects commonly encounter. Plants adapt to protect against these insects with structures that include spines, trichomes, glandular structures, surface waxes, and more. Descriptions of these plant surface characteristics are fairly common; however, quantitative measurements of plant surfaces are largely lacking and are often complicated to obtain. Measuring plant surfaces often requires labor-intensive imaging techniques such as cryo-SEM. For this study, we wanted to test if we could get a detailed surface topography for plants using a 3D profilometry technique called gel-based profilometry (GelSight, Inc). To address this question, we imaged sixteen plants species with the gel-based profilometry, using two different individuals per species and imaging the adaxial and abaxial surface of each leaf sample. Also, if numerous trichomes were present on the plant surface when first imaged, a second scan was taken with trichomes shaved off. This gave a more accurate surface profile for roughness measurements. All roughness measurements were generated using MountainsMap topography software. Overall, this simpler profilometry technique allowed us to achieve detailed measurements, and our initial results demonstrate small differences in the average surface roughness of these plant species. These variations, even those measuring a few micrometers, can make a significant difference in a small insect's ability to properly attach and locomote.

8-5 HERNANDEZ, J*; BELDEN, L/K; MOORE, I/T; Virginia Tech; *jess228@vt.edu*

Sexual activity and the cloacal microbiome in female tree swallows

Social behaviors play a role in shaping the diversity and composition of an animal's bacterial communities. Sexual activity, in terms of copulations, is one way through which bacteria can be transmitted socially between individuals. While considerable research has focused on the sexual activity or the microbiomes of animals, little research has focused on the intersection of the two. Here, we experimentally assessed how female sexual activity influences the cloacal microbiome of female tree swallows, *Tachycineta bicolor*. We administered estradiol, ATD (1,4,6-Androstatriene-3,17-dione), and control implants to female tree swallows at the beginning of the breeding season. Manipulation of hormonal activity via estradiol and ATD implants has been well established as an experimental method to increase and decrease sexual activity in female birds, respectively. Then, we assigned parentage of nestlings (a proxy for sexual activity) to determine the minimum number of sexual partners per female. We collected cloacal swabs from experimental females during incubation and subsequently used 16S rRNA gene amplicon sequencing to characterize each females' cloacal microbiome. Additionally, we collected body condition and fitness metrics, such as female mass and reproductive success, to determine if there were negative repercussions of potentially pathogenic cloacal bacteria. This study will broaden our understanding of how sexual activity plays a role in shaping the cloacal microbiomes of wild birds. By understanding how bacterial communities are shaped we can begin to untangle the potential tradeoffs associated with alternative behavioral strategies.

P1-195 HERNANDEZ, CA*; HEINICKE, M; GAMBLE, T; SILER, CD; DAZA, JD; University of Texas Arlington, Arlington and Sam Houston State University, Huntsville, University of Michigan, Dearborn, Marquette University, Milwaukee, The University of Oklahoma, Norman, Sam Houston State University, Huntsville, University of Texas Arlington; *nandezsendo@gmail.com*

Morphological Variation of Gliding Geckos and Other Closely Related Forms

Gliding geckos from the genus *Ptychozoon* are nested within a clade of chiefly Indo-Pacific gekkotans including *Lepidodactylus*, *Pseudogekko*, *Luperosaurus*, and *Gekko*. Recent molecular analyses indicate the non-monophyly of three of these genera (*Gekko*, *Lepidodactylus*, and *Luperosaurus*), suggesting the need for significant taxonomic rearrangement in this part of the gekkotan tree. Here we study a sample of 31 species representing all major subgroups within this clade. Whole body microCT data (CT and diceCT) was studied using a phenotypic data set of 863 traits. Using the current molecular hypothesis and taxonomy as a framework, we mapped morphological variation using the ACCTRAN optimization. The monophyly of this clade is supported by 3 non-ambiguous traits, 1) frontal interorbital/frontoparietal suture width ranging from 36-40%, 2) frontal supraorbital shelf demarcated medially by narrow shallow longitudinal furrow often bearing row of foramina, 3) frontal supraorbital shelf oriented dorsolaterally. The genus *Ptychozoon* is diagnosed by the lack of contact between the parietal and the supraoccipital, and several other characters may support recognition of this genus (low neural spines, expanded carpus, and extensive body flaps). The node ((((*G. badenni*, *G. grossmanni*) *G. preticolus*) (*Luperosaurus iskandari*, *Gekko vitattus*)) *Ptychozoon*) was supported by having the first sacral rib overlapping the acetabulum. This preliminary study has the potential to provide diagnostic characters required to resolve the taxonomy of this clade of Indo-Pacific gekkotans, and to understand better the morphological changes in gliding geckos.

P1-198 HERNANDEZ, AI*; SCANLAN, LG; COOK, W; SCHMITZ, L; Claremont McKenna College, Claremont, CA, Claremont McKenna, Scripps, and Pitzer College, Claremont, CA, Claremont McKenna, Scripps, and Pitzer College, Claremont, CA; *ahernandez20@students.claremontmckenna.edu*

Visual Fields in Mudskippers and Related Gobiid Fishes

Mudskippers are a charismatic assemblage of gobiid teleosts with extended phases of activity on land. Their amphibious lifestyle is considered to be coupled to a range of peculiar morphological features found in all major functional systems, including their visual system. For example, the eyes of mudskippers are placed far up dorsally in the head in comparison to other gobies, and common wisdom holds that mudskippers have large panoramic field of views. We tested this hypothesis with the ophthalmic reflex technique and quantified the static visual fields of the African mudskipper (*Periophthalmus barbarus*) and two related gobiids, the ornate rainbow goby (*Stiphodon ornatus*) and the flaming arrow goby (*Sicyopus zosterophorus*). Surprisingly, our results demonstrate that the static panoramic field of view of the African mudskipper is smaller (maximum extent ca. 290 deg) than the panoramic fields of the two related gobies (ca. 315 deg). However, the reduced panoramic field of the African mudskipper is traded for a region of binocular overlap that, while similar in terms of its maximum width, is nearly twice as long along the dorsal hemisphere. This pattern of reduced panoramic but enlarged binocular field in the African mudskipper holds true for visual field measurements in both air and water. Regions of binocular overlap are considered to improve visual performance, and we propose that the elongated binocular field of view seen in the African mudskipper may represent a selective advantage tied to their intertidal habitat at the water-air interface.

97-1 HERNANDEZ, LP*; OLSEN, AM; BRAINERD, EL; The George Washington University, Brown University; *phernand@gwu.edu*

Convergent means of breaking constraint: How alternative means of premaxillary protrusion have allowed fishes to break functional constraints

Breaking intrinsic developmental constraints can allow for the origin of morphological novelties that overcome functional constraints. Kinethmoid-mediated premaxillary protrusion within cypriniform fishes is one such novelty that breaks some of the morphological constraints seen in acanthomorph-type premaxillary protrusion. Within acanthomorphs significant protrusion requires integrated evolution of the neurocranium to facilitate sliding of a greatly elongated ascending process of the premaxilla, a constraint that is broken by the addition of a kinethmoid to the upper jaw linkage in cypriniforms. This additional linkage allows for increased kinematic flexibility allowing species to more easily feed throughout the water column. Such trophic flexibility also characterizes cyprinodontiform premaxillary protrusion, where the evolution of a novel ligament has allowed for correlated movement of the premaxilla and dentary with no concomitant integration with the neurocranium. Importantly, the impact that different morphological novelties can have on the evolutionary, functional, and ecological history of a specific lineage varies. In the case of kinethmoid-mediated premaxillary protrusion this novelty is associated with ecological diversification; the novelty opens a great number of trophic niches via increased performance. This cypriniform ecological and trophic diversification is also correlated with increased species diversification. Breaking structural constraints may have allowed for increased trophic diversification within these two discrete lineages.

P2-210 HERNANDEZ, LP; PRADO, MA*; MENDOZA-CASTILLO, JM; The George Washington University; *phernand@gwu.edu*

Histological diversification in the muscular anatomy of the palatal organ with Cypriniformes

Cypriniform fishes are characterized by several trophic novelties that have likely played an important role in the evolutionary success of this group. One such novelty, the palatal organ, is a dorsal mass of complexly arranged muscle fibers within the buccopharyngeal cavity tied to the branchial elements laterally and to the chewing pad caudally. In goldfish and carp this muscular pad is incredibly well innervated and produces localized protrusions that are used to trap edible items while bottom feeding. The palatal organ has only been investigated in those species with either a greatly hypertrophied vagal lobe (goldfish and carp) or species with a greatly hypertrophied palatal organ (Catostomidae and a few cyprinids). There is no comparative data on the histological structure of the palatal organ across the whole of Cypriniformes. The general assumption has been that the function of the palatal organ is conserved across cypriniforms, and requires the careful control made possible by a hypertrophied vagal lobe to function properly. Few have considered the possibility that the palatal organ may have become adapted for different functions during cypriniform evolution. However, before formulating testable functional hypotheses, the histological structure of the palatal organ in a diverse group of cypriniforms must first be analyzed. In this study, we investigate the muscular composition of palatal organs within 39 species, within several families. There was not a consistent difference in muscular architecture between members of Cobitoidea and Cyprinoidea. Nearly all species examined have some type of muscular palatal organ, characterized by a complex mesh of differently sized muscle fibers; one exception is *Gyrinocheilus*, which has very reduced muscularity of the palatal organ.

77-1 HERNDON, CJ*; FENTON, FH; Georgia Institute of Technology; *co.herndon@gmail.com*

Corazon espinado: microelectrode closed-loop control in cardiac tissue

Proper contraction of cardiac muscle relies on the coordinated propagation of transmembrane voltage, and disturbances of this propagation can result in deadly cardiac arrhythmias. One such disturbance strongly associated with the onset of fibrillation is a dynamical instability at the cellular level known as alternans, a beat-to-beat alternation in action potential duration (APD). A theoretical model known as the restitution hypothesis describes and predicts alternans via a return map in APD, and decades of work have shown that this model successfully reproduces many experimental observations. Furthermore, the restitution hypothesis likewise predicts a method for suppressing the onset of alternans which has been confirmed by some computational simulations of cardiac cells and tissue; however, few experiments have addressed these predictions due to its difficult implementation. In this talk, I will discuss our development of a closed-loop control scheme to experimentally address the predictions made by the restitution hypothesis via high resolution microelectrode recordings of transmembrane voltages in zebrafish, frog, and rabbit hearts. I will present our results which conclusively show the appearance of alternans in opposition to predictions made by theoretical models and provide an improved model that describes the dynamics.

S9-6 HERREL, A*; ARASPIN, L; PADILLA, P; COURANT, J; SERRA MARTINEZ, A; REBELO, R; IHLOW, F; BACKELJAU, T; MOKHATLA, M; GINAL, P; RöDDER, D; MEASEY, J; CNRS/MNHN, Paris, France, Uuniversity of Lisbon, Portugal, ZFMK, Bonn, Germany, RBINS, Brussels, Belgium, Stellenbosch University, South Africa; *anthony.herrel@mnhn.fr*

Rapid Local Adaptations in an Invasive Frog (Xenopus laevis): the Importance of Functional Trait Measurements to Predict Future Invasions.

The control and eradication of invasive species is an ever-increasing problem for wildlife management and conservation practitioners. Understanding the potential future spread of invasive species is critical to inform management decisions. One often used tool to predict future species distributions is species distribution modelling (SDM) under alternative scenarios of climate change. Although extremely relevant and insightful, most of these models suffer from two drawbacks: 1) the lack of physiological data describing the dependence of organisms on changes in temperature and hydric state; 2) they ignore any potential for adaptive differentiation of invasive populations. To test what the effect could be of these two parameters we focused on invasive populations of the invasive amphibian, *Xenopus laevis*. We collected data on anatomy and physiology (temperature dependence of performance traits) for animals from the source population as well as invasive populations. These data were then used to inform SDMs that predict future spread under different climate change scenarios and to test for the potential adaptive divergence of invasive populations relative to the native population in morphology and physiology. Our results show that incorporating physiological data in SDMs does provide different predictions on future distribution ranges with a much higher invasion potential than previously estimated. Furthermore, our results show rapid (less than 30 years) changes in morphology and physiology in different populations suggesting local adaptation. These results stress the importance of using biologically informed data to inform conservation practices.

50-7 HEWES, A*; SCHWENK, K; University of Connecticut, Storrs; *amanda.hewes@uconn.edu*

A Comparative Study of Lingual Prey Capture in Iguanian and Scincid Lizards

Among lizards, prey are captured with the tongue or the jaws. All iguanians are lingual feeders, and lingual feeding has evolved independently from jaw-feeding ancestors in several other squamate lineages. We compared the functional morphology of lingual feeding in the skink, *Tiliqua scincoides*, with several iguanians using high-speed videography, paraffin histology, and carbohydrate histochemistry. Each prey capture event involves tongue protrusion, tongue-prey contact, and tongue retraction. The proportion of each event devoted to contact and retraction is significantly longer in *Tiliqua* than in iguanians. Tongue-prey contact in *Tiliqua* also involved extensive foretongue spreading, greatly increasing contact area, whereas in iguanians, the contact area is typically minute. Preliminary phylogenetic PCA of tongue histological characters shows that *Tiliqua* groups with jaw-feeding scincid and lacertid taxa, not with iguanians. The iguanian tongue is covered with lingual glands, which are absent on the foretongue of *Tiliqua* and most other skinks. However, the sublingual glands in *Tiliqua* are hugely hypertrophied compared to iguanians and to a lesser extent, jaw-feeding skinks. All taxa secrete neutral mucins, but a preliminary analysis of AB-PAS staining intensity suggests that *Tiliqua* secretes more mucins per unit area than *Sphenodon*, iguanians, and jaw-feeding scincids and lacertids, suggesting greater viscosity and ‘stickiness' of *Tiliqua* mucus, a hypothesis we are pursuing with materials testing. All data suggest that *Tiliqua* compensates for a weak adhesive mechanism compared to iguanians by secreting more, stickier mucus, increasing area of contact, and slowing retraction speed to prevent prey loss.

57-1 HEWS, D*; LISIČIĆ, D; GLOGOŠKI, M; BLAŽEVIĆ, SA; HRANILOVIĆ, D; HEWS, Dia; Indiana State Univ, Terre Haute, Univ Zagreb, Faculty of Science, Croatia , Univ Zagreb, Faculty of Science, Croatia; *diana.hews@indstate.edu*

Behavior and Neuroendocrine Differences in Island and Mainland Populations of Wall Lizards (Podarcis sicula): Do They Mirror Typical Within-Population Variation in Stress-Coping Styles?

Alternative reproductive tactics may fit other paradigms that consider behavior differences, including stress-coping styles and personality: consistent individual behavioral differences in multiple contexts or consistent within-individual behavioral correlations. Behavior types often differ in neuroendocrine measures. While many vertebrates show such behavior variation, the ecological contexts favoring these types are less clear. Studying adult males in an island and a mainland population of the Italian Wall Lizard, *Podarcis sicula* , we asked if personality/coping styles typically described for a single population could represent extremes of a continuum, with one personality (less reactive) expressed on the island and the other (more reactive) on the mainland. In the field, we measured either antipredator behavior following a simulated predator approach (flight initiation distance, FID; hiding duration, HD), or breeding-season plasma testosterone (T) and corticosterone (CORT; baseline and 30-min post capture) level in two sets of males, and in the lab we measured behavior and brain monoamines for another set. Island males had lower condition (scaled mass index), shorter HD, lower T, lower aggression, higher open-field activity and lower brain levels of norepinephrine and epinephrine. Novel object exploration, FID, baseline CORT, 30-min CORT, brain dopamine and serotonin did not differ. Future work should examine more populations, and identify selective factors, such as differences in predators and life-history measures, that favor expression of different stress-coping styles in different populations.

40-2 HEYDARI, S*; PO, T; MCHENRY, MJ; KANSO, E; University of Southern California, University of California, Irvine; *sinaheyd@usc.edu*

Sea Star Inspired Crawling and Bouncing

The oral surface of sea stars is lined with arrays tube feet that enable them to achieve highly controlled locomotion on various terrains. The activity of the tube feet is orchestrated by a nerve net that is distributed throughout the body; there is no central brain. How such a decentralized nervous system produces a coordinated locomotion is yet to be understood. We developed mathematical models of the biomechanics of the tube feet and the sea star body. In the model, the feet are coupled mechanically through their structural connection to the sea star body. We formulated hierarchical control laws that capture salient features of the sea star nervous system. Namely, at the tube foot level, the power and recovery strokes follow a state-dependent feedback controller. At the system level, a directionality command is communicated through the ring and radial nerves to all tube feet. We studied the locomotion gaits afforded by this hierarchical control model. We find that these minimally-coupled tube feet coordinate to generate robust forward locomotion, reminiscent of the crawling motion of sea stars, on different terrains and under various heterogeneity in the tube feet parameters and initial conditions. Our model also predicts a transition from crawling to bouncing consistent with our experiments performed on *Protoreaster nodosus*. We conclude by commenting on the implications of these findings for understanding the Echinoderms decentralized nervous system and their potential application to autonomous robotic systems.

36-1 HILL, EC*; JARMAN, MJ; BUTLER, MA; University of Hawaii; *hille7@hawaii.edu*

The Resolution Solution: Increasing Nodal Support in the Problematic Phylogeny for a Large Adaptive Radiation of Papuan Asterophryne Frogs

With over 300 species, the Asterophryinae subfamily is the largest part of the largest amphibian family in the world. Centered in New Guinea and its satellite islands, it forms an adaptive radiation based on microhabitat use. Historically, intergeneric relationships have been difficult to resolve using established morphometric techniques due to phenotypic convergence. However, recent molecular studies have shed light on deeper nodal relationships beginning with Kohler and Gunther (2006) including 40 species, Rivera et al. 2017 including 155 species, and most recently Tu et al. 2018 including 134 species. Unfortunately, many deeper nodes, including the large genus Oreophryne remained unresolved, which may have resulted from rapidly evolving mitochondrial loci that have proven difficult to sequence for all taxa (CYTB, ND4). In addition, some regions of uncertainty within the tree may be due to gaps in geographic sampling. We conducted additional expeditions to Papua New Guinea and collected over 50 new species of Asterophryne from five locations (1 satellite island and 4 mainland sites). We sequenced the loci used in Rivera et al. 2017 (SIA, BDNF, NCX-1, CYTB and ND4), in some cases designed new primers to amplify the fast evolving loci (ND4) for problematic taxa to complete the dataset. Using Bayesian inference as implemented in MrBayes and Bayesian inference + time calibration as implemented in BEAST, we recovered a substantially more resolved phylogeny. We compared the resulting topologies and nodal support to previous phylogenies and investigated the patterns of ecomorph evolution. This analysis will provide a clearer picture of the patterns of early divergence in this particularly fascinating adaptive radiation of microhylid frogs.

S1-10 HINDLE, AG; University of Nevada Las Vegas; *allyson.hindle@unlv.edu*

Diving deep: Mechanistic insights into the extreme physiology of Antarctic seals

Weddell seals are a deep-diving Antarctic species that have been the subject of many seminal studies on diving physiology and behavior. Isolated dive-hole experimental paradigms allowed physiological telemetry and biochemical samples to be collected from unrestrained and freely foraging seals. From these studies, we now recognize the Weddell seal as an elite diver, capable of surviving profound hypoxemia upon submergence, and exhibiting extreme cardiovascular adjustment to distribute limited oxygen stores to key tissues. The mechanisms that define cardiovascular control and provide cell-level protection against hypoxia and subsequent reoxygenation represent the next level in our understanding of the strategies of this extreme breath-hold diver. Neither genetic nor pharmacological manipulations are possible in Antarctic marine mammals, however the availability of a sequenced genome as well as emerging primary cell culture resources provide new avenues to apply modern molecular tools to these questions. Targeted analyses have revealed limited but significant differences in protein coding sequences that can be linked to diving traits such as oxygen storage and vasoregulation. On the other hand, comparative genomic analyses have identified gene regulation as the major signal of evolutionary innovation in the Weddell seal. In particular, differential expression of microRNAs as well as HIF-1a-regulating transcription factors may be important aspects of cardiovascular physiology that enable Weddell seals to dive long and deep.

P1-197 HODGE, JR*; PRICE, SA; WAINWRIGHT, PC; Clemson University, University of California, Davis; *jennifer.renee.hodge@gmail.com*
Ancestral effects on convergence in zooplanktivorous butterflyfishes
Establishing patterns of morphological convergence among organisms that share similar ecologies is the first step toward understanding the interplay between adaptation and constraint. In fishes, zooplanktivory is a specialized type of foraging often associated with particular morphological traits including large eyes, an emarginate caudal fin, a slender body shape and small body size. However, the morphological trends associated with zooplanktivory have yet to be described comparatively across a broad taxonomic scale and the effects of the ancestral foraging condition on the expected trajectories of morphological change remain unknown. As a first look we focus on marine butterflyfishes (family Chaetodontidae), a group that includes species with multiple forms of benthic foraging as well as zooplanktivory. Evolutionary model-fitting indicates that zooplanktivorous butterflyfishes are converging on eye size, caudal fin shape, body depth and body size optima that are separate from benthic foraging lineages. We find that the ancestral foraging strategy impacts both the direction and magnitude of morphological changes following transitions to zooplanktivory for some, but not all of the aforementioned traits. Eye diameter and maximum body size increase when lineages transition from coral grazing but decrease with transitions from benthic hunting. In contrast, caudal fin shape and body depth change in the same direction following transitions from each form of benthic foraging, becoming more emarginate and shallow-bodied, respectively. Our results emphasize the importance of considering the effects different ancestral states may have on patterns of morphological convergence and the description of ecomorphs.

P2-100 HODGSON, ML*; WEBBER, RL; MCGAW, IJ; WYETH, RC; St. Francis Xavier University, Memorial University; *x2016pkc@stfx.ca*
Can problem-solving during natural foraging give insight into behavioural innovation by the American Lobster, Homarus americanus?
Phenotypic plasticity is a key adaptation for organisms facing a variable environment. In animals, behavioural innovation can contribute substantially to such plasticity. An increasingly common approach to studying behavioural innovation has been to assess problem-solving abilities when an animal is challenged with an extractive foraging task. Most studies to date have focused on vertebrates. However, invertebrates with variable prey types and that have diverse motor capabilities could also benefit from behavioural innovation in foraging. The American Lobster, *Homarus americanus*, is an omnivorous generalist that inhabits variety of benthic environments with a broad array of potential diet items and that also demonstrates a wide range of motor capabilities. Thus, our goal was study behavioural innovation in this species by testing the problem-solving behaviours of lobsters performing an extractive-foraging task in the field. We constructed solvable-task containers that were baited with *Sebastes marinus*, a common bait used in the lobster fishing industry. The baited container was attached below a tripod deployed in lobster habitat. A downwards-facing camera on the tripod recorded the lobsters' behaviours. We are developing an ethogram of foraging behaviours from the videos, and are quantifying the frequency and duration of different behaviours in advance of solving the task. If behavioural innovation contributes to foraging success in lobsters, larger (i.e. older) lobsters should be more adept at solving the task than smaller (i.e. younger) lobsters and/or should do so with a greater variety of behaviours. Our findings will improve understanding of problem-solving abilities of crustaceans, and contribute towards a more comprehensive view of behavioural innovation across animal phyla.

80-2 HODINKA, BL*; ASHLEY, NT; Simon Fraser University, Western Kentucky University; *brett_hodinka@sfu.ca*
Effect of sleep loss on executive function and baseline 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 acute sleep loss (SL) is unknown. To assess the effects of SL, wild-caught male longspurs were placed in captivity (12L:12D) and trained for 2 months using a series of memory tests, including color association and spatial learning to assess executive function. Birds were then placed in automated sleep fragmentation cages that utilize a moving wire to force movement every 1 min (60 arousals/h) during 12D (inactive period) or control conditions during 12L (active period). After a single round of SL (or control) treatment, color association and spatial learning tests were conducted. Baseline plasma corticosterone concentration, body mass, and satiety were also assessed. SL significantly elevated corticosterone levels and increased accuracy during the color association test, but not the overall time required to complete the test. SL had no effect upon spatial learning, body mass, or satiety. Taken together, these results suggest that Lapland longspurs exhibit a behavioral, but not a physiological, resilience to acute SL.

P3-230 HOESE, WJ*; BURNAFORD, JL; Cal State Univ Fullerton; *bhoese@fullerton.edu*
Southern California Ecosystems Research Program: A Year-round Program Fostering Undergraduate Ecology Research
The Southern California Ecosystems Research Program (SCERP) is a two-year undergraduate research-training program that fosters participation of minority and urban-raised students in undergraduate research in ecology. Scholars start with a 5-week intensive summer field-research course in cohorts of 5-6, and progress to independent academic-year research with faculty mentors in the Department of Biological Science. Second-year scholars return as summer peer-mentors for the new scholars. This promotes group cohesion and develops leadership skills in continuing scholars. Over the course of two years, each student participates in five original research projects: four short-term group projects and one long-term independent project; scholars present each project at a scientific meeting. During the academic year, scholars enroll in weekly professional development seminars led by SCERP faculty. Our core goal is to train students to be independent researchers, while cultivating written and oral communication and critical thinking skills, guiding them to develop a research ethic that prepares them for graduate study and future careers. We remain connected with our former scholars; over 90% of SCERP graduates (N=83) are employed in biology-related careers. We have been particularly successful at placing students in M.S. (32), Ph.D. (11), and single-subject teaching credential (5) programs. Established in 2002 with support from the NSF that ran until 2016, SCERP currently operates with support from philanthropic donations, private foundations, and the university. SCERP engages advanced students in research, prepares scholars for graduate school and future careers in biology, and creates a community of scholars that remain connected to the program and CSUF Biology.

P1-54 HOFFMAN, DK*; UYEDA, JC; NESBITT, SJ; Virginia Tech; *devinkh5@vt.edu*

Variable Evolutionary Rates in the Morphology of the Extinct Clade Aetosauria (Reptilia: Archosauria)

Though evolutionary rates of living organisms can be estimated using molecular data, paleontological studies of morphology can be hindered by a reliance on parsimony, which fails to account for saturation and homoplasy. One such parsimony-based study used the Aetosauria, a clade of armored, crocodylian-line archosaurs, whose osteoderms are debated to evolve faster than the rest of the skeleton, and may be too homoplastic for reconstructing deeper clade relationships. One previous attempt to resolve the debate was limited to sub-setting data by the parsimony framework used. We use this same dataset (26 taxa, 83 characters) and implement partitioning, then a phylogenetic reconstruction in a ML framework to better address the debate. Using PartionFinder 2.0 we found osteoderms (= 33 characters) evolve at a different rate than the endoskeleton (= 50 characters). When we used this dataset to reconstruct the phylogeny of aetosaurs, with variable gamma distributed rates, we found osteoderm characters had a lower global evolutionary rate than endoskeletal characters. We conclude that though osteoderms evolve slower on average, the different gamma shapes show osteoderms are more variable in their evolutionary rates than endoskeletal features. Although the phylogeny we generated is identical in topology to the parsimony hypothesis, when using the same collapse rules, only by phylogenetic comparative methods (PCMs) can we address the debate in evolutionary rates. By accounting for rate heterogeneity across characters, we can resolve phylogenetic hypotheses with better estimates of support. With these refined hypotheses and PCMs to trace evolutionary rate shifts for these extinct clades, we inform our understanding of the macroevolutionary processes surrounding faunal turnovers, mass extinctions, and radiations.

P1-251 HOFFMAN, AJ*; FINGER, JW; WADA, H; Auburn University; *ajh0077@tigermail.auburn.edu*

Mild Developmental Stress and its Effects on Adult Tissue Oxidative Status

Oxidative status has been implicated as playing a vital role in physiological processes and mediating life histories, as well as adaptive phenotypic adjustments to stressors. The antioxidant defense system is also highly plastic in vertebrates, and a significant amount of variation in individuals' ability to resist oxidative stress as adults can be explained by the conditions experienced during development. Thus, the early life environment can cause a potentially beneficial alteration in the antioxidant system. At the same time, many studies have found differences in antioxidant levels and the amount of damage sustained between tissues in response to the same stressor. One possibility is that organisms prioritize protection of certain tissues over others, potentially those with greater impacts on fitness. We tested the hypothesis that male zebra finches (*Taeniopygia guttata*) exposed to a chronic mild stressor early in life will be better able to cope with a high stressor as adults, and will be characterized by upregulated antioxidant enzymes and decreased oxidative damage compared to the controls. Furthermore, we predict differences between tissue types, and expect reproductive tissue to have greater levels of protection than other tissues sampled. To test this hypothesis, we exposed juvenile male zebra finches to a prolonged mild heat stress (38° C) or control (22° C) temperature over 28 days. As adults, the males were then exposed to either a high heat stressor (42° C) or control temperature for 3 consecutive days. Four hours following the final treatment bout, birds were euthanized and the organs were collected. Using Western blots we quantified antioxidant enzyme levels [superoxide dismutase (SOD-1 and SOD-2) & glutathione peroxidase-1] and lipid oxidative damage (4-hydroxynonenal) in the liver and testes tissue.

P1-17 HOGAN, AVC*; BALANOFF, AM; BEVER, GS; Johns Hopkins School of Medicine, MD, Johns Hopkins University, MD; *ahogan7@jhmi.edu*

Developmental and Evolutionary Scaling in the Olfactory System of Birds

Birds show large variation in olfactory morphology, including the olfactory bulb and olfactory turbinates, yet studies on the relationship between these structures are lacking. To test the hypothesis that these olfactory elements co-vary across development and evolution, we first examined their scaling relationship in a developmental series of the chicken. Results show coordinated growth, with the olfactory bulb and olfactory turbinate scaling isometrically, and developing with some independence from other neighboring structures. Such a high degree of coordination in the growth of these structures is somewhat surprising given that olfactory epithelium extends over more than just the turbinate and may theoretically expand or contract independent of turbinate morphology. Numerous possibilities exist, but it may be that the size of the olfactory cavity is constrained by the surrounding craniofacial architecture or that the respiratory function of the nasal cavity limits the forward spread of olfactory receptors within the nasal cavity. Our first step in exploring these possibilities was to determine whether ontogenetic coordination translates to conserved patterns of phylogenetic isometry. Initial sampling, which included all the major avian crown clades, indicates a significant level of phylogenetic allometry, but with isometry dominating within certain groups, including Passeriformes. Although no specific hypotheses can currently be ruled out, our data indicate a complex structural history for avian olfaction. One that needs to be studied in combination with both the physiology of olfaction in mind, as well as the structure of neighboring systems.

54-6 HOLDING, ML*; STRICKLAND, JL; RAUTSAW, RM; MASON, AJ; HOFMANN, EP; HOGAN, MP; COLSTON, TJ; NYSTROM, G; GRAZZIOTIN, F; GIBBS, HL; ROKYTA, DR; PARKINSON, et al., CL; Florida State University, Clemson University, Clemson University, Florida State University, Instituto Butantan, Ohio State University; *matthewholding28@gmail.com*

Comparative analysis of venom complexity and diet diversity in rattlesnakes using a novel, genome-wide phylogeny

Organisms are more than the sum of their parts, making the study of complex integrated phenotypes imperative for understanding the interplay between the evolution of traits and the evolution of species. Molecular trait complexity is particularly important in species interactions, where more diverse networks of species interactions may select for molecular complexity in offensive or defensive traits, such as secreted toxins. Animal venoms, as injected secretions with a tractable genetic basis, are optimal systems for testing the hypothesis that the evolution of more complex molecular traits is associated with interacting with diverse prey taxa. The rattlesnakes (Crotalus and Sistrurus) are the most speciose group of vipers, consisting of ~50 currently described species. We have collected venom glands of 147 individuals snakes, representing most rattlesnake lineages. We use over 1500 nontoxin sequences from venom gland transcriptomes to infer the phylogeny of rattlesnakes, and characterize the composition and complexity of toxin expression in the transcriptomes and in chromatographic profiles of whole venom. We combine a novel, dated phylogeny of rattlesnakes, venom gene expression data, and published diet data to test the hypothesis that more complex venoms evolve in response to a more taxonomically complex diet. Our work provides new insight into the evolutionary history of this complex and iconic group, and relates complexity in patterns of gene expression to the complexity of ecological interactions an organism must face.

P1-231 HOLDING, ML*; TREVINE, V; ZINENKO, O; STRICKLAND, JL; RAUTSAW, RM; HOFMANN, EP; HOGAN, MP; GRAZZIOTIN, FG; PARKINSON, CL; SANTANA, SE; DAVIS, MR; ROKYTA, DR; Florida State University, Instituto Butantan, V. N. Karazin Kharkiv National University, Clemson University, University of Washington, Burke Museum of Natural History and Culture, Illinois Natural History Survey; *matthewholding28@gmail.com*

The beak of the snake: fang length evolution in vipers is predicted by diet

Fangs, stingers, spines, and harpoons are used by diverse animal taxa to inject venom into their prey. Strong selection on venom composition has been repeatedly documented, and we might expect the venom injection apparatus to be under similarly strong selection to meet specific functional demands. Snakes in the family Viperidae (true vipers and pitvipers) consist of ~320 species widely studied by both ecologists and evolutionary biologists. Vipers provide an opportunity to determine how venom injection systems evolve in response to functional demands of prey killing. Utilizing museum collections, we obtained measurements of fang length in >2000 individual specimens representing 200 viper species. We then leverage data collected from over 100 published diet studies to test the hypothesis that longer fangs evolved in response to demands associated with feeding on mammalian prey. We find support for this hypothesis, where the percentage of mammals in viper diets is positively correlated with relative fang length. Finally, when controlling for head size, the Gaboon Viper is dethroned as the snake species with the longest fangs, and overtaken instead by the Speckled Forest Pitviper of South America. Venom and the venom delivery system merit further work to determine if they are part of a broader functional and evolutionary module that facilitates feeding in venomous animals.

S4-9 HOLEKAMP, K. E.*; MONTGOMERY, T. M.; STRAUSS, E. D.; Michigan State University, University of Nebraska; *holekamp@msu.edu*

Social competition and cooperation affect reproductive success of female spotted hyenas

The reproductive biology of many female mammals is affected by their social environment and their interactions with conspecifics. In mammalian societies structured by linear dominance hierarchies, such as that of the spotted hyena (*Crocuta Crocuta*), a female's social rank can have profound effects on both her reproductive success and her longevity. In this species social rank determines priority of access to food, but it also affects females' use of space, energetics, growth, den attendance and social networks. Rank effects appear to be mediated in part by nutrition, prenatal androgen exposure and immune function. Infanticide by higher-ranking females may also function to suppress reproduction in subordinate females. Despite the apparent costs of gregariousness to low-ranking females, gregariousness can also have positive effects on their fitness. These positive effects appear to result from having female allies, both kin and non-kin, who cooperate to advertise and defend a shared territory, acquire and defend food resources, maintain the status quo, and sometimes also to rise in social rank.

104-4 HOLLOWAY, ND*; MACKENZIE, DS; RILEY, BB; Texas A&M University; *nholloway@bio.tamu.edu*

Evidence for expression of the sodium iodide symporter (NIS) in novel neural and ovarian locations in teleost fish

Iodine, an essential component of thyroid hormone, can only be obtained through the diet. The sodium iodide symporter (NIS) transports iodide across mammalian intestinal and thyroid epithelia to deliver iodide for thyroid hormone production. To determine whether a homolog of NIS performs a similar function in teleost fish, we confirmed expression of a homolog of mammalian NIS in both sub-pharyngeal thyroid follicles and intestine in multiple teleost species, indicating a conserved mechanism for intestinal-thyroid iodine transport across vertebrates. We then examined expression in these locations during development using *in situ* hybridization (ISH) staining of zebrafish (*Danio rerio*) embryos. This revealed expression of *nis* as early as 2 days post fertilization (dpf) along the dorsal surface of the yolk sac, suggesting a function to import iodine from yolk, potentially placed there by maternal deposition. To evaluate this possibility, RT-PCR and further *in situ* staining of ovarian tissue in gravid female zebrafish confirmed *nis* mRNA presence in the ooplasm and granulosa layer of early stage follicles. This suggests NIS can function to transport iodine into the yolk, and that maternally-deposited NIS mRNA may be available for early embryogenesis. Additionally, ISH in embryos revealed *nis* expression in the central nervous system throughout days 2-5 dpf, with adult whole brain ISH localizing expression in the hypothalamus, cerebellum, and optic tectum. RT-PCR on whole brain tissue from 5 species of adult fish representing 3 taxonomic orders likewise revealed robust expression. These unexpected, non-canonical locations suggest novel, as yet undescribed reproductive and neural functions of NIS in teleost species.

P1-86 HOLLOWAY, F*; DE BRUIJN, R; KHOSHABA, E; LOPES, PC; Chapman Univ.; *lopes@chapman.edu*

Neurogenomic Changes During the Transition to Parental Care in Virgin Japanese Quail

The extent to which parental care is critical for offspring survival varies among species. Japanese quail are precocial birds, but parental behavior is still critical during the first few weeks post-hatch as chicks can die from hypothermia if not kept warm by parents. Interestingly, as Japanese quail have been selected for egg production, most captive-bred quail do not exhibit spontaneous parental behavior. Previous research, however, has shown that induction of parental care in this species can be done through a process of overnight sensitization to chicks. We used this model to study the neurogenomic alterations associated with the transition to parental care behavior in birds with no reproductive experience. To do this, we compared the transcriptome of quails exposed to chicks overnight to that of control (no overnight exposure) birds in three brain regions (hypothalamus, BNST and Tn). To confirm that the induction worked, we observed all adults in the presence of new chicks for 20 min the morning after sensitization and quantified parental and aggressive behaviors. We found an upregulation of Urocortin 3 (*Ucn3*) in the hypothalamus of sensitized animals of both sexes relative to controls, while Neurotensin (*NT*) was upregulated only in sensitized females, and *Btg2* downregulated only in sensitized males. In mammals, UCN3 seems to potentiate the neuroendocrine response to stress and to have a role in social memory. NT is linked to rodent maternal care and is upregulated in hypothalamic regions of postpartum mice. BTG2 may be involved in neuroplasticity. As these peptides have not previously been associated with modulation of parental behaviors in birds, our work may therefore contribute to the discovery of novel potential modulators of avian parental care.

S10-5 HOLZMAN, R*; OLSSON, K; Tel Aviv University; *holzman@tauex.tau.ac.il*
Using performance landscapes to understand adaptive diversification within fishes
The complex relationship between form and function provides the foundation for the generation of organismal diversity. Selection acts directly on performance, which is the product of interacting phenotypic components. Thus, the ability to predict how multiple phenotypic traits interact in determining performance is key to understanding the evolution of complex functional systems. Here, we demonstrate how performance landscapes, which map the performance consequences of different phenotypic combinations, can be used to understand adaptive evolution of suction feeding fishes. A hydrodynamic model of the suction forces exerted on the prey allows us to explore the complex performance space for aquatic predator-prey interactions, and enables us to predict prey capture performance for any given phenotype. Using this model, we generated performance landscapes for three prey types that pose different challenges to the predators, namely planktonic prey that senses the hydrodynamic disturbance generated by the predator, visually oriented prey that escapes the looming predator and attached prey that clings to its holdfast. We explored the topography of the multidimensional performance landscape and determined it to be rugged with multiple local performance peaks. We used the landscape to generate a-priori hypotheses regarding the position of extant species relative to the theoretical optima in this performance space, which we tested by mapping prey-capture kinematics of fishes from four radiations onto the three generated performance landscapes. Whereas previous research generally focused either on studying phenotypic diversification using morphological traits, or on the biomechanical basis of performance, we integrate these approaches using a detailed mechanistic model to explore how a highly nonlinear and multidimensional performance space shapes organismal diversity in suction feeding fishes.

97-7 HOLZMAN, R*; EYAL, M; MALUL, D; JACOBS, C; Tel Aviv University, Technion; *holzman@tauex.tau.ac.il*
You suck, We suck, Everyone sucks: Homo sapiens display poor suction feeding performance
Hardy's Aquatic Ape Theory proposes that humans evolved to become a two-legged hairless creature via a semi-aquatic diversion that took place around the Pliocene, and that access to marine-based food was a major selective force for this diversion. Among aquatic vertebrates, the most common prey capture strategy is suction feeding. By rapidly expanding the mouth cavity, suction feeders generate a fluid flow outside of their mouth, drawing prey inside. Suction feeding has repeatedly and secondarily evolved in aquatic vertebrates, including marine mammals. However, it is unclear whether humans possess this ability, as could be expected based on their proposed (albeit controversial) history. Using a high-speed flow visualization technique, we characterized the spatio-temporal patterns in the flow fields produced during suction feeding in *Homo sapiens*. We found that mouth opening speed was an order of magnitude slower in *Homo sapiens* compared to fishes. The speed of suction flows was 5x slower than expected based on *H. sapiens* gape diameter (ca 5 cm), and equivalent to that of fish with a gape of about 1cm. Further, flows were not unidirectional; high efflux out of the mouth was observed during mouth closure. Taken together, our results indicate that *H. sapiens* are poor underwater feeders. Adaptations for suction feeding either never existed or have regressed since the Pliocene. Our study therefore failed to provide support for the Aquatic Ape Theory.

P1-164 HOM, KN*; TERRAZAS, M; FORLANO, PM; CUNY Graduate Center, St. Mary's College, CUNY Brooklyn College; *khom@gradcenter.cuny.edu*
Oyster toadfish calling in noisy NYC waters
Aquatic animals that require sound to communicate and find mates need to filter out relevant signals from noise in their environment. There are limited studies on how ecologically relevant noise affects aquatic life, and even fewer studies examining the effect of noise on fish that use sound to communicate for reproduction. An excellent model to examine the effect of anthropogenic noise on acoustic behavior is the oyster toadfish (*Opsanus tau*). *O. tau* use an advertisement called the "boatwhistle", to find mates yet appear to thrive and reproduce within the waters surrounding New York City, a large and noisy urban environment. The goal of this study was to categorize and quantify noise and *O. tau* vocalizations and examine any changes in acoustic behavior in response to noise. We hypothesized that over a 24 hr period, the number of *O. tau* calls would be greatest when anthropogenic noise is lowest (after dark), and toadfish will temporally space their calls to avoid masking by noise throughout the day. We collected passive acoustic recordings from Manhattan's Pier 25 (Hudson River, NY) near known *O. tau* breeding sites. We quantified the number of *O. tau* vocalizations and categorized types of noise, counted the number occurrences, and calculated the duration of anthropogenic noise over 24 periods. We found that anthropogenic noise (i.e., construction noise and boat traffic) is within *O. tau's* hearing range and mostly occurs during daylight hours. *O. tau* call both day and night but 70% of calls happen between sunset and sunrise. Additionally, we observed an inverse relationship between abundance of noise and the number of *O. tau* calls throughout a 24 hr period, suggesting a behavioral strategy for communication in a noisy environment.

138-5 HOOD, KE*; NAVARRO, E; HURLEY, LM; Indiana University, Bloomington, IN; *hoodk@indiana.edu*
Playback of female rejection vocalizations modifies male house mouse (Mus musculus) behavior
Sexual communication is frequently studied from the perspective of male senders signaling to female receivers. However, these interactions are often dynamic with both male and female partners actively sending and receiving signals. Both male and female house mice (*Mus musculus*) signal during sexual interactions. Males primarily produce ultrasonic vocalizations (USVs) that are correlated with investigation and mounting of females, while females primarily produce broadband vocalizations (BBVs) that are correlated with non-vocal rejection behaviors such as kicking and lunging. In order to test the effect of BBVs separately from non-vocal rejection behaviors, male CBA/J mice (n=19) were separated from freely-behaving females with a Plexiglass barrier. In this paradigm, females did not produce any BBVs of their own and males continuously produced high levels of USVs. In response to BBV playback males significantly decreased USV production and increased digging behavior. To identify the role of vocalization structure in the male response males (n=8) were presented with playback of white noise bursts replacing BBVs, which also caused USVs to decrease. Males (n=8) presented with an anesthetized non-behaving female also decreased USV production to BBV playback, although males with anesthetized females produced significantly fewer USVs overall than males with awake females. Overall, these results indicate that males modify their behavior in response to playback of a female signal but this response is strongest in the specific context of an awake female partner. The response may generalize to all broadband noise, including white noise bursts. Response to female BBVs may be used in the future to better understand the mechanisms underlying auditory perception in male mice.

S4-3 HOOK, KA*; FISHER, HS; University of Maryland, College Park; *khook@umd.edu*

The importance of female reproductive traits: from mice to seed beetles

When females mate with more than one male in a reproductive cycle, post-copulatory sexual selection is hypothesized to favor male traits that allow them to outcompete rivals in their race to the egg and female traits that allow them to exercise choice in sperm use. This in turn can lead to conflict between the sexes and a co-evolutionary arms race as they both attempt to optimize their fitness. While it is well understood that these evolutionary processes can critically influence both male and female traits, female traits driven by post-copulatory sexual selection remain relatively understudied. Here I present my research investigating female reproductive traits in both rodents and arthropods. Using a cross-species comparison of six species of mice in the genus *Peromyscus*, we recently characterized the viscosity of the fluid collected from various regions of the female reproductive tract using a combination of optical microscopy and fluorescent nanoparticle tracking. From these data, we assessed the relationship between fluid complexity and mating system and established when and how subtle changes in the microenvironment impacts the collective motion of sperm. My previous work in seed beetles (*Callosobruchus maculatus*) allowed me to establish the pivotal role of female mating behavior in sperm use patterns and sperm competition. My work also suggests that delayed female remating is adaptive for females and is not mediated by sexual conflict driven by male manipulation via components of the ejaculate, as is often assumed. Hinging on male-female and sperm-female interactions, these studies highlight the importance of investigating female traits as well as the co-evolutionary interactions between the sexes for understanding reproductive traits driven by post-copulatory sexual selection.

P1-169 HOOVER, EL*; DICKERSON, S; BECK, H; OUFIERO, CE; Towson U; *ehoove2@students.towson.edu*

Modulation of takeoff kinematics in a nocturnal gliding mammal under varying photic environments.

The photic environment can influence whole-organismal performance as motor output may be adjusted based upon the amount of sensory information being received. For example, the amount of light available for an organism to see can affect function as the optic flow and depth perception may be reduced. Therefore, organisms in low light environments may have to adjust their motor output to compensate for reduced visual information. To date, most studies have examined animal performance under full spectrum light, including nocturnal animals. Our understanding of whole-organismal performance is therefore limited to organism's functioning under full spectrum light, and may not represent performance under more ecologically relevant conditions. The goal of this study was to determine the effect of ambient light level on the takeoff performance of a nocturnal gliding mammal. Specifically, using four trained sugar gliders (*Petaurus breviceps*) we examined their kinematics during takeoff under full spectrum light (lux = 97.17 ± 15.53 (s.d.)) and near dark (lux = 0.939 ± 0.388 (s.d.)) at fixed takeoff heights and distances. Using mixed models, we found that under near dark conditions gliders had increased takeoff heights, vertical velocities and body angles. However, there was no difference in total velocity, acceleration, or kinetic power. These results suggest that when visual information is limited, gliders jump higher and faster at takeoff, potentially to increase their glide height and prolong their glide distance. This may help compensate for the limited visual information to ensure they reach their target.

78-1 HOOVER, AP*; KATIJA, K; The University of Akron, Monterey Bay Aquarium Research Institute; *ahoover1@uakron.edu*

Manse and Tail: Flow structure and morphological constraints of the filtration feeding mechanisms by giant larvaceans

Giant larvaceans (Bathochordaeus) are found throughout the world's midwater region and play an important role in the carbon cycling of these ecosystems. Even though they inhabit the mesopelagic region, larvaceans still manage to be successful filter feeders, with filtration rates of as high as 80 L/hr. This feat is accomplished with the help of a mucus house structure that is built and discarded daily. The house structure allows the larvaceans to direct flows and particles to the filters and mouth of the organism. The flows in the house are driven by the motion of the larvacean tail, which is located at the end of the house filter and oscillates due to a complementary set of muscles on both sides of the tail. This talk will examine this fluid dynamics surrounding this pumping mechanism by using numerical models and experiments to explore the interplay between the tail, the house, and the resulting fluid dynamics that drive this pump. The fully-coupled fluid structure interaction problem is solved using an adaptive and parallelized version of the immersed boundary method (IBAMR).

P2-79 HOPE, SF*; KENNAMER, RA; GRIMAUDO, A; HALLAGAN, JJ; HOPKINS, WA; Virginia Tech, University of Georgia, SREL, Stockton University, New Jersey; *shope@vt.edu*

Does Within-Nest Variation in Incubation Temperature Lead to Differences in Competitive Ability Within Avian Broods?

Across taxa, parents have major effects on their offspring by influencing the early developmental environment. In birds, one of the most important aspects of the developmental environment is egg incubation. Small changes (<1°C) in average incubation temperature have large effects on offspring post-hatch phenotypes. Further, it has recently been shown that average incubation temperatures differ among eggs within the same nest, to the extent (i.e., >1°C) to which differences in offspring phenotypes should result. A potential, yet unstudied, consequence of within-nest incubation temperature variation is inequality in competitive ability among individuals in the same brood. This could alter early social dynamics, and thus further affect offspring phenotypes. To investigate if incubation temperature affects competitive behavior, we incubated wood duck (*Aix sponsa*) eggs randomly at either 35 or 36°C and formed mixed-incubation temperature broods of similar-age ducklings once hatched. We conducted four behavioral trials to determine duckling competitive ability for heat and food. Contrary to our predictions, we found no effect of incubation temperature on duckling competitive behavior. However, we found that ducklings incubated at the higher temperature had larger body sizes than those incubated at the lower temperature throughout the study. Thus, our results suggest that individuals incubated at low temperatures are at a physiological deficit, but this is not exacerbated by decreased competitive ability.

P2-106 HORVATH, T*; BERGEY, L; RITCHIE, L; SEMANCHIK, P; Centenary University; *Tess.Horvath@centenaryuniversity.edu*

Competitive interaction and foraging speed in the invasive shrimp, Palaemon macrodactylus, and three species of native Palaemon shrimp in New Jersey Waters.

Competitive interactions and foraging speed were observed in four estuarine grass shrimp, Palaemon species. Three species of shrimp were native to New Jersey waters (P. pugio, P. vulgaris, P. intermedius), while the fourth species was an invasive species originating in Japan (P. macrodactylus). Since invasive species can have an economic and ecological impact on native species, they are important organisms to study. It was hypothesized that the invasive would be more aggressive and faster at finding food than the native species due to their larger average body size. Two shrimp were placed in a maze to run separate, but identical courses to reach a common food source. Two different food sources, mussels and clams were used as bait for this experiment and, for each shrimp, the time to locate and reach the food source was measured. For each food source, a Kruskal-Wallis H test was used to determine whether there were significant differences, between the four species. When mussels were used as bait, the times to reach the food source were not significantly different between groups, $\chi2(3) = 7.072$, $p = 0.070$. When clams were used as bait, the times to reach the food source the differences between groups was not significantly different, $\chi2(3) = 2.506$, $p = .474$. After reaching the food source, the shrimp were allowed to remain in the area of the bait and their interactions were observed and recorded. P. macrodactylus were more aggressive toward their competitors, suggesting that this invasive species may have a favorable advantage controlling food sources.

28-4 HOSSAIN, M*; STAPLES, A; VIRGINIA TECH; *mdmoh81@vt.edu*

Passive Vortical Flows Compensate for Low Flow Speeds in the Interior of a Coral Colony

Metabolic processes like photosynthesis and the transfer of nutrients from the overlying water column to the interior of a coral colony are primarily controlled by the concentration gradients and velocity profiles around the coral. Numerous reef-scale studies have been performed to understand mass transport mechanisms in corals, but smaller scale flow dynamics within branching coral colonies has largely remained unexplored. Measurements have shown that the flow velocities in the interior of densely branched coral colonies can be reduced by up to 90%. In spite of this drastic reduction in flow magnitude, the polyps at the interior of these densely branched corals continue their biological activities normally, pointing to an unknown mechanism for preserving mass transport rates. In this study, we uncovered the mechanism for preserving mass transport rates through a single Pocillopora meandrina colony. We performed three-dimensional simulations of the flow field through the colony (obtained via CT scans of a P. meandrina skeleton) using the immersed boundary method for a realistic Reynolds number of 20,000. The computed flow fields in the interior of the colony are highly vortical because of vortex shedding from the colony's branches, which facilitates mixing and mass transfer. We calculated the advection time scale throughout the interior of the colony in order to characterize the rate of mass transport there. Though average flow speeds were reduced by up to 64% in the interior of the colony, the advection time scale was roughly constant throughout the colony. Thus, the complex, branched geometry of the colony was shown to serve as a passive mass transport enhancement mechanism which compensates almost exactly for drastic velocity reductions in the coral's interior.

24-6 HOUTZ, JL*; SHIPLEY, JR; ZIMMER, C; VITOUSEK, MN; Cornell University, Max Planck Institute of Animal Behavior; *jlh498@cornell.edu*

Impacts of Gut Microbiota on Developmental Temperature Priming in Birds

Early-life challenges, such as suboptimal temperatures during development, can have profound effects on the phenotype. Recent evidence from several mammalian species suggests the gut microbiome may act as a mediator of developmental plasticity, including thermally-induced plasticity. Other recent research has shown that tree swallow (*Tachycineta bicolor*) nestlings developing in suboptimal temperatures have higher stress-induced corticosterone levels and greater thermogenic capacity via enlarged pectoral muscles. Here, we tested the hypothesis that cold-induced phenotypic plasticity is mediated by the gut microbiome. Nestlings were raised at either a cold (31°C) or neutral (35°C) temperature and given an antibiotic cocktail or a water control. Cold-reared birds mounted stronger corticosterone stress responses and higher stress-induced glucose levels than those reared at neutral temperatures. However, antibiotic treatment eliminated both of these effects. Neither temperature nor antibiotic treatment affected baseline corticosterone or glucose levels. Antibiotic treatment increased pectoral muscle mass in cold-reared birds; basal and cold-induced metabolic rates will be analyzed in the future to test whether treatment influenced thermogenic capacity. Thus far, our results demonstrate that gut microbiota may impact cold-induced phenotypic plasticity through alterations of stress responsiveness.

120-5 HOWE, SP*; ASTLEY, HC; University of Akron; *sph43@zips.uakron.edu*

Bio-inspired Control Algorithms Integrating Steady Swimming and Maneuvering in Fish Robots

The majority of fish use whole-body undulations to power swimming and generate maneuvers. This style of locomotion offers certain benefits including efficiency and stealth, and consequently fish are excellent models for designing autonomous under water vehicles (AUVs). While straight swimming can be generated by simple cyclical motions, unsteady behaviors such as turning are more complex. Previous control strategies for maneuvering in fish robots fall into two major categories. The first adds a lateral offset to the normal locomotor wave, biasing the undulation to the right or the left without interrupting normal swimming. The second imitates the C-start maneuver in fish, in which all body segments deflect simultaneously on one side followed by a rapid, posteriorly propagating straightening, which interrupts typical locomotor body oscillations. We developed a turning model based on the kinematics of routine maneuvers from the Giant Danio (*Devario aquepinnatus*), which consist of pulses of curvature that start near mid-body and propagate posteriorly. These pulses are non-cyclic events and can be modeled as a transient wave with a speed, amplitude, and width. Using a 3D printed robot, we will be evaluating the performance of the pulse model compared to the offset wave and C-start methods. We have also successfully implemented the pulse, the C-start, and offset control models in a multilink robotic system. Preliminary data shows that the pulse model behaves similarly to the live fish model. All three models are able to execute maneuvers, but further testing will show how the maneuverability, agility, and controllability compare between the turn models.

31-4 HOWE-KERR, LI*; BACHELOT, B; WRIGHT, RM; KENKEL, CD; BAY, LK; CORREA, AMS; Rice University, Smith College, University of Southern California, Australian Institute of Marine Science; *lih2@rice.edu*

Symbiont diversity correlates with variability in holobiont stress tolerance

Coral reefs are experiencing global declines as climate change and other stressors cause environmental conditions to exceed the physiological tolerances of host organisms and their microbial symbionts (collectively termed the holobiont). To assess the role of symbiont community composition in holobiont stress tolerance, diversity metrics and abundances of dinoflagellate endosymbionts were quantified from eight *Acropora millepora* coral colonies (genets) that thrived under or responded poorly to various stressors. Four best performer coral genets were selected for analysis because they survived 10 days of high temperature, high pCO2, bacterial addition, or combined stressors, whereas four worst performer genets were analyzed because they experienced significant mortality under these stressors. Seven of eight genets mainly hosted *Cladocopium* symbionts, but also contained *Symbiodinium, Brevolium,* and/or *Durusdinium* symbionts at lower abundances. Control fragments of each genet ultimately identified as best performing had low symbiont alpha and beta diversity, whereas the worst genets had higher alpha and beta diversity. After 10 days of stress, symbiont communities in worst performers had a greater proportional increase in symbiont variability (relative to control fragments) than did the best performers, with bacteria and heat treatments causing the most drastic changes in symbiont communities. These findings emphasize that community diversity metrics may be important indicators of resilience in hosts central to diverse disciplines, from agriculture to medicine.

P3-244 HOWELL, BK*; HAGEY, TJ; WINCHELL, KM; Mississippi University for Women, Washington University in St. Louis; *bkhowell@myapps.muw.edu*

Adapting to Urban Habitats: How Toe Pad Shape Varies in Puerto Rican Anoles

Urban areas have been increasing across the globe, and this urbanization can have profound effects on wildlife in these areas. Our project focuses the lizard on *Anolis cristatellus* in Puerto Rico, investigating how they have adapted to urban environments, specifically the shape of their adhesive toe pads (i.e. toe pad width, length, and size of lamellae, etc.). Previous work has found lamellae number and toe pad area differ between males from urban sites vs. natural sites (Winchell et al. 2016). Using previously collected flatbed scans of male *Anolis cristatellus* from 13 sites, roughly half urban and half natural with 20 individuals per site, I placed landmarks around the fourth toe of the hind limb, with points that also focus on solely the adhesive area of the toe, and lamellae number five through ten, using tpsDig. To analyze our data, we used geomorph and Morpho packages in R. We conducted a principal component analysis to determine which axes explain the most variation in our data and a canonical variant analysis to determine if toe pad shape varied between lizards from urban and natural sites. We found that lamellae size increased in urban areas when compared with natural sites. We also found that changes in toe pad length are more dramatic than changes in toe pad width between the two groups. We expect that urbanization is driving a change towards more adhesive toe pads in anoles as they presumably adapt to using manmade substrates.

P3-76 HOWERIN, HM*; FOLTZ, SL; Radford University; *hhowerin@radford.edu*

The Perfect Home: What Nestbox Features and Environmental Conditions Do Eastern Bluebirds and Tree Swallows Prefer?

As human-caused habitat disturbance continues to affect wildlife in an abundance of ways, studying these species and understanding these impacts are growing in importance. Both eastern bluebirds (*Sialia sialis*) and tree swallows (*Tachycineta bicolor*) readily breed near humans and will use artificial nestboxes; however, not all boxes are used equally. In this study, various nestbox features and their surrounding environmental conditions are compared to determine which are preferred by each species. We collected data on numerous variables including box orientation, age, box height, and dimensions, nearby human activity levels, canopy cover, and species and diameter at breast height (DBH) of the closest tree. Data analysis is ongoing, but we predict some overlap in species preferences, potentially leading to interspecies conflict. Results from this study may further illuminate how nestbox-using species select breeding sites, particularly in areas with human disturbance.

82-1 HOWEY, CAF; University of Scranton, Scranton, PA, 18510 and Pennsylvania State University, University Park, PA 16802; *christopher.howey@scranton.edu*

Thermoregulation and Foraging Behavior of Timber Rattlesnakes (Crotalus horridus) in a Disturbed Landscape

Prescribed fire is a landscape disturbance that alters the physical and thermal characteristics of a habitat. Changes to the thermal landscape may benefit ectothermic organisms as they are able to maintain elevated body temperatures that may coincide with preferred body temperatures. However, changes to the physical characteristics of a burnt landscape may affect other ecological aspects including risk of predation and foraging efficiency. It was the objective of this project to determine if prescribed fire affected the thermal landscape and thermoregulatory behaviors of an ectothermic species, the timber rattlesnake (*Crotalus horridus*), and to determine if physical changes to the habitat affected the behaviors of this organism. I radio-tracked *C. horridus* for two years before and two years after a prescribed fire in central Pennsylvania. I recorded behaviors, movement rates, home range sizes, and body temperatures of each snake throughout the project. Biophysical models were placed in burnt and unburnt treatments each year to measure operative temperatures. I found that burnt landscapes provided warmer operative temperatures. Radio-tracked *C. horridus* also maintained warmer body temperatures when occupying burnt habitat. However, foraging behaviors were solely restricted to unburnt habitat. Trapping efforts suggest no change in small mammal abundance in burnt and unburnt landscapes. Rather, data from a concurrent scent-trailing study suggest that *C. horridus* may not be able to detect chemical stimuli on burnt substrate. Thus, even though small mammals were present in the burnt treatment, *C. horridus* may not have been able to detect suitable ambush sites.

136-1 HU, Y*; HARPER, M; DONAHUE, J; ACOSTA, B; MCMENAMIN, S; Boston College; *hucy@bc.edu*
Thyroid Hormone Mediates Proximal-Distal Patterning in Zebrafish Fin Skeleton
Caudal fin morphology varies extensively among fish species, yet we know very little about the developmental programs underlying such diversity. Further, the molecular pathways that create proximal versus distal morphological characteristics in the fins are poorly understood. In zebrafish, the caudal fin skeleton is composed of bony fin rays made up of individual segments, which taper and shorten distally, and form a primary branch at about half of the fin's length at adult stage. Mutations in various ion channels are known to cause overall scaling of the entire fin, but the morphological features along the proximal-distal axis are maintained in proportion. In contrast to these proportionally scaled changes, we identify a novel role for thyroid hormone in patterning the proximo-distal morphology of the fin rays. While thyroid hormone is a well-known endocrine regulator of skeletal development and is generally considered to promote bone mineralization, the role as a proximo-distal patterning factor is novel. We show that the hormone mediates both the proximo-distal morphology of the ray segments as well as the position of the fin ray branches, but not overall fin size. Thus, thyroid hormone acts independently of the bioelectricity-mediated pathways that regulate fin growth. Sonic hedgehog signaling is known to be essential in fin ray branching, and we show that thyroid hormone acts upstream of this pathway. Further, our expression analyses show differences in the transcriptomes of proximal versus distal regions of the regenerating fin, suggesting target pathways that create proximal versus distal morphologies; our data are consistent with thyroid hormone regulation of these proximo-distal expression patterns. In all, our results provide new insights into the mechanisms underlying proximo-distal identity as well as adaptations in the fin skeleton.

P3-135 HUANG, S*; TANG, Y; TAO, J; Arizona State University; *jtao25@asu.edu*
SBOR: A Self-Burrowing-Out Robot Inspired by Razor Clam
We observed that Atlantic razor clams burrow out of the substrate very rapidly using a simple strategy: cyclic extension and contraction of a soft, hollow muscular foot. This is notably different from its burrowing-in strategy where closing/opening of the shell and dilation of the foot are also involved. Inspired by the burrowing-out strategy, we designed a minimum self-burrowing pneumatic soft robot, which consists of a silicone tube reinforced with a symmetrical, double-helix wrapping of inextensible thread. The threads limit the actuator to axial extension/contraction motion under inflation/deflation. The cyclic extension/contraction of the robot naturally drive it out of the sand, mimicking razor clams. The burrowing-out behavior of the robot was studied by varying the inflation-deflation periods and the relative density of the sands. Each burrowing cycle features an initial advancement due to inflation, followed by a slip due to deflation, resulting in a net stride. When the robot burrows out, the stride first increases due to the decrease in overburden pressure, and then decreases after the top of the actuator moves out of the soil, due to the reduction in the effective length of the actuator. The results also indicate that the average burrowing-out speed decreases with increasing soil relative density. A simplified model based on soil mechanics is developed to model the burrowing-out behaviors and its prediction matches very well with the experiment results. From this model, the burrowing-out behavior is readily explained by the asymmetric nature of the resistant force on the two ends of the actuator. An insight is that in order to burrow-in, additional symmetry breaking features such as asymmetric geometry, friction or external load are needed to increase the resistant force (anchorage) in the upward direction and to reduce the resistant force in the downward direction.

P2-152 HUBERT, D/L*; BENTZ, E/J; MASON, R/T; Oregon State University; *hubertd@oregonstate.edu*
Transcriptional Response to Acute Thermal Stress in the Red-sided Garter Snake (Thamnophis sirtalis parietalis)
Red-sided garter snakes are the most northerly living reptile in the western hemisphere. These terrestrial ectotherms experience extreme fluctuations in temperature, emerging after brumation with body temperatures near 0 ”C and ambient temperatures often 20-30 ”C. Utilizing basking behaviors, body temperatures can rapidly rise from just above 0 ”C to near 35 ”C. While environmental temperatures vary greatly, these snakes use behavioral thermal regulation to maintain body temperatures in an ideal thermal zone when active. This behavioral thermal regulation is effective within a range of temperatures, however when the temperature exceeds those boundaries behavior is not sufficient alone to maintain homeostasis and they become inactive. The bounds of these thermal conditions were determined experimentally using the loss of righting response for both high and low temperatures. RNA-seq was used to characterize the transcriptional response to acute thermal stress. Heart, liver, testis, and brain tissues were used to capture the transcriptional response to both acute cold stress and heat stress and have been analyzed for differential gene expression analysis and functional gene ontology enrichment. Over 90 genes were found to be differentially expressed when treatment transcriptional activity was compared to transcriptional activity for control conditions. The top 3 differentially expressed genes were heat shock proteins and gene ontology analysis shows that the primary gene response is to thermal stress. Understanding both the physiological boundaries of the thermal conditions that these snakes can survive, as well as the transcriptional strategies that they employ to help them survive creates a better understanding of how these animals thrive in a dynamic thermal environment.

139-5 HUBICKI, CM*; DALEY, MA; Florida State University, University of California, Irvine; *chubicki@fsu.edu*
Optimal control predictions of running behavior in cursorial birds: non-rigid terrain, scaling, and maneuvering
Many species of bipedal runners, such as cursorial birds, can run at a variety of speeds. However, each species has a pattern for choosing gait features‡(e.g. stride length - SL, stride frequency - SF, and duty factor - DF)‡for achieving any selected speed. This work uses theoretical math models combined with optimal control methods to predict these gait features across speeds by minimizing energy cost. Specifically, this work compares a spring-legged math model with swing costs against the experimental gaits of helmeted guinea fowl (*Numida meleagris*) during steady running across speeds. A three-parameter fit (spring stiffness, damping constant, and leg inertia) generated steady gaits on rigid terrain from 1.3m/s to 3.1 m/s with SL, SF, and DF similar to measured guinea fowl data - all as a consequence of energy minimization. These parameters are fitted once for the species, and are constant across speeds and terrain conditions. Further, modeling the terrain as a dissipative surface (e.g. sand or soft soil) predicts an increased DF, consistent with experimental data. We are currently testing the broader ability for the model to predict gait features of species with varied leg length and inertia relative to body mass (e.g. red-legged seriema (*Cariama cristata*) and elegant crested tinamou (*Eudromia elegans*)). Preliminary analysis suggests that birds with larger leg inertia prolong their flight phases as the model predicts. In ongoing work, we are applying this modeling framework to multi-step manuevers, such as a 90-degree turns, to test scenarios that require higher-level decision-making.

53-4 HUDSON, SB*; VIRGIN, EV; SMITH, GD; BRODIE JR., ED; FRENCH, SS; Utah State University, Dixie State University; *spencer.hudson@usu.edu*

Energetic strategy, oxidative cost, and performance outcome vary according to magnitude of an integrative immune challenge

The central tenet of life-history theory posits allocation to fitness-related traits reduces the amount of available resources that can be invested into competing traits, resulting in trade-offs. Immunity and whole-organism performance capacity fit within the life-history framework as physiologically costly traits crucial for survival. Life-history trade-offs may occur when the demands of immune traits impinge upon investment in performance traits, and vice versa. Whether shifts in performance capacity occur under such conditions was determined in side-blotched lizards (Uta stansburiana) through comparisons of maximal sprint speed and rates of healing from wounds (i.e., cutaneous biopsies) of various sizes. Energy budget (i.e., food intake) and oxidative stress (i.e., pro-oxidants versus antioxidants) associated with immune and performance investment were also compared among lizards by wound size. Findings herein reveal sprint speeds are not constrained when healing from wounds of increasing sizes. Instead, healing and sprint speed deviate with wound size such that both are concurrently invested when healing from small wounds, at a trade-off for medium wounds, and variably invested for large wounds. Such findings indicate performance expression adjusts according to the demands of an immune challenge, perhaps to offset the energetic and oxidative costs of immunological prioritization. However, energy intake decreases and oxidative stress increases with greater wound size, suggesting components of self-maintenance or long-term survival may become compromised if an immune challenge exceeds a certain magnitude.

P1-45 HUEBNER, CD*; TREIDEL, LA; ROBERTS, KT; WILLIAMS, CM; UC Berkeley; *christopherhuebner@berkeley.edu*

Effects of Life History and Starvation on Temperature Preference of a Wing-Dimorphic Cricket, Gryllus lineaticeps

Organisms must allocate resources to support different performance traits. Since resources are finite and the conditions that optimize one trait may decrease performance in another, the prioritization of certain traits may come at the cost of others. The performance traits that an organism prioritizes allocation toward determine their life history strategy. For ectotherms, different performance traits like locomotion and fecundity are optimized at different body temperatures. Ectotherms behaviorally thermoregulate to select suitable microhabitats that optimize combinations of metabolic and performance traits. Thus, we hypothesized that life history strategies determine ectotherm thermal preferences. However, thermal preferences are not fixed. In response to starvation reductions in thermal preference commonly occur to conserve energy and the extent to which life history strategies determine the impact of starvation on thermal preference is unknown. Wing-dimorphic crickets have either long (LW) or short (SW) wings and specialize in dispersal or reproduction, respectively. Crickets were placed in a thermal gradient of 15-50 C° and the temperatures at which they settled 30, 40, and 50 minutes after placement were recorded. This experiment was conducted both in the field with freshly caught individuals and in the lab with crickets reared under common conditions. In both the lab and field, LWs preferred significantly higher temperatures compared to the SWs. Under starved conditions crickets preferred a cooler environment and morph differences disappeared. Together these findings suggest that life history strategy determines thermal preferences, but when resources are sparse, energy conservation is prioritized at the cost of performance.

129-4 HUIE, JM*; THACKER, C; TORNABENE, L; University of Washington, Natural History Museum of Los Angeles County; *jmhuie@uw.edu*

Co-evolution of cleaning and feeding morphology in Caribbean and eastern Pacific gobies

Cleaning symbioses are mutualistic relationships where cleaners remove and consume ectoparasites from their clients. Cleaning behavior is rare in fishes and is a highly specialized feeding strategy only observed in around 200 species. Cleaner fishes vary in their degree of specialization, ranging from species that clean as juveniles or facultatively as adults, to nearly obligate or dedicated cleaners. Here we investigate whether these different levels of trophic specialization correspond with similar changes in feeding morphology. Specifically, we model the evolution of cleaning behavior across the family Gobiidae, which contains the most successful radiation of dedicated and facultative cleaner fishes. We compared the cranial morphology and dentition of cleaners and non-cleaners across the phylogeny of cleaning gobies and found that facultative cleaners independently evolved three times and have converged on an intermediate morphology relative to that of dedicated cleaners and non-cleaning generalists. This is consistent with their more flexible feeding habits. Cleaner gobies also possess a distinct scraping tooth morphology, which suggests they are adapted for scraping parasites off their clients and show little similarity to other cleaner clades. We propose that evolutionary history and pre-adaptation underlie the morphological and ecological diversification of cleaner fishes.

46-6 HULETT, RE*; POTTER, D; LUO, YJ; RICCI, L; SRIVASTAVA, M; Harvard University; *rhulett@g.harvard.edu*

Identifying regulators of neural cell-type diversity during regeneration in the acoel Hofstenia miamia

The nervous system is extremely complex, composed of many cell-types creating intricate circuits responsible for coordinating action. Adding to the previously known diversity of cell-types in the nervous system, single-cell RNA sequencing (scRNAseq) in select organisms has uncovered tremendous heterogeneity in neural cell-types. Within these adult organisms, few are capable of regenerating diverse neural cell-types and even fewer are able to regenerate their entire nervous system. Acoel worms represent a major phyletic lineage capable of robust regeneration and include the new research organism, *Hofstenia miamia*. *Hofstenia* is capable of whole-body regeneration, i.e. it has the ability to replace any missing cell-type, via differentiation of its adult pluripotent stem cells, called neoblasts. *Hofstenia* has an organized nervous system and can regenerate all missing neural cells-types and structures, and we sought to identify the molecular/genetic regulators governing the transition from neoblast to differentiated neural cell-type during regeneration. Utilizing scRNAseq data, we identified putative neural populations and subpopulations, which we validated using fluorescent in situ hybridization and immunohistochemistry. Within each major neural population, we recovered candidate transcription factors that we hypothesize to govern differentiation of neural populations during regeneration. We are utilizing systemic RNAi to determine the functions of these transcription factors during regeneration with regards to the replacement of diverse neural cell-types. This work will reveal mechanisms for neural regeneration as well as provide a comparative framework to understand the evolution of these mechanisms.

S3-1 HULSEY, CD; University of Konstanz, Germany; *darrin.hulsey@uni-konstanz.de*

The evolutionary developmental genetics of vertebrate tooth size

Tooth sizes vary extensively across vertebrates. Substantial amounts of this variation can be attributed to isometric scaling with changes in organismal body size, but there are a number of additional factors that influence diversification of tooth sizes. Trophic specializations such as crushing hard-shelled prey or piercing provide clear functional bases for predicting changes in tooth size components such as the width and length of teeth. However, teeth are also used for a large vareity of non-trophic organismal functions that could influence tooth size and these will be discussed as potential mechanisms of tooth size diversification. The developmental genetic mechanisms governing tooth size are likely to be equally diverse, and I will highlight recent insights into the mechanistic basis of vertebrate tooth size divergence gleaned from transcriptomics and comparative genomics of cichlid fishes.

104-2 HUNT, KE*; BUCK, CL; HUDSON, J; FERNáNDEZ-AJó, A; HEIDE-JøRGENSEN, MP; FERGUSON, SH; MATTHEWS, CJD; George Mason U, N Arizona U, U Manitoba, Greenland Inst Nat Res, Fish Oc Canada; *kehunt@gmu.edu*

Patterns in Reproductive Seasonality Inferred From Annual Testosterone Cycles In Baleen Of Adult Male Bowhead Whales (Balaena mysticetus)

Whale baleen accumulates steroid hormones as it grows, such that a single baleen plate can be used to reconstruct an individual's endocrine history over the timespan of baleen growth, 1-2 decades in bowhead whales (*Balaena mysticetus*). We analyzed testosterone (T) and corticosterone (B) in baleen of nine adult males from eastern Canada and Greenland to infer breeding season and frequency, and associated adrenal activity. Baleen plates of 184-314 cm length were drilled at 2 cm intervals (each interval representing ~1-2 mo), followed by assay of immunoreactive T and B. T concentrations cycled along baleen of all nine males. Average T periods ranged from 21 cm in the smallest whales to 14 cm in the largest whales, consistent with annual bowhead baleen growth rates and differential growth rate associated with age (slower in older individuals). Change in T peak amplitude over time was significantly related to whale body length (a proxy of age), suggesting influences of sexual immaturity, reproductive competition, and possible reproductive senescence. Annual T peaks were strongly correlated with stable nitrogen isotope (δ15N) peaks in summer but with an offset of several months, indicating elevated T concentrations during spring, the purported breeding season. B concentrations cycled synchronously with T in some males, while variation was irregular in others, consistent with known bowhead whale breeding behavior (i.e. likely differences in reproductive competitiveness). We conclude that male bowheads experience annual testosterone cycles, and that baleen hormone analysis enables investigation of reproductive seasonality in whales.

S2-12 HUNTER, R/G; University of Massachusetts Boston; *richard.hunter@umb.edu*

Transposons, Stress and the Endocrinology of the Deep Genome

Transposons have played a significant role in the evolution of eukaryotic genomes, and exaptation of transposons has led to innovations such as the mammalian placenta and the adaptive immune system. Since McClintock's discovery of what she called "controlling elements," it has been evident that they tend to mobilize in response to stresses to the organism. This observation raises two questions: how does the genome control the stress-induced expression of transposons? Moreover, how do transposons detect stress? Much of the epigenetic machinery has been evolved to suppress or control these elements, and our work has shown the mammalian brain uses some of the same mechanisms of transposon control as have been observed in other organisms. We have shown that stress rapidly induces an increase in the repressive histone H3 lys9 trimethyl mark in the rat hippocampus. Further, corticosteroids themselves, acting via the glucocorticoid receptor (GR) act to increase the expression of B2 SINE and IAP-LTR retrotransposons, offering an answer to the question of how transposons detect organismal stress. Further, we have observed a potentially novel mechanism by which transposon derived RNA might serve to block GR action, leading to glucocorticoid resistance at the genomic level. Our observations that transposon expression varies substantially across sex suggest that sex steroids may also interact with these elements. There is abundant evidence that transposons and steroid receptors have been involved in an ancient interplay across vertebrate evolution. Roughly a third of the GR targets in the rat hippocampus are within or near transposons, and many steroid response elements in gene promoters are transposon derived. This data argues that, beyond their established role in genome evolution, transposons play day to day role in normal endocrine physiology.

P3-175 HURD, PL*; DITTMANN, N; KRUSCHKE, Z; VANDENBERG, P; University of Alberta; *phurd@ualberta.ca*

Behavioural differences between unstudied male and female morphs in the kribensis cichlid

The kribensis cichlid is an environmentally sex determined fish with two relatively well documented alternative male morphs. The red morph is more aggressive and is biased towards breeding haremically, while the yellow morph is less aggressive and monogamous. Water chemistry in the first 30 days of life influences sex ratio at adulthood. More acidic conditions produce more males and more of those males are of the red morph. A further two male colour morphs, known as blue and green, and two alternative female colour morphs, have been noted in the hobbyist literature but remain unstudied. We find these in the lab, produced by the same pairings that produce red and yellow males. Here we compare the behaviour of these different morphs.

44-5 HUYNH, AH*; RICE, AM; Lehigh University; *avh210@lehigh.edu*
Chemical communication in a hybridizing chickadee system: olfaction and reproductive isolation
Understanding how mating cues promote reproductive isolation upon secondary contact is important in describing the speciation process in animals. Divergent chemical cues have been shown to act in reproductive isolation across many animal taxa. However, such cues have been overlooked in avian speciation, particularly in passerines, in favor of more traditional signals such as song and plumage. Here we show evidence for odor as a mate choice cue, potentially contributing to premating reproductive isolation in a chickadee hybrid zone. Using gas chromatography-mass spectrometry, we document significant species differences in uropygial gland oil chemistry between the black-capped (Poecile atricapillus) and Carolina chickadee (P. carolinensis). We also demonstrate significant preferences for conspecific over heterospecific odor cues in wild chickadees using a Y-maze design. Our results suggest that odor may be an overlooked but important mating cue in these chickadees, potentially promoting premating reproductive isolation. In addition, we also show evidence for a loss of odor preferences in adult hybrids. This loss of behavioral response may be coincident with other cognitive deficiencies previously found in hybrid chickadees, and may contribute to the stability of the hybrid zone via postzygotic reproductive isolation.

P2-201 HUYNH, G*; DUMAN, A; AZIZI, E; University of California, Irvine; *aduman@uci.edu*
Effects of Caffeine on Jump Performance in Rhinella marina
Caffeine is consumed widely for its stimulatory effects. Previous work has shown caffeine affects Ca2+ release in muscle, which increases force production at the level of the muscle tissue and whole limb or body. Increased performance has implications for reducing effects of fatigue, and potentially increasing performance. This study seeks to quantify the effects of caffeine on jump performance in *Rhinella marina* (n = 5), a toad that relies heavily on muscular mechanisms for propulsion. Using force plate ergometry and high speed video we captured kinematic and kinetic characteristics of toads jumping after injecting them with 0.126 mg of caffeine per kg of body weight, a sham injection, and with no injection. Preliminary results suggest force and velocity at takeoff as well as distance travelled during the jump are greater following the administration of caffeine. Continuing work aims to relate results at the whole animal level with changes to muscle contractile properties. This work serves to better quantify how caffeine affects key performance outcomes in muscle driven movements in animals and humans.

P2-149 IBARRA, JN*; WHITTEMORE, KS; NAQUIN, TE; SILVA, MA; CHO, A; TEEPLE, JB; SCHENK, HJ; MOCKO, K; BURNAFORD, JL; HOESE, WJ; California State University, Fullerton; *jennifer.ibarra@csu.fullerton.edu*
Salinity Responses of the Desert Shrubs Isocoma acradenia and Larrea tridentata
Desert organisms are great for studying adaptive responses to high-stress environments. For example, desert plants must cope with limited water availability, high exposure to solar radiation, and in many cases, with the accumulation of salts into their soils. Saline soils inhibit or even prohibit the growth of plants via ion toxicity and osmotic stress. We investigated the salinity responses of two coexisting desert shrubs, the halophyte *Isocoma acradenia* and the glycophyte *Larrea tridentate*, on a slope adjacent to Soda Dry Lake in the Mojave Desert, California, hypothesizing that ion concentrations in these shrubs would be related to the salinity of the surrounding soil. We collected predawn plant and soil samples in 30-40 meter intervals along a belt transect from the dry lakebed up the slope and measured soil conductance and ion concentration in xylem sap and leaves. Conductance was higher in soil associated with *Isocoma* (mean ± SE: 5447.50 ± 5038.75 µS/cm) than with *Larrea* (mean ± SE: 90.63 ± 23.13 µS/cm). *Isocoma* leaves contained about 4× more sodium (mean ± SE: 549.19 ± 19.94 mmol/kg) than potassium (mean ± SE: 133.73 ± 18.75 mmol/kg), and *Larrea* leaves maintained a 1:1 ratio. Trends were similar in xylem sap, with *Isocoma* having higher levels of both ions than *Larrea*. *Isocoma* may concentrate sodium in leaves or excrete it. It is notable that plants with overlapping distributions have such different ion concentrations. There are no previously described salt-excreting members of *Asteraceae*, and if *Isocoma* can be confirmed as such, it will be a new discovery.

P2-217 IIJIMA, M*; MUNTEANU, VD; DIAMOND, KM; BLOB, RW; Clemson University; *miijima8@gmail.com*
Locomotor mechanics of juvenile alligators reveals ontogenetic changes in the roles of the fore- and hindlimbs
Crocodylians are the sole surviving lineage of archosaurs that retain a generalized, quadrupedal body plan. As such, data on crocodylian locomotor biomechanics can provide a useful context for understanding the ontogeny and evolution of functional performance in this formerly diverse lineage. Previous studies of subadult American alligators (2–4 kg) suggested that the hindlimbs play dominant roles in weight support and propulsion during terrestrial locomotion. Since morphological data indicate that the center of mass shifts anteriorly throughout growth, we predict smaller alligators will show even greater dominance of the hindlimbs on land. We tested this prediction by measuring ground reaction forces of juvenile alligators (220–240 g) during single-limb footfalls on a force platform, as they walked through a trackway at their natural speeds. Force data show that forelimbs of juvenile alligators contribute an even larger role in weight support and braking than in subadults. The mean peak vertical force and impulse for the forelimbs during stance are as much as one-third greater than of those of the hindlimbs. Peak braking force and braking impulse are also much greater in the forelimbs than the hindlimbs for juvenile alligators, whereas peak propulsive and medial forces and impulses are greater in hindlimbs. The greater role of the forelimb in body support in juvenile alligators does not match predictions based on ontogenetic morphological changes. This could imply that at very small sizes, alligators can use kinematics that release them from constraints expected from their body mass distribution. Alternatively, ontogenetic shifts in the position of the center of mass may follow a non-linear trend such that juvenile alligators do not match the predictions of linear models.

P2-190 IMPLICITO, C.J*; STARK, A.Y; Villanova University; *cimplici@villanova.edu*
The Effect of Surface Temperature on Adhesion of a Temperate Ant
Tropical regions of the world are known for specialist species who are uniquely adapted to intense, but relatively consistent conditions. Being near the equator, one key environmental feature is temperature. In the tropics, surface temperature of canopy branches, which are often directly exposed to the sun, can heat to > 50°C. For small cursorial canopy organisms like ants, the thermal boundary layer above these superheated substrates elevates body temperature to near critical levels. Interestingly, adhesive performance is also impacted by surface temperature. Specifically, the adhesion-mediating secretion ants produce on their soft tarsal pads should become less viscous and cause ants to slip more easily on hot surfaces. Previous work shows that adhesion is only reduced on hot substrates in some species, suggesting species-level variation in adhesive performance and mechanism as a function of surface temperature. While the tropics are known for intense and consistent heat, temperature in temperate regions can drastically vary from below -5°C to 35°C. Therefore generalist ants in the temperate zone must remain attached at a broader range of temperature than tropical arboreal ants. We investigated adhesive performance of one common temperate ant species (*Camponotus pennsylvanicus*) as a function of temperature, expecting that unlike specialist tropical species, this temperate generalist ant will maintain adhesive performance across the range of temperatures tested. The results of this study have important implications for understanding the ant adhesive system as well as differences in the functional morphology of specialist and generalist species.

110-3 INGLE, DN*; PORTER, ME; Florida Atlantic University, Boca Raton, FL; *dingle2014@fau.edu*
Cetacean vertebral trabecular bone mechanical properties and structure vary among swimming modes and diving behaviors
Among cetaceans, species with rigid, torpedo-shaped bodies are considered as the fastest and most active swimmers. Interspecific variation is encoded in the axial skeleton, where vertebral morphology varies among species with different locomotion modes. Here, we categorized 10 species of cetaceans (Families Delphinidae and Kogiidae) into functional groups determined by swimming modes (rigid vs. flexible body) and diving behavior (shallow vs. deep). We quantified trabecular bone mechanical properties and structure among cetacean functional groups and regions of the vertebral column. We hypothesized that trabecular bone would be stronger, stiffer, and thicker in shallow-diving, rigid-bodied swimmers and in the caudal vertebral column. Vertebrae were obtained from necropsies and dissected from four regions of the vertebral column (thoracic, lumbar, and two caudal). Vertebrae were µCT scanned in a Bruker SkyScan 1173, and trabecular thickness was quantified. After scanning, 6mm3 bone cubes were sawed from vertebrae and compression-tested at 2 mm/min using an Instron E1000 material tester. Yield strength and toughness were calculated using stress-strain curves. Rigid-bodied, shallow-diving cetaceans had the strongest, toughest, and thickest trabecular bone in the caudal region of the vertebral column, and had the greatest values of all functional groups. Conversely, flexible deep-divers showed no regional variation in trabecular mechanical properties and structure and had overall less strong, tough, and stiff bone. These data suggest 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 descents in the water column.

P3-196 ISMAIL, A*; GOLDINA, A; Elizabethtown College; *goldinaa@etown.edu*
Assessing the effect of antidepressant sertraline on agonistic behavior of the subordinate crayfish Orconectes rusticus
Use of medication by humans has had unintended consequences for aquatic organisms. Excreted metabolites end up in the water, where they are absorbed by various organisms, altering their physiology. Currently, it is unclear how exposure to these pharmaceuticals alters behavior. Sertraline, a selective serotonin re-uptake inhibitor (SSRI), is a widely prescribed antidepressant that has been shown to enter aquatic environments. In crayfish, increased serotonin levels increase aggression by decreasing individual willingness to retreat. Serotonin levels increase in winners of agonistic interactions, and decrease in subordinates. However, increased serotonin levels via SSRI exposure, might increase the animal's willingness to re-engage in agonistic interactions, ultimately altering social hierarchy and decreasing survival. In this study we examined the effect of sertraline on agonistic behavior of subordinate crayfish Orconectes rusticus. Same sex *O. rusticus* were paired in a status establishment fight. Following status establishment, the subordinate individual was injected with either 1) sertraline, 2) serotonin, or 3) saline control. The dominant individual was injected with a saline control. Following pharmacological treatment, the dominant and subordinate individuals were re-paired, and their interaction was compared to the status establishment fight. All agonistic interactions were recorded and the quantity of offensive and defensive behaviors was used to determine which animal was dominant. Aggression intensity was compared within dyads and between pharmacologic treatments. Our preliminary findings show that serotonin and sertraline, but not saline, increase aggressive behaviors of subordinate crayfish. However, exposure to either chemical does not cause status reversal.

128-5 ISON, T*; CHARBONNEAU, D; WAUGH, A; LINKSVAYER, T; DORNHAUS, A; University of Arizona, Tucson, Arizona State University, Phoenix, University of Pennsylvania, Philadelphia, University of Pennsylvania, Philadelphia; *tjison@email.arizona.edu*
The Effects of Aging: Task Allocation and Inactivity in Two Ant Species
Eusocial insects and other colonial organizations are considered to be some of the most effective and intricate social establishments in the natural world. In particular, insect colonies are thought to employ efficient and dynamic task allocation mechanisms matching workers to tasks needing work. Worker age is typically related to the tasks they perform where younger workers tend to perform safe tasks (e.g. nursing) closer to the center of the nest where they first emerge into adults and transition to outward and riskier tasks (e.g. foraging) over the course of their lives; this idea of temporal polyethism has been demonstrated in honey bees and is thought to apply in some degree to most social insect species. Here we examine temporal polyethism in two ant species with very different life histories – the long lived and slow paced Temnothorax rugutalusand the fast paced with a short worker lifespan Monomorium pharaonis by tracking the behavior of workers through their aging process. Our data will show how age relates to individual inactivity (known to vary consistently among individuals) as well as the type of task performed in each life stage. Both study species have shown evidence of high inactivity levels in younger workers, however the inactivity-age relationship in T. rugutalus is more complex than that of the M. pharaonis. This may be because of the long lifespan of T. rugutalus where older workers may senesce versus short-lived workers who may die before their physiologies degrade. Studying the role of age in task allocation among widely different species, as well as the relationship between inactivity and age, offers insight into the stability and adaptive task allocation in dynamic environments.

P1-171 JACKSON, C P*; FISCHER, E K; O'CONNELL, L A; Stanford University, Stanford; *christo4@stanford.edu*

Behavioral Variation of Poison Frog Tadpoles in an Open Field

Many species, though phylogenetically very similar, have radically different behaviors. Evaluating these behavioral differences is key to understanding how species' behavior can change to adapt to their environment. However, comparing behavior across species can be difficult in the wild due to uncontrollable factors in the field and ecological variation between species. Thus, a need arises to develop standardized assays in the lab to measure specific components of behavior. Closely related South American poison frogs differ radically in their ecology and behavior. We chose to use the open field test as our selected behavioral assay, as it is a standard method of assessing an animal's activity level, boldness, and exploratory behavior, but it has yet to be tested in poison frogs. We tested the viability of the open field test to explore variations between poison frog tadpoles of three species:*Ranitomeya imitator*, *Ranitomeya variabilis*, and *Dendrobates tinctorius*. We found that individual tadpoles varied in their behavior in an open field, and that tadpole activity also varied across species: *R. imitator* traveled more, at higher average speeds, and explored more of the arena than either *R. variabilis* or *D. tinctorius*. We observed no variation in tadpole activity for time of day. Our results support the viability of the open field arena test in poison frogs and show that different species of poison frog tadpoles exhibit behavioral variation in the open field. We suggest this variation in tadpole activity and exploration may be due to different species having varying tadpole pond sizes and aggression levels.

14-4 JACOBS, C*; DAY, S; HOLZMAN, R; Tel Aviv University, Rochester Institute of Technology; *corrinej2@gmail.com*

A power amplification dyad in Syngnathidae

Suction feeding is the most common prey capture strategy across teleosts. However, the intensity of the suction flow is constrained by the fish's ability to produce fast movements as muscles contract slowly and over small distances. During rapid movements, tendons can act like springs, temporarily storing work done by muscles and then releasing it to power body movements. This is known as power amplification and the only known example 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 ~20000°s-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. Using a high-speed flow visualization technique, we characterized the spatio-temporal patterns in the flow fields produced during pivot feeding in 3 species of the Syngnathidae family. We discovered that due to power amplification, the Syngnathidae were able to create 8x greater flow velocities than similar-sized fish without this mechanism. The measurements from the flow fields were used 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). The power used for suction feeding was found to closely match the available power within the tendon of the sternohyoideus muscle, suggesting dyad power amplified system. This allows for the rapid head rotation buy the epaxial tendon and 8x greater flow velocities, compared to fish with no such mechanism, from the sternohyoideus muscle tendon. As far as we are aware, this is the first documented duel power amplified biomechanical system used for separate functions simultaneously!

P2-53 JACOBS, JL*; HALL, AS; SMITH, EN; University of Texas at Arlington, Thermo Fisher Scientific; *justin.jacobs@uta.edu*

Learning to swim: evolutionary transition from terrestrial to aquatic life in South American coralsnakes

Without limbs for grasping or climbing, snakes must use only bones and associated musculature of their skull and spine to successfully thrive in their environment. Among snakes, those in aquatic environments differ in substantive ways from terrestrial snakes: more teeth, flatter skulls, flattened tails, etc. We investigated the transition from terrestrial to aquatic life in a radiation of new world elapid snakes, coralsnakes in the genus *Micrurus*. Using a phylogenetically-aware analysis of morphology, we used high resolution computed tomography (CT) to study skull and vertebral morphology. We document character evolution in this ecological transition and analyzed these data using three-dimensional geometric morphometrics. By comparing our taxa to more distantly related coralsnakes, we reconstruct the evolution of *Micrurus* morphology and, by extension—ecology, over transitions to aquatic life. We also discuss our ongoing study seeking parallel adaptations to aquatic life in the Asian elapid snakes.

S5-9 JAFFAR-BANDJEE, M; STEINMANN, T; KRIJNEN, G; CASAS, J*; University of Tours, CNRS, University of Twente; *casas@univ-tours.fr*

Efficiency of odor capture by multiscale pectinate insect antennae

While the pectinate antennae of silk moths and other insect groups are considered as the paragon of sensitivity to sexual pheromones since centuries, we still lack a mechanistic understanding of odor capture by such structures. 3D printing cannot currently fabricate multiscale structures spanning the antennal four orders of magnitude. We therefore focus on the functional, two-scales sub-structure of an antenna of Samia cynthia (Lepidoptera, Saturniidae): a brush of sensory filliform sensilla attached to one rami, the supporting tubular structure. A semi-analytical model to compute mass transfer, originally developed for heat transfer in pipes, is adapted to the specific geometry of longitudinal sensilla facing the flow. Particle Image velocimetry (PIV) is used with scaled-up physical models for estimating the leakiness of the structure, i.e. the proportion of flow passing through the structure rather than around. The combination of these experimental and modeling approaches delivers the capture efficiency over a biologically relevant range of air speed. We found that two distinct processes are setting pheromone capture efficiency. At low Re numbers, leakiness at the higher organizational scale, i.e. the entire substructure, determines the efficiency of odor capture. At higher Re numbers, advection at the lower organizational scale of a single sensillum is determining efficiency. We study how this trade-off results into capture efficiency of the entire sub-structure and observe that the multiscale architecture of the pectinate antenna of insects is highly adapted for odor capture over a large range of flow speeds. We end by discussing the embedding of this sub-structure in an entire antenna, using cylinders as proxy for the sub-structures. Their diameter is determined such that the cylinders have the same drag as the sub-structures.

29-8 JAN, I*; SANGHA, G; SCHULZ, JR; Occidental College; *tjan@oxy.edu*
The Cone Snail Strikes Back: A Biomechanical Study of an Ultrafast Prey Capture
While predatory cone snails have been extensively studied for their venom properties, their ultrafast prey capture mechanism remains relatively recondite. The fish-hunting *Conus catus* of the family Conidae hydraulically propels a hollow radular harpoon that tethers and injects venom into prey. In this biomechanical study, we studied the priming step, prey strike, and venom delivery of the prey capture. Energy is stored as the radular harpoon is forced against a unique cellular latch within the proboscis, a distensible appendage, until adequate pressure exceeds the latch mechanism. Subsequently, the radular harpoon reaches high accelerations—achieving velocities that mark this prey strike as the fastest in mollusks and one of the fastest in animals—before even more rapidly decelerating as the bulbous base travels to the end of the proboscis. We observed fast venom delivery following such high-speed prey strike, as the velocities of ejected venom dramatically dissipate prior to or during proboscis withdrawal. To determine if similar mechanisms exist in other members of the Conoidea superfamily, we studied *Hastula hectica* of the closely related Terebridae family to identify analogous structures critical to the ultrafast prey capture of *C. catus*. Consequently, this system may be found in a large subset of diverse marine gastropods beyond just cone snails.

P2-236 JANE, A*; FREDERICH, M; BYRON, CJ; University of New England, Biddeford, ME; *mfrederich@une.edu*
Detection of the invasive parasite Proctoeces maculatus at blue mussel aquaculture sites
Blue mussels (*Mytilus edulis*) are heavily farmed in the Gulf of Maine and are exposed to the rapid changes of the ecosystem, as well as to the potential for infection of newly invasive parasites. To develop a measure of mussel health in the changing ecosystem, 10 mussels were collected bimonthly from an inshore and offshore mussel farm site and processed for histology. Additionally, temperature and chlorophyll concentration were measured to assess connections between the organisms' surroundings and organismal health. Of the mussels analyzed over 29 months, 91% exhibited oocyte atresia and 49% exhibited digestive gland atrophy, indicating exposure to environmental stress. Histological analyses also showed infections with trematode worms. Because speciation is not possible via histology, PCR was performed on mussels that showed infections. As a species of concern off the coast of Maine, *Proctoeces maculatus* was tested for using species-specific PCR primers; sequencing of the respective samples is ongoing. *P. maculatus* has not yet been documented as far north as the Gulf of Maine, but is currently expanding its range northward into New Hampshire and has caused severe economic damage to bivalve aquaculture in the southern areas of its current documented range. An eDNA assay to detect *P. maculatus* in the waters around the mussel farm is currently in development. Therefore, our findings show that *M. edulis* farming in the Gulf of Maine is affected by the rapid environmental changes of the ecosystem, indicated by a shift away from proper tissue growth, and potentially show the first record of the parasitic trematode *P. maculatus* in Maine waters.

122-4 JANKAUSKI, MA; Montana State University; *mark.jankauski@montana.edu*
On the Nonlinear Mechanics of the Honeybee Thorax
The thorax (or thorax-wing assembly) of flying insects is widely believed to behave as a resonant mechanical oscillator. Thorax resonance is likely critical to the function of asynchronous muscles and may reduce the energetic costs of flight. Some orders of insects, such as Diptera or Hymenoptera, modulate their wingbeat frequencies during flight to affect aerodynamic force production. This implies that, if the thorax indeed behaves as a resonant oscillator, it must behave nonlinearly – linear oscillators have fixed resonant properties. To address potential nonlinearity, we performed a series of experiments on freshly sacrificed Honeybee *Apis mellifera* thoraxes. First, we conducted static force-displacement tests on the thorax about its ventral axis. Over the approximate range of in-vivo displacements, we found the thorax behaved approximately as a nonlinear hardening spring that became stiffer as it was compressed. Next, we mounted the thorax on a custom vibration shaker system in order to identify the thorax's linear resonant frequency as a function of compression. From zero to maximum compression, the thorax resonant frequency increased by as much as 100 Hz. This is consistent with the static force-displacement testing, since the thorax linear natural frequency is theoretically proportional to its stiffness. Our results suggest that insects may adjust the equilibrium state of their thorax in order to modulate wingbeat frequency.

P3-77 JARA, RF*; CREGO, RD; SAMUEL, MD; ROZZI, R; JIMéNEZ, JE; University of North Texas, University of Wisconsin-Madison; *rociojara@my.unt.edu*
Nest-Site Selection and Breeding Success of Passerines in the Southernmost Forest of the World
Among the hypotheses explaining nest-site selection and survival, the ‘total-foliage' hypothesis predicts that nests concealed in vegetation should have higher survival. An alternative, the ‘predator proximity' hypothesis, states that nests placed further away from predators will have higher survival. We examined these hypotheses on Navarino Island, where the predator assemblage has recently changed with the introduction of ground predators. During three breeding seasons, we monitored nests for the five most abundant open-cup forest-dwelling passerines. We identified nest predators using camera traps and assessed habitat characteristics that may affect nest-site selection and survival. The main nest predator was the native raptor *Milvago chimango*, whereas *Neovison vison* was the only ground predator, depredating one nest. Birds selected nest-sites with more understory cover, which, according to the total-foliage hypothesis, would provide more concealment against predators. However, understory cover did not influence nest survival. Some of the habitat characteristics that influenced nest survival of these species were consistent with the total-foliage hypothesis (e.g., nest concealment), whereas others supported the predator proximity hypothesis (e.g., nest height from the ground). There seems to be a disconnect between birds assessing the risk of predation (and selecting the appropriate nest-site) and the actual risk of predation. This could be due to recent changes in the predator assemblage caused by the introduction of ground predators to this island. The higher survival of nests placed further off the ground suggests that ground predators may be more prevalent than what we reported based on our camera trap data.

67-4 JARMAN , MJ *; HILL, EC; BUTLER , MA; University of Hawaii, Honolulu ; *mjarman@hawaii.edu*

When You Need a Miracle: Amplifying and Sequencing Degraded DNA Through Touchdown and Nested PCR Techniques.

There are many situations where investigators are faced with degraded DNA samples, but still need to obtain sequence data. This can include the analysis of ancient DNA, museum specimens, and even fresh tissues that have been delayed in transit and allowed to decompose. Particularly when samples are rare or prohibitively expensive to replace, it can be important to maximize data obtained from limited and damaged material. Two major problems are low template concentration and fragmented template. We explored the efficacy of touchdown and nested PCR strategies, without the use of special reagents, to recover sequences under less than ideal situations. We found that when DNA quantities are very low, it is difficult to amplify and visualize the data. We used the touchdown PCR technique to minimize the use of template DNA and avoid temperature optimization for each primer/template combination. Theoretically, PCR can work with a single strand of template, however, starting with very low concentration typically does not yield enough product to obtain reliable sequence information. We used the nested PCR technique, adding a second set of primers that are designed to sit internally to the original primer set. We were able to use the PCR product from the initial touchdown PCR as template for the nested PCR, yielding high concentrations of amplified DNA to visualize on agarose gels and Sanger sequence. Using combinations of these techniques we were able to obtain sequences of up to 600 base pairs for phylogenetic study, even in samples with little high molecular weight template (too low to visualize on an agarose gel). These methods may be applicable to many situations where template is degraded and in low quantity.

S6-6 JAWORSKI, JW; Lehigh University, Bethlehem, PA; *jaworski@lehigh.edu*

Acoustic models for wing specializations of silent owl species

Many owls species are known to be able to hunt in effective stealth to themselves and their prey, a feat which is attributed in full or in part to their wing specializations. Two of these specializations, the trailing-edge fringe and the velvety pennula on the upper-wing surface, are investigated using mathematical models with the goal to establish a physics-based understanding of their associated noise generation. These models take into account the porous and/or elastic nature of these owl wing features to examine their ability to potentially disrupt standard routes of noise production in low-speed flows. An emphasis is placed on the relevance of noise results to the range of sizes of owl species, with accompanying morphological measurements where appropriate. The technological impact and applications of noise-reduction technologies inspired by owl plumage will also be described.

S8-3 JAYNE, BC; University of Cincinnati; *jaynebc@ucmail.uc.edu*

What Defines Different Modes of Snake Locomotion?

Animals move in diverse ways, as indicated in part by the wide variety of gaits and modes that have been described for vertebrate locomotion. "Gaits" and "modes of locomotion" both refer to any repeatable pattern of movement of the propulsive structures. Much variation in the gaits of limbed animals is associated with changing speed, whereas different modes of snake locomotion are often associated with moving on different surfaces. For several decades different types of snake locomotion have been categorized as one of four major modes: rectilinear, lateral undulation, sidewinding and concertina. Herein, I highlight some of my work from the last three decades that suggests such a scheme may be overly conservative. For example, during aquatic lateral undulation the timing between muscle activity and lateral bending changes along the length of the snakes, which is unlike terrestrial lateral undulation. Lateral undulation at the edge of a surface while bridging a gap also uses a different motor pattern than lateral undulation on a horizontal surface that supports the entire length of the snake. In all types of concertina locomotion, the distance from the head to the tail changes substantially as snakes alternately flex and then extend different portions of their body. However, snakes climbing with concertina exert forces medially to attain a purchase on the branch, whereas tunnels require pushing laterally to form an anchoring region. Furthermore, different motor patterns are used for these two types of concertina movement. Some snakes climb vertical cylinders with helical wrapping completely around the cylinder, whereas all other forms of concertina bend regions of the body alternately to the left and right. Regardless of the taxonomy that is ultimately favored for categorizing modes of snake locomotion, it should be one that does not obscure important functional differences.

P3-75 JEAN-PAUL, J*; BERGEY, L; RITCHIE, L; XAVIER, C; Centenary University; *jefferson.jean-paul@centenaryuniversity.edu*

Effects of Light Conditions and Morphological Size on Predation of the Invasive Grass Shrimp, Palaemon Macrodactylus, and a Native Species, Palaemonetes Pugio.

Palaemon macrodactylus, an invasive species of grass shrimp, were collected off the coast of of New Jersey waters to determine effects of light conditions on predation of two different species of grass shrimp, Palaemon macrodactylus and Palaemon pugio. Size also played a factor in my experiment. In this experiment, the Fundulus heteroclitus was the predator of the grass shrimps. This experiment was tested to determine if the invasive species of grass shrimp were better at defending themselves against predators than the native species in the absence and presence of light. This study was important because it will show us if the invasive species can compete better than native species, and if they can then eventually they will overtake the population and kick out the native species of shrimp. This can lead to a decrease of the native population or even possible extinction. Kaplan-Meier survival curves and Cox proportional hazards regression was used to study the effects of species and lighting condition on risk of death due to predation. A significant ($p = 0.015$) crossover interaction between species and lighting on risk of predation was observed, where the hazard ratio comparing risk in full darkness to full light for Palaemonetes pugio was 4.5 times that value for Palaemon macrodactylus.

P1-137 JENDREY, CR*; TURNER, M; University of Washington, Seattle, WA; *chrisjendrey@gmail.com*
Star Gazing: Observations on the Movement and Feeding Behaviors of Ochre Sea Stars (Pisaster ochraceus)
Pisaster ochraceus (ochre sea star) is a major motile predator often found in rocky intertidal zones along the Pacific coast of North America. Commonly referred to as a keystone predator, *P. ochraceus* plays a significant role in shaping the structure of intertidal communities. During low tide, *P. ochraceus* are commonly found occupying shaded, damp crevice microhabitats in the intertidal zone to avoid adverse abiotic and biotic conditions, such as intense sunlight and predation by gulls. To better understand the behavior of these predators, we examined their diet and movement *in-situ* on San Juan Island, WA. Diet was monitored in the summers of 2018 and 2019 by turning over all individual stars within a fixed plot and noting the presence and identity of prey. Movement was tracked using time lapse photography collected in July 2019. Despite the crevices being nearly devoid of food, *P. ochraceus* spent much of their time inside crevices, where they moved the slowest, if at all. When submerged underwater during high tide, they moved outside the crevice, where prey is more abundant, exhibiting the fastest movement along the crevice edge. Our results support the idea of a feeding vs refuge tradeoff, wherein the abiotic stressors outside of the crevice exceed the sea star's need to feed. Although this predator can exert a major effect on the local prey community, their ability to forage and exert said community effect is limited by the abiotic conditions of their habitat.

91-1 JIAO, Y*; COLVERT, B; MAN, Y; MCHENRY, M; KANSO, E; University of Southern California, University of California, San Diego, University of California, Irvine; *jiaoyush@usc.edu*
Evaluating Evasion Strategies in Zebrafish Larvae
Predation is a primal interaction between species, yet it is unclear what evasion strategies are effective for prey survival. Existing theories suggest that the prey should escape in an optimal direction that maximizes its distance from the predator or in a random and therefore unpredictable direction. Here, we propose several evasion models of zebrafish larvae, including the distance-optimal and random strategies. We built probabilistic models that account for sensory and response noise and used statistical methods to assess these models in comparison to experimental data. This novel approach allowed us to evaluate the relative merits of multiple evasion strategies in predicting the behavior of prey. We found that two strategies are best supported by experimental observations: the distance-optimal strategy and a simpler strategy where prey fish swim orthogonally to the predator's heading. The orthogonal strategy is a special case of the distance-optimal strategy in the limit of fast predators, yet it requires less sensory effort. We argue that the orthogonal strategy is optimal when considering the neuro-sensory circuits underlying evasion. To probe these circuits, we developed a biomechanical model of the fast response of larval zebrafish that addresses the physical constraints on the motor control of evasion. Taken together, these results suggest that fish adopt a strategy that saves both the perception complexity and the physical difficulty in motor actuation.

38-2 JIMENEZ, YE*; BRAINERD, EL; Brown University; *yordano_jimenez@brown.edu*
Regionalized contributions of the epaxial musculature to swimming and suction feeding in bluegill sunfish
Many fishes can recruit the axial musculature for both swimming and suction feeding, yet little is known about how this dual-function muscle operates under the distinct mechanical demands of these behaviors (lateral versus dorsal axial flexion). Using electromyography and sonomicrometry, we measured muscle activity and strain for suction feeding and burst swimming in three dorsoventral epaxial regions in a bluegill sunfish. Sunfish consistently activated the dorsalmost epaxial region for low- and high-performance strikes and added activation of the middle and ventral regions for high-performance strikes on live prey. By contrast, sunfish always activated all three epaxial regions for fast-starts. Our results suggest that sunfish use recruitment patterns similar to largemouth bass, where they increase performance for suction feeding by activating the epaxial muscle from dorsal to ventral, and in the case of swimming, from ventral to dorsal. We also found that longitudinal strain varied with respect to distance from the vertebral column, as predicted by beam theory. Strains for fast-starts were highest in the lateral region and lowest in the medial region, while strains for suction feeding were highest in the dorsal region and lowest in the ventral region for suction feeding. Our EMG data suggest that sunfish vary regional muscle recruitment for modifying swimming and suction feeding performance. Our strain data suggest that the different modes of axial bending used for feeding and swimming behaviors create distinct strain gradients. Future studies examining the relationship between longitudinal strain and muscle fiber strain are needed to quantify regional differences in power output for swimming and suction feeding.

80-5 JIMENO, B*; LANDRY, D; STAGER, M; WOLF, C; PRICHARD, M; CHEVIRON, Z; BREUNER, C; University of Montana; *bjimenorev@gmail.com*
Metabolic traits, but not corticosterone concentrations, are associated with reproductive investment in tree swallows
Organisms continuously face environmental fluctuations, and allocation of metabolic investment to meet changing energetic demands is of fundamental importance to survival and reproductive success. Glucocorticoid (GC) hormones (e.g. corticosterone –CORT-) play an important role in energy balance and acquisition on the face of environmental challenges, by mediating metabolic processes involved in energy metabolism. Although fluctuations in GCs and metabolic rate are expected to covary, surprisingly few empirical studies have demonstrated relationships between GC concentrations and metabolic rate in wild, free ranging animals. We measured CORT (baseline and stress-induced) and metabolic traits (resting metabolic rate –RMR-, cold-induced VO2max, and aerobic scope) in female tree swallows (*Tachycineta bicolor*) during chick-rearing, and tested for their associations with several variables of reproductive performance. We found that only metabolic traits were associated with reproductive success; females with higher reproductive output showed higher resting metabolic rate and lower VO2max. Moreover, we found a positive relationship between resting metabolic rate and baseline CORT, but other associations between metabolic rates and CORT levels were not significant. This suggests that while baseline CORT may be a good indicator of an individual´s baseline metabolic investment, stress-induced CORT may be more stimulus-specific, and does not reflect aerobic scope or the upper limits of aerobic performance. Overall, our results suggest that metabolic traits may be better predictors of reproductive investment in tree swallows than CORT parameters. They further suggest the available energy budget may be more constrained in females investing more heavily in a current reproductive event due to elevated baseline metabolic costs.

P3-26 JOGLEKAR, IU*; CLARK, AC; University of Texas at Arlington; *ishaajoglekar@gmail.com*

Evolution of Conformational Landscape in Reef-Building Coral Caspases

Caspases belong to a class of cysteinyl proteases that play an integral part in cell development and apoptotic cell death as an evolutionarily conserved function. Apoptotic cell death is a defining characteristic of metazoans; however, the number of caspases identified is distinct for each species and extends back to more than 430 million years. Although the use of C. elegans and D. melanogaster as model organisms have provided key insights in establishing the molecular basis of apoptosis, the disparate cell death pathways have obscured its evolutionary origins. Reef-building corals of the Phylum Cnidaria are an emerging model for caspase studies. Research suggests that Cnidarian apoptotic pathways may be similar to and as complex as vertebrate pathways. Recent findings suggest that corals characterized as disease-susceptible undergo an apoptotic response, whereas tolerant species exhibit an autophagic response. Caspases have developed overlapping substrate profiles and common and unique allosteric sites for fine-tuning caspase activity, through hundreds of millions of years of evolution and are therefore an excellent model system for studying protein evolution. Comparison of the caspase repertoire of these corals lying on the opposing ends of the immunity spectrum will provide advanced knowledge in the fields of protein evolution, controlled cell death and coral biology. Protein folding studies on the reconstructed ancestral proteins between humans and invertebrate species will provide insights into the molecular and biophysical mechanisms that mediate caspase function and evolution. These studies aim to test the central underlying hypothesis, that, differences in the evolution of caspase activity, substrate specificity and allosteric regulation underlie the ecological trajectories of each coral species.

S3-8 JOHANSON, Z*; UNDERWOOD, C; MANZANARES, E; FERNANDEZ, V; CLARK, B; SMITH, M; Natural History Museum, London, UK, Birkeck, University of London, UK, Universitat de Valencia, Spain, King's College, London, UK; *z.johanson@nhm.ac.uk*

Evolution of the Dentition in Sharks

Sharks and their relatives belong to the major vertebrate group, Chondrichthyes, with an evolutionary history that extends back over 450 million years. Recent research has focused on an improved understanding of the phylogenetic relationships of chondrichthyans, in particular stem-group relatives of the crown groups Elasmobranchii (sharks and rays) and Holocephali (chimaeroids). Knowledge of these relationships is crucial to understanding how chondrichthyan teeth, within a patterned dentition, have evolved in the elasmobranchs, including in new model taxa such as the catshark *Scyliorhinus* and the Little Skate *Leucoraja*. Development of the dentition in the elasmobranchs, and particularly in sharks like *Scyliorhinus*, is becoming increasingly well understood, including genes involved in tooth regeneration and rotatory successive replacement. Rays like the Little Skate show very similar processes with respect to tooth addition, as new teeth are iteratively added to sets across the jaw. In an evolutionary sense, teeth arranged into files on the jaw first appear in stem chondrichthyans known as acanthodians (420-250 million years ago), with this character, rotatory succession, retained in stem relatives of the elasmobranchs and holocephalans, representing the primitive condition for sharks and rays. However, the holocephalans are particularly notable, with extant representatives (crown group holocephalans) characterized by dentitions lacking teeth, lost during the evolution of the group; neither tooth germs, nor successive teeth have been observed in embryos or adults. Exactly when, and how, these teeth were lost, compared to the elasmobranchs is an area of research ripe for exploration.

P1-230 JOHANSON, Z*; UNDERWOOD, C; TWITCHETT, R; SMITH, M; Natural History Museum, London, UK, Birkeck, University of London, UK, King's College, London, UK; *z.johanson@nhm.ac.uk*

Microstructure and Mineralogy in Dental Plates of Harriotta raleaghae (Holocephali): Novel Dentine and Conserved Patterning Combine to Create a Unique Chondrichthyan Dentition

Among cartilaginous fishes (Chondrichthyes), Holocephali is the sister group to the Elasmobranchii (sharks, rays). Crown group holocephalans lack teeth, instead having dental plates in the upper and lower jaws. In the Chimaeridae and Rhinochimaeridae, adult plates include extensive trabecular dentine supporting crushing tritoral pads along with unusual series of dentine ovoids along the lateral plate margins. Instead of ovoids, juveniles have elongate rods of dentine. In *Chimaera*, dentine includes the unusual calcium phosphate mineral whitlockite, containing magnesium (Mg). We examined the dentition of the rhinochimaerid *Harriotta*, to determine whether whitlockite occurs more broadly within the Holocephali, and to investigate dental plate development in juveniles and adults, where tissues are continually renewed deep to the oral surface. Here, rods, ovoids and tritoral pads develop within patterned and organized spaces in the trabecular dentine framework. Patterning is reminiscent of other chondrichthyan dentitions, but in adults, mineralizing tissue in ovoids and tritors is initially a granular, disorganised cluster of crystals differing in shape and composition (ß-tri calcium phosphate) from hydroxyapatite crystals in other mineralized vertebrate tissues. Elemental analysis shows there is relatively more Mg in these early-forming tissues, decreasing as mineral density increases towards the oral surface. We propose that Mg in dental plates characterizes at least the Chimaeridae and Rhinochimaeridae, and is related to the Jurassic origins of the Chimaeriformes in Mg-rich, aragonitic seas.

32-1 JOHN, JS*; THOMETZ, NM; BOERNER, K; DENUM, L; KENDALL, TL; RICHTER, BP; GASPARD, JC; WILLIAMS, TM; University of California Santa Cruz, San Francisco University, San Francisco, CA , Mote Marine Laboratory & Aquarium, Sarasota, FL, Mote Marine Laboratory & Aquarium, Sarasota, FL, Pittsburgh Zoo & PPG Aquarium, Pittsburgh, PA; *jsjohn@ucsc.edu*

Energetics of swimming in tropical marine mammals- Examining metabolic tradeoffs in West Indian manatees and Hawaiian monk seals

One of the most challenging aspects of the marine environment for mammals is thermoregulation due to the high heat transfer rate of water. Despite this there are few marine mammal species found exclusively in tropical regions and little is known about the energetic consequences of warm water adaptations on locomotor costs in these species. Working with Hawaiian monk seals (*Neomonachus schauinslandi*) and West Indian manatees (*Trichechus manatus*) as our model tropical species, we used flow-through respirometry to measure resting metabolic rate (RMR), stroke cost (SC), and cost of transport (COT) in 2 adult manatees at Mote Marine Lab (Sarasota, FL) and 1 adult monk seal at Long Marine Lab (Santa Cruz, CA). We found low average RMRs for both the monk seal (748.7 $kJ \cdot hr^{-1}$) and manatees (885.9 $kJ \cdot hr^{-1}$) relative to other marine mammals. In contrast, SC and COT were in line with predicted marine mammal values for both the monk seal (SC = 5.1 $J \cdot kg^{-1} \cdot stroke^{-1}$, COT = 1.7 $J \cdot kg^{-1} \cdot m^{-1}$) and manatees (SC = 2.6 $J \cdot kg^{-1} \cdot stroke^{-1}$, COT = 1.0 $J \cdot kg^{-1} \cdot m^{-1}$). This dichotomy indicates that thermoregulatory costs strongly influence RMR, but that costs associated with locomotion are more strongly affected by hydrodynamic interactions. While allometric analyses have proven useful in predicting energetic costs for many marine mammal species, the divergent thermoregulatory and hydrodynamic factors highlighted here for tropical species need to be accounted for when modeling energetic costs across tropical, temperate, and polar species.

70-2 JOHNSEN, S*; CAVES, EM; Duke Univ., Exeter Univ.; *sjohnsen@duke.edu*

How our perceptual and cognitive biases may influence our study of animal vision

It has long been appreciated (and celebrated) that certain species have sensory capabilities that humans do not share, for example ultraviolet vision and magnetoreception. What is less appreciated however, is that our position as terrestrial human scientists can significantly affect our study of animal senses and signals, even within modalities that we do share. For example, our acute vision can lead us to over-interpret the relevance of fine patterns in animals with coarser vision, and our Cartesian heritage as scientists can lead us to divide sensory modalities into orthogonal parameters (e.g. hue and brightness for color vision, angle and degree for polarization vision), even though this division may not exist within the animal itself. In addition, we often use lab-based assays to make ecological predictions, even though the sensory environment is completely different. Finally, we may assume that what is salient and striking to us must be so to other animals. This talk examines two cases from marine visual ecology where a reconsideration of our biases as sharp-eyed Cartesian land mammals can help address questions in visual ecology. The first case examines the enormous variation in visual acuity among animals with image-forming eyes, and focuses on how acknowledging the typically poorer resolving power of animals can help us interpret the function of color patterns in cleaner shrimp and their client fish. The other case examines the how the typical division of polarized light stimuli into angle and degree of polarization is problematic, and how a Stokes vector interpretation is both closer to the physiological truth and resolves a number of issues, particularly when considering the propagation of polarized light underwater and whether polarization vision can be used to break camouflage.

P2-7 JOHNSON, LE*; TREIBLE, LM; Trinity University, Georgia Southern University; *ljohnso6@trinity.edu*

Synergistic Effects of UVA and UVB Radiation on Moon Jellyfish Proliferation and Potential Coping Mechanisms

Ultraviolet radiation (UVR) composed of ultraviolet A (UVA: 320-400 nm) and ultraviolet B (UVB: 280-320 nm) can penetrate up to 30 m into the water column. Jellyfish are often considered robust to environmental stressors, which could explain localized increases in jellyfish blooms. To test resilience to UVR stress, this study exposed *Aurelia aurita* polyps to artificial UVA and UVB radiation (both isolated and combined) to determine the effects on asexual reproduction and potential mitigating mechanisms. There was no difference in reproduction between polyps exposed to isolated UVA (379.68 nm = 11.3 uWcm^{-2}) and polyps that did not receive UVR. Polyps asexually reproduced when exposed to short term (~7-9 days) isolated UVB (305.22 nm = 8.7 uWcm^{-2}), but long-term exposure limited reproduction and attachment. When exposed to both UVA (11.6 uWcm^{-2}) and UVB (8.6 uWcm^{-2}), polyps did not reproduce and experienced 100% mortality within 20 days. Furthermore, *A. aurita* polyps do not appear to have chemical or behavioral mechanisms to combat UVR exposure. Polyps did not contain mycosporine-like amino acids (MAAs) which absorb UVB radiation and have been found in other aquatic organisms. Polyps also did not sequester carotenoids (antioxidants) from their brine shrimp (*Artemia* sp.) diet. When exposed to combined UVA and UVB in the presence of a nearby UVR refuge, polyps did not migrate to the refuge. These results suggest that polyps lack mechanisms to alleviate UVR stress, so the planula larvae stage must be important for settlement away from UVR to establish the success of the polyp stage. Importantly, studies that only examine impacts of UVB potentially underestimate the full effect of UVR.

103-1 JOHNSON, TL*; DEFINO, NJ; RAUSCHER, MJ; HECKSCHER, ES; FOX, JL; Case Western Reserve University, University of Arizona, University of Chicago; *jlf88@case.edu*

Interneurons for Mechanosensory Processing in Adult Drosophila

Sensory-motor integration is important for coordinating behaviors like walking and flying. In the larvae of *Drosophila melanogaster* , neurons expressing the gene Even-skipped receive mechanosensory and proprioceptive input, and are necessary for coordinating muscle contractions. When these neurons are ablated by expression of the apoptotic transgene Reaper, larval crawling becomes uncoordinated. The function of these neurons is unknown in adults, but anatomical evidence suggests that Even-skipped neurons receive input from the halteres, the flies' gyroscopic reduced hindwings. We hypothesized that Even-skipped neurons receive critical sensory input from halteres, which help transmit signals to the wings and head to function properly. To test this hypothesis, we compared the behavior of intact wild-type flies, flies with mechanically ablated halteres, and flies expressing Reaper in the Even-skipped neurons. We tested adult flies performing three different behaviors: free take-off, tethered flight, and tethered flight with imposed body rotations. We observed body position, wing amplitudes, and head positions during these behaviors. Flies expressing Reaper in the Even-skipped neurons behaved similarly to flies with mechanically-ablated halteres, and both of these groups performed significantly differently from wild-type flies. These behavioral results are consistent with the hypothesis that Even-skipped neurons provide essential sensory input via the halteres.

P3-192 JOHNSON, ZV*; LONG, L; LI, J; ALJAPUR, V; ARROJWALA, M; HEGARTY, BE; LEE, T; GU, K; LECESNE, RL; MOORMAN, JM; STREELMAN, JT; MCGRATH, PT; Georgia Institute of Technology; *zachary.johnson@biosci.gatech.edu*

Depth sensing and deep learning: new insights into social bower building behaviors in Lake Malawi cichlids

Advances in genetics, neuroscience, and computer science facilitate the use of new and non-traditional systems to study the biological basis of phenotypic diversity. Lake Malawi cichlids are promising in this regard, having undergone explosive speciation in the past ~1 million years, radiating into ~1,000 phenotypically diverse species. We develop tools for studying the neurogenetic basis of species differences in bower building behaviors in these fishes. Bower building is a sociospatial mating behavior exhibited by ~200 species, whereby reproductive cues cause males to construct crater-like "pits" or mountain-like "castles" by moving mouthfuls of sand for days or weeks at a time. We designed an automated recording system that integrates a low-cost mini computer, a high-definition RGB camera, and a depth sensor to measure bower behaviors in many aquariums simultaneously. We train a Convolutional Neural Network (CNN) to automatically classify bower construction behaviors, spawning, and feeding behaviors from video data with high accuracy in multiple individuals and species. We analyze depth data to measure temporal patterns of bower activity, and to show that bower construction is spatially repeatable across trials. By linking video and depth data together, we quantify a remarkable phenotype in pit-castle F1 hybrids, in which males express both parental behaviors independently in sequence, first digging a pit and then building a castle. Lastly, we ground truth brain single nuclei sequencing in combination with FACS as a means for investigating the neurogenetic basis species differences in bower behavior.

98-8 JOHNSON, KM*; SIROVY, KA; KELLY, MW; Louisiana State University, Baton Rouge; *kmjohnson@lsu.edu*
VARIATION IN DNA METHYLATION AND GENE EXPRESSION BETWEEN AND WITHIN FAMILIES OF THE EASTERN OYSTER Crassostrea virginica
Populations of eastern oysters (*Crassostrea virginica*) in the Northern Gulf of Mexico will be challenged by predicted changes in environmental conditions associated with climate change. As environmental variation shifts, a combination of phenotypic plasticity and local adaptation will be important mechanisms that may allow one population to outperform another within a given estuary. Recent evidence suggests that there are population specific patterns in DNA methylation in *C. virignica* and that DNA methylation is significantly affected by changes in the environment. In this study we have explored changes in DNA methylation and gene expression 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; 21 psu) or at a low-salinity site (Chauvin, LA; 9 psu). To test for the effects of rearing environment and genotype 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 changes in gene expression using 3'TAG-sequencing. With this approach it was possible to genotype each individual in order to disentangle genetic from environmental drivers of both DNA methylation and transcriptome level plasticity. This analysis identified some variation in methylation and expression between families within a site - suggesting a genetic basis for the variation; and highlighted that the majority of plasticity was observed between common garden out-plant sites but within the low salinity population.

21-7 JOHNSON, MW*; TRICOMO, AS; SHOUGH, AE; SANDERS, JC; COHEN, SC; San Francisco State University, Humboldt State University, University of Portland, Southern Illinois University Edwardsville; *mjohnson18@mail.sfsu.edu*
Investigating the Foraging Behavior of Leptasterias spp. Across Intertidal Microhabitats
The coastal intertidal zone contains much fine-scale habitat variation, related to a variety of abiotic factors including wave exposure. *Leptasterias* spp. is a genus of predatory sea stars found along the west coast of North America, and across intertidal microhabitats with varying levels of exposure to wave stress. *Leptasterias* spp. are limited dispersers - embryos are brooded, which may lead to differentiation or local adaptation. Preliminary data suggests behavioral differences among stars from different microhabitats that may reflect differential adaptation to prey accessibility and stressors associated with low and high wave exposure. We investigated the foraging activity of *Leptasterias* spp. from sites with inferred high and low wave exposure in central and northern California. Prior to collection, we estimated field prey availability by quantifying abundance in 50 cm^2 quadrats surrounding individual stars. Crawl distance and prey choice were then tested in static seawater tanks and in a two-current flume tank. High and low wave-exposed sites showed different prey composition, and stars from low wave-exposed sites crawled farther than high wave-exposed stars (Mann Whitney U = 173.5, p = 0.038). Although *Leptasterias* spp. showed an overall tendency to detect and choose prey in a two-current flume tank (One-sample proportion test, p = 0.053), prey choice did not differ between stars of different microhabitats. *Leptasterias* spp. may use chemoreception in foraging, and the extent to which other behavioral differences reflect microhabitat and clade may vary.

P2-117 JOHNSTON, M*; FINTON, C; BRASS, K; OPHIR, AG; CAMPBELL, P; Oklahoma State University, Department of Integrative Biology, Stillwater, OK, Cornell University, Department of Psychology, Ithaca, NY, University of California Riverside, Department of Evolution, Ecology, and Organismal Biology, Riverside, CA; *polly.campbell@ucr.edu*
Central oxytocin and vasopressin receptor distributions in the house mouse, Mus domesticus, and non-commensal congeners, M. spretus and M. spicilegus
The neuropeptides oxytocin (OT) and arginine vasopressin (AVP), together with their non-mammalian homologs, modulate a broad range of vertebrate social and reproductive behaviors. In mammals, species differences in forebrain distributions of the oxytocin receptor (OTR) and vasopressin receptor 1a (Avpr1a) evolve rapidly, often in association with differences in sociality or mating system. We used autoradiography to compare the distribution and density of OTR and Avpr1a expression in three closely related species of Old World mice that differ in social structure and population density: the house mouse, *Mus domesticus*, the Algerian mouse, *M. spretus*, and the mound-building mouse, *M. spicilegus* (n = 9-11/sex/species). The most striking species differences were found for OTR, which was significantly higher in *M. domesticus* and statistically identical in *M. spretus* and *M. spicilegus* in the majority of analyzed brain regions. House mice live at high population densities relative to the two non-commensal species; we speculate that higher forebrain sensitivity to oxytocin evolved in association with selection to enhance social memory and reduce social aggression under commensal conditions. As the first comparative analysis of OTR and Avpr1a in *Mus*, this study lays the groundwork for experimental tests of ecologically relevant functions of OT and AVP in this highly tractable system.

P3-234 JOHNSTONE, J/B*; RAHMAN, M/S; University of Texas Rio Grande Valley; *jackson.johnstone01@utrgv.edu*
Impacts of rising temperature on gonadal functions, heat shock protein expression, cellular apoptosis, and body fluid conditions in Atlantic sea urchin
Increasing surface sea temperatures are having an increasing impact on marine and coastal 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 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.

112-4 JONES, CLC*; HUBER, RJ; KIM, W; PRATER, C; SHAFER, ABA; WAGNER, ND; FROST, PC; Enivronmental and Life Sciences Graduate Program, Trent University, ON, Department of Biology, Trent University, ON, Department of Biology, Trent University, Peterborough, ON, Department of Geography, Loughborough University, UK, Department of Forensic Science, Trent University, ON, Center for Reservoir and Aquatic Systems Research, Baylor University,TX; *catrionajones@trentu.ca*

Animal co-limitation by calcium and phosphorus revealed through experimental nutrigenomics

Lakes across the Canadian Precambrian Shield and northern Europe are experiencing declines in ambient phosphorus (P) and calcium (Ca) at unprecedented rates. While these declines may create or exacerbate nutrient-stress in aquatic food webs, our ability to detect and quantify nutrient-stress of these two elements on zooplankton remains limited. Here, we use next generation RNA sequencing technology and differential gene expression analysis to examine the molecular phenotypes produced by single and combined limitation of these two key dietary nutrients in the freshwater zooplankter, *Daphnia pulex*. Our results reveal an intermediate phenotype in Ca- and P-stressed animals, which provides evidence that *D. pulex* experiences nutritional co-limitation by both nutrients. We used transcriptome data to identify the most highly up- and down-regulated metabolic pathways, which are presumably involved in mitigating the physiological effects of poor P- and Ca-nutrition. These data provide us with the necessary groundwork to begin unravelling complex multi-nutrient interactions in nature and allow us to start making predictions about the effects of multiple declining nutrients on populations and communities. We believe that nutrigenomics has the potential to address many of the inherent complexities in studying nutritional interactions. Further work is needed however to lay the genomic groundwork necessary to carry out this type of analysis on non-model organisms (i.e. genome sequenced and annotated, gene ontogeny predictions, etc).

126-7 JONES, MM; NUñEZ, CMV*; University of Florida, Gainesville, The University of Memphis; *cmnunez@memphis.edu*

Rising up to the challenge of their rivals: mare behavior alters stallion response to opponent playback

Feral horses are a beloved icon across the United States, but with few remaining predators and no legal hunting, population management is essential. Female contraception with porcine zona pellucida has become a popular option. Though behavioral effects to treated individuals have been established, we know little about impacts to untreated counterparts. On Shackleford Banks, a barrier island in North Carolina, treated females show decreased social fidelity, moving among groups more frequently than untreated females, likely affecting resident males' behavior. To test this hypothesis, we asked whether the timing of female group changes predicted male responsiveness to audio playback of simulated rivals (male squeal vocalizations) or control sounds (human voices reciting, "hello horse"). Males' latency to return to normal behaviors and their time spent vigilant were highest when playbacks occurred during and directly after female group changing behavior. These findings suggest that female turnover can exacerbate male responsiveness to rivals, an important consideration if agencies aspire to manage animal populations with minimal effects to species' behavior.

P3-155 JONES, AE*; WEBB, JF; University of Rhode Island, Kingston, RI; *aubree_jones@uri.edu*

Implications of the Relatively Long Larval Phase of a Salmonid (Brook Trout, Salvelinus fontinalis) for Mechanosensory Lateral Line System Morphology

The cranial canals of the salmonid mechanosensory lateral line system are well-developed in adults and contain more neuromast receptor organs than in other teleost fishes. Larvae (fry) emerge from the gravel after the yolk is absorbed, up to several months post-fertilization. We *hypothesize* that the comparatively long larval stage of salmonids, during which neuromasts can increase in number, explains adult LL morphology. An ontogenetic series of hatchery-reared brook trout (*Salvelinus fontinalis*) was used to describe the ontogeny and distribution of neuromasts from day-of-hatch (alevin, larvae), through the larval period, to 6 months post-hatch (parr, juveniles). SEM and histology showed that although all neuromasts sit on the skin surface, two distinct groups are evident even in young larvae: presumptive canal neuromasts (PCNs; which become enclosed in canals) and superficial neuromasts (SNs; which remain on the skin). SN and PCN number increase during the long larval period before PCNs are enclosed in bony canals. In addition, PCNs appear before SNs and then increase in size at similar rates so that PCNs tend to be larger than SNs. PCNs and SNs are both oval-shaped (but demonstrate variation in length:width ratio) with a central sensory strip containing sensory hair cells. These changes in neuromast number and morphology likely affect their sensitivity to water flows, which is especially important in high flow environments. During the early vulnerable stages of brook trout life history, such morphological changes are predicted to have important impacts on behavioral role, and ultimately survival. Funding: NSF Graduate Research Fellowship and a URI Enhancement of Graduate Research Award to AEJ.

P1-196 JONES, DD*; SCHMITZ, L; Scripps College, Claremont, CA, Claremont McKenna, Scripps, and Pitzer Colleges, Claremont, CA; *djones7425@scrippscollege.edu*

Retinal Topography of Mudskippers and Related Gobiid Fishes

Mudskippers are amphibious fish of the Gobiidae that occupy tidal environments characterized by a well-defined air-water horizon. According to the terrain hypothesis, mudskippers should have a pronounced, horizontally oriented high density zone of neural cells across the retina. Such a horizontal streak would allow the fish to monitor the horizon with high visual acuity. Previous data suggest the presence of horizontal streaks in mudskippers yet it is unknown whether this feature can be interpreted as an evolutionary adaptation to tidal habitats. We tested for the presence of horizontal streaks and their potential adaptive significance by studying retinal topography of the African mudskipper *Periophthalmus barbarus* and two related gobiids, the ornate rainbow goby *Stiphodon ornatus* and the flaming arrow goby *Sicyopus zosterophorus* . Retinal topography maps were generated on the basis of stereological cell counts of Nissl-stained wholemounts. The resulting maps of the density of neural cells in the retinal ganglion cell layer revealed that horizontal streaks are not restricted to mudskippers. Contrary to our prediction, the horizontal streak was most prominent in the ornate rainbow goby, extending from the temporal region along the entirety of the retinal meridian. The horizontal streak seen in the flaming arrow goby was somewhat less pronounced but still extended along the entirety of the meridian, while that of the mudskipper was confined to the temporal aspect of the eye. Our results suggest that the horizontal streak of mudskippers cannot be interpreted as an evolutionary adaptation specific to an intertidal habitat. We propose that both intertidal and shallow river habitats with clear water can favor the evolution of horizontal streaks.

92-6 JONES, BC*; DUVAL, EH; Florida State University; *jonesbc@gmail.com*

Development of the glucocorticoid stress response and its effects on growth in a tropical passerine

The dampened hormonal stress responses in neonates is thought to be an adaptive response against the damaging effects of exposure to chronically high concentrations of glucocorticoids, such as retarded growth. Glucocorticoids facilitate the mobilization of stored energy but can also promote anabolic processes in specific contexts. Understanding the development of the glucocorticoid stress response and when and how glucocorticoids affect growth are important for predicting how growing animals will respond to perturbations. We investigated the development of the hormonal stress response and the relationship between endogenous corticosterone (Cort) and growth in the lance-tailed manakin (Chiroxiphia lanceolata). We subjected 11-day-old nestlings and adult manakins to a standardized capture and restraint protocol to measure baseline and stress-induced levels of Cort post-capture. We found that nestlings had an attenuated stress-response and faster negative feedback compared to adults. We also compared concentrations of Cort to mass and skeletal growth. Baseline concentrations had an inverted U-shaped relationship with both mass and structural growth. Stress-induced concentrations had a negative relationship with structural growth but did not affect mass. These results demonstrate the importance of validating the timing of stress series protocols in developing young independent of those used for adults. Further, Cort appears to facilitate growth at low concentrations, while overall mass is buffered against the negative effects of high concentrations of Cort at the expense of structural growth. This is likely important for altricial avian species, as they rely on fast structural growth, particularly of wings, to minimize predation risk in the nest.

5-3 JORGE, J*; PATEK, SN; Duke University; *jfj7@duke.edu*

Taking a swing at measuring small-scale, high acceleration impacts: a novel two-pendulum approach

Impact dynamics underlie many biological motions including prey capture and locomotion. Oftentimes, the size and time scale of these impacts allow for measurement with force transducers, strain gauges, or accelerometers. However, motions like the ultrafast mandible strikes of a trap jaw ant occur at incredibly small scales placing them outside the range of traditional sensors. Furthermore, these strikes have many uses (from prey capture to mandible powered jumps) against diverse biotic and abiotic materials. When measuring these strikes, we must consider the material properties of the struck target, whether or not the target is fixed, and the contact duration. Here we measure energy transfer from a trap jaw ant into a target with a novel two-pendulum device. The device consists of two separate pendulums with an ant affixed to the end of one pendulum and a target affixed to the end of another. We tested impacts on two target materials: spring steel and polyurethane. We hypothesized that impacts on spring steel would yield higher energy outputs than the more compliant polyurethane. Each target material was tested by positioning the ant close to either a freely-swinging target or a fixed target to provoke a strike. Our data supported the hypothesis that, due to differences in energy absorption, impacts with polyurethane yield lower average energy of pendulum motion (6.3 µJ) than with spring steel (22 µJ). Fixing the targets did not significantly affect measured energy. Contact duration was a key predictor of energy across all treatments. Longer contact durations led to lower measured energy, which is a fundamentally different dynamic of these small impact systems compared to larger jumping animals that maximize ground contact time to enhance energy exchange during impact.

P2-70 JOSHI, MM*; KLAR, EA; ABERNATHY, AL; SIBLEY, AL; BELT, JM; NEWBREY, MG; Columbus State University, Columbus, GA; *joshi_meenal@columbusstate.edu*

Background levels of intersex in Largemouth Bass (Micropterus salmoides) revealed through histological evaluation of gonadal tissue from three interconnected water bodies

There are no published studies explicitly identifying the background levels of intersex in male Largemouth Bass (Micropterus salmoides), and this lack of knowledge limits our ability to interpret the species-specific severity of intersex. For example, we would interpret perturbations to fecundity to be minimal if a population exhibited a hypothetical value of 65% intersex when compared to a natural background level of 60% intersex. In contrast, the effect of intersex on fecundity is interpreted to be much greater if the hypothetical background level was 0% intersex. We hypothesized the occurrence and prevalence of intersex should be the same among the Chattahoochee River and two of its tributaries, Columbus, GA, USA. Largemouth Bass were collected using backpack and boat electrofishing techniques from Lindsey and Heiferhorn creeks, and Lake Oliver of the Chattahoochee River. Gonads from all fish were prepared histologically and stained using hematoxylin and eosin. In Largemouth Bass from Lake Oliver (n=37 males), the occurrence of intersex was 76%. However, in Lindsey and Heiferhorn creeks (n=20 males), none of the males exhibited intersex; therefore, the background level of intersex is 0%. Conversely, the occurrence of intersex in Lake Oliver is markedly higher and present in most of the males examined. This evaluation demonstrates that no intersex should be expected in Largemouth Bass and also showcases the extremes in intersex among connected waterbodies within the same drainage.

42-4 JUAREZ, BH*; MOEN, DS; ADAMS, DC; Iowa State University, Oklahoma State University; *bryanhjuarez@gmail.com*

Morphology Predicts Interspecific Jumping Performance in Frogs

Ecological and evolutionary processes depend on individual fitness. Oftentimes, organismal performance is a more accurate predictor of individual fitness than morphology. Recent work has shown that organismal performance, such as feeding performance in fishes, can sometimes be estimated from morphology. Here we test whether morphological proxies can predict jumping performance across 167 individuals from 29 species of frogs. First, we used biological and physical principles to mathematically derive three anatomical proxies for three aspects of jumping performance: jumping velocity, energy, and power. These anatomical proxies use non-invasive anatomical measurements such as the hip length, leg length, body size, and mass of frogs to estimate jumping performance. Second, we used phylogenetically generalized least squares and ordinary least squares regression to assess the precision with which these anatomical proxies allow us to predict jumping performance across the morphological, ecological, and geographical diversity represented in our interspecific dataset. Preliminary analyses indicate that we are reasonably able to estimate all three aspects of jumping performance. The ability to predict jumping performance from morphology (e.g. using museum specimens) allows the rapid sampling of many individuals. Therefore, relative to traditional laboratory methods, this new method enables us to more easily collect the large sample sizes necessary to test different macroevolutionary-level hypotheses regarding the jumping performance of anurans, and possibly other jumping animals.

5-4 JUNG, SJ*; KIM, S; WU, B; DOMBROSKIE, J; Cornell University; *sj737@cornell.edu*
Shattering raindrops on biological surfaces (insect wings, bird feathers)
Many biological surfaces (e.g. bird feathers, insect wings, and plant leaves) are super-hydrophobic with physical morphology at different scales. However, it is not well understood how a raindrop impacts natural super-hydrophobic surfaces, and its significance of biological functions. In this present study, we found that a spreading drop at a high speed can generate wrinkled pattern (including shock-like waves) on a spreading liquid in the presence of surface morphology at the micro scale. Furthermore, the spreading drop is suddenly ruptured by growing holes followed by the shock waves, which leads to a decrease in contact time more than 50%. As a result, heat and momentum transfers are reduced by raindrops, which may lower the hypothermia risk of animals or less affect the stability of insect flights. Additionally, we revealed that the drop fragmentation sheds smaller satellite droplets, which play a crucial role in promoting wet pathogenic dispersal by carrying pathogenic spores along. Therefore, our results shed light on multi-functional aspects of biological super-hydrophobic surfaces.

114-1 JURESTOVSKY, DJ*; USHER, L; ASTLEY, HC; University of Akron; *djj64@zips.uakron.edu*
Propulsion via vertical undulation in snakes
Snakes have multiple modes of locomotion including lateral undulation, concertina, rectilinear, and sidewinding. During lateral undulation, snakes generate posteriorly-propagating waves of body bending which press against irregularities in the environment and generate propulsive reaction forces. We hypothesize that snakes are capable of using the same mechanism in the vertical plane, using vertical waves of body deflection to generate propulsion from vertical substrate irregularities. We used six corn snakes (*P. guttatus*) to test this hypothesis using an array of horizontal cylinders oriented perpendicular to the direction of travel, one of which was instrumented to record forces. Surrounding this setup are motion capture cameras recording at 120 fps and a GoPro camera to track the snake's kinematics and to confirm that the snake is crossing the cylinders with minimal horizontal bending (and thus not generating propulsion via lateral undulation). Results show snakes produce both propulsion and braking across the pegs, with various trials showing pure propulsion, pure braking, or a combination of both. The magnitudes of peak propulsive force and braking are 0.0586 body weights (BW) (0.043 - 0.075 BW) and 0.0590 BW (0.039 - 0.077 BW), respectively. In contrast, when an inert rope approximately the same weight as the snakes was dragged across the force sensor, it produced only braking force. While this experimental setup was designed to elicit locomotion solely via vertical undulation in order to demonstrate the mechanism most clearly, it is likely that in complex, three-dimensional natural terrain, snakes can combine both lateral and vertical undulation for maximal locomotor efficacy.

129-3 JUSTYN, NM*; HEINE, KB; PETEYA, JA; HOOD, WR; SHAWKEY, MD; WANG, B; HILL, GE; Auburn University, John Carroll University, Ghent University; *nmj0005@tigermail.auburn.edu*
Persistence of Carotenoids in the Red Eyespots of Copepods (Tigriopus californicus) on Carotenoid-free Diets
Copepods can serve as a model for investigations into the functions of carotenoids in animals. Previous work on *Tigriopus californicus* demonstrated that copepods rely on their diet to accumulate carotenoids in their bodies and suggested that, despite their red color, eyespots contained no carotenoids. When fed a carotenoid-free diet of yeast, the orange coloration of the bodies of copepods fades away while the eyespot remains a bright red color. The eyespots of copepods play an important role in many behaviors including diel vertical migration, food acquisition, and predator detection. Elucidating the mechanism behind the source and maintenance of eyespot color in copepods is therefore crucial to understanding these behaviors. Here we used Raman spectroscopy to detect the pigments present in copepods fed both normal and carotenoid-free diets. We detected the red carotenoid, astaxanthin, in *T. californicus* eyespots of both diet groups, as well as in the eggs and the cuticles of normal red-colored individuals. Additionally, we also identified canthaxanthin for the first time in the antennae and caudal rami of normal and diet-restricted individuals, as well as in the bodies of diet-restricted individuals. We will discuss the implications of the persistence of carotenoids in the eyespot even with no access to dietary carotenoids.

114-2 KABA, AK*; RIESER, JM; PAEZ, VM; ASTLEY, HC; GOLDMAN, DI; Georgia Tech, Akron University; *abdul.kaba1@gmail.com*
Amplitude Modulation in Sidewinding Locomotion Driven by Contact Sensing Facilitates Movement in Heterogeneous Environments
As sidewinders move, only some portions of the snake are in contact with the ground at any time. This changing contact pattern can be modeled as vertical wave coupled to the lateral wave. The result is a sideways motion that causes a broad animal profile along the direction of movement and potentially makes obstacle negotiation more difficult than other modes of undulatory locomotion. Biological experiments revealed that the sidewinder is able to squeeze its body, which we hypothesize is achieved by increasing the amplitude of the horizontal wave, to move past rigidly-anchored vertical posts placed in their path. To test our hypothesis, we created a sidewinding robot from 14 alternating horizontally-and vertically-actuated servo motors connected with 3D printed brackets. The horizontal motors commanded a sinusoidally-varying lateral wave and the sinusoidally-driven vertical motors created a changing contact pattern. We implemented a controller and contact sensing capabilities on our robot, the robot responds to contact by increasing its horizontal amplitude for one full cycle. We positioned the robot at the same initial condition relative to the post for 30 trials each with and without the controller. Without control, the robot was always unsuccessful as its tail end gets caught and the robot spins around the post. With the controller, the robot was able to pull its tail end towards its head to successfully squeeze past 80% of the trials.

28-1 KACZMAREK, EB*; LI, EY; BRAINERD, EL; Brown University; *elskabette@gmail.com*

XROMM Analysis of Air-Breathing in the Royal Knifefish, Chitala blanci

Approximately 50 families of fishes contain species that are known to breathe air. The ability to breathe air, in addition to ventilate their gills with water, allows these species to survive in oxygen-poor habitats. While the behaviors and anatomical structures used to breathe air are diverse, numerous species possess a respiratory gas bladder and use buccal pumping to ventilate it. It is likely that buccal pumping was used by the first air-breathing fishes and by the tetrapodomorphs that transitioned to living on land, which makes it an evolutionarily interesting behavior. The kinematics of this method of air breathing have been previously described from 2D x-ray videos of a handful of fish species. Here we present the first 3D kinematics of air-breathing in the royal knifefish, *Chitala blanci*, a facultative air-breather that uses four-stroke buccal pumping. We used X-ray Reconstruction of Moving Morphology (XROMM) to measure cranial bone motions and muscle shortening. As air is released from the gas bladder, the suspensoria abduct and the cleithra retract, depressing the hyoid bars. The buccal cavity then compresses to expel the stale air through the opercular valves. Opercular elevation depresses the lower jaw via the interoperculomandibular ligament, and the cleithra retract by 5 to 10 degrees, causing the hyoid bars to depress by up to 40 degrees to draw in fresh air. The sternohyoideus does not shorten during hyoid depression. Knifefish also rely on large amounts of lateral expansion to widen their laterally-compressed heads—the suspensoria abduct as much as 10 degrees, and the two halves of the lower jaw spread 20 degrees apart from each other, as do the left and right hyoid bars. Comparing the air-breathing kinematics among species may shed light on the evolutionary history of this important behavior.

14-3 KAHANE-RAPPORT, SR*; SAVOCA, MS; CADE, DE; SEGRE, PS; BIERLICH, KC; CALAMBOKIDIS, J; FRIEDLAENDER, AS; JOHNSTON, DW; WERTH, AJ; GOLDBOGEN, JA; Stanford University , Duke University, Cascadia Research Collective , University of California, Santa Cruz , Hampden-Sydney College ; *skahaner@stanford.edu*

From Feast Mode to Least Mode: How Lunge Filter Feeding Biomechanics Constrain Rorqual Foraging Ecology Across Scale

Large body size is widely recognized to confer many benefits, including reduced transport costs and enhanced diving capacity. Such advantages should allow divers to increase their ability to forage at depth, increasing overall foraging efficiency. Rorqual whales engulf a large mass of prey-laden water at high speed and filter it through baleen plates retaining prey. This lunge feeding mechanism incurs a large energetic cost due to high drag, but provides the animal with extraordinary prey consumption rates. However, as engulfment capacity increases with body length across species (Engulfment=length$^{3.2}$*$10^{0.61}$,r^2=0.96), the surface area of the baleen filter does not increase proportionally (Baleen area=length$^{1.85}$*$10^{0.18}$,r^2=0.83).Therefore, we hypothesize that these scaling differences lead to longer filtration time (Filter time α length$^{1.5}$) for rorquals of larger body size because the baleen surface area filters a disproportionally large amount of water. We tested this hypothesis on 4 rorqual species using 40 cetacean-mounted video and 3D accelerometry tag deployments with corresponding drone photogrammetry that provided direct measures of body size, lunge rates, and filtration times. Our findings show that filter time increased with body length (Filter time=length$^{1.8}$*$10^{-0.6}$, r^2= 0.86), whereas the number of lunges per dive decreased with size (Lunges per dive =length$^{-0.8}$*$10^{1.7}$, r^2=0.55). Although larger rorqual whales should have increased diving capacity, the disproportional cost and filter time required to engulf larger volumes progressively limits dive time that could otherwise be spent selecting the highest quality prey patches.

26-5 KAHN, AS*; PENNELLY, CW; LEYS, SP; Moss Landing Marine Laboratories, Moss Landing, CA, University of Alberta, Edmonton, Canada; *akahn@mlml.calstate.edu*

Factors Affecting the Behaviors of Sessile Animals on the Deep Seafloor

Deep-sea communities are linked with processes occurring at the ocean's surface despite their relative distance apart. Time-series observations have highlighted the responses of benthic animals to episodic pulses of food and rhythmic changes in surface climate; however, in most of these cases observations have been made on mobile fauna. How and whether sessile animals on the abyssal plain can also respond behaviorally to changes in surface climate has largely been ignored. We combed through 30 years of time-lapse camera data from Station M, a long-term study site on the abyssal plain off the coast of California, to survey behaviors and activity of sponges and benthic cnidarians. The sessile fauna of the abyssal plain initially appear static but time-lapse observations yield a new, long-term perspective showing the dynamic lifestyles of these animals. Several hexactinellid sponge species rhythmically contracted and expanded back to full size, a process taking days to weeks that coincides with a reduction in filter feeding by one-third to nearly one-half. In general, cnidarian behaviors were at shorter timescales, occurring more frequently and with less time spent contracted than sponges. Zoanthids had rhythmic contraction behaviors whereas the cerianthid anemone *Bathyphellia australis* retracted its body into its tube with no apparent pattern or periodicity. These observations expand on the natural history of these difficult-to-observe taxa. Furthermore, the behaviors of these sponges and cnidarians may affect their role in nutrient cycling.

P2-185 KAIMAKI, D-M*; ATTIPOE, AEL; STOUKIDI, MN; LABONTE, D; Imperial College London; *domna-maria.kaimaki@ic.ac.uk*

Temperature-Induced Viscosity Changes of the Insect Pad Secretion

Many insects use adhesive footpads to climb on plants. These pads are covered by a thin liquid film, hypothesised to aid surface attachment via viscous and capillary forces. However, as many insects live in environments with considerable daily temperature fluctuations, relying on viscosity may pose significant limitations on their attachment system. So how does the secretion's viscosity change with temperature? Conventional rheological techniques are unsuitable to answer this question, due to the secretion's minute volume (~100fL) and its propensity for fast evaporation. Here, we use dewetting, the spontaneous rupture of a thin liquid film due to thermodynamic instabilities, to overcome these challenges. The speed of dewetting can be linked to the liquid's viscosity via a dimensional argument which balances the capillary and viscous forces at play during film rupture. To quantify the temperature effect on viscosity and decouple it from that on surface tension, dewetting experiments were performed at biologically relevant temperatures (20-50°C) and on conducting coverslips of varying wettability. Joule heating of the coverslips and a custom-built temperature controller were employed to induce and monitor temperature changes, surface wettability was varied via vapour deposition of different silanes, and Indian stick insects were used as a model species. Across the temperature range, the secretion's viscosity decreased sevenfold, from approximately 55mPas at 20°C to 8mPas at 50°C. Our *in vivo* viscosity measurements enable further investigation of wet adhesion models by comparing viscosity changes to the temperature dependence of frictional and adhesive forces. These experiments will increase our understanding of the complex viscoelastic pad/secretion/surface interface, and the functional relevance of the pad secretion in general.

115-6 KAMRAN, M*; POLLOCK, AMM; DITTMAN, A H; NOAKES, DLG; Oregon State University, Corvallis, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, Oregon State University, Corvallis and Oregon Hatchery Research Center, Alsea ; *kamran.mary@gmail.com*

Homeward Bound: What the Salmon Nose Knows?

Aquatic habitats tend to be highly complex sensory environments with little to no light but are oftentimes rich in terms of dissolved compounds. Reliance on chemoreception can be particularly advantageous in these environments as chemical cues provide animals information about their surroundings. For aquatic species, olfactory cues play a critical role in mediating a range of behaviors such as kin recognition, avoidance of predators and homing. Pacific salmon exhibit natal homing, where adults return to their natal tributaries in freshwater to spawn. These migrations are remarkable in terms of both the spatial and temporal scales over which these movements occur, with adults travelling thousands of kilometers to their natal tributaries after a period of several years at sea. We know that imprinting of odors occurs at critical developmental periods and this may be the mechanism through which juveniles learn odors associated with their home streams. While salmon are able to detect several classes of compounds, odors that serve as olfactory cues during navigation remain unidentified. We conducted a series of behavioral choice assays using juveniles to evaluate the effectiveness of candidate odorants for imprinting within hatcheries. By improving olfactory imprinting and homing success of hatchery fish, we may be able to minimize interactions between hatchery and wild salmonid populations.

P1-89 KAMSKA, V*; DALEY, M; BADRI-SPROWITZ, A; Max Planck Institute for Intelligent, University of California, Irvine; *kamska@is.mpg.de*

Potential for elastic soft tissue deformation and mechanosensory function within the lumbosacral spinal canal of birds

Avians show a specialization of their lumbosacral (LS) region, which is unique amongst vertebrates. The birds' neural canal is enlarged in the range of seven lumbosacral segments. A glycogen body sits on top of both spinal cord hemispheres, and a network of denticulate ligaments spans ventrally under the spinal cord. Accessory lobes are organized pairwise in each segment directly connected to the spinal cord hemispheres. The lumbosacral canal is relatively easily visible, due to its macroscopic dimensions in the millimeter range, but it is hard to observe its soft tissue in detail. The question of its functionality has raised a long time. Necker (1999) hypothesized a function similar to that of the inner ear and argued the 'lumbosacral organ' (LSO) presents another center of equilibrium. In this project, we characterize the LS region both with a combination of state of the art tools and classical dissection, towards a new, different hypothesis. Specifically, we attempt to quantify the possibility of elastic deformation of soft neural tissue, within the enlarged and fluid-filled LS cavity. Caused by external acceleration from locomotion, soft LS tissue would be excited to oscillate within the neural canal, leading to the stimulation of mechanoreceptors. To create a new 3-dimensional map of all LS soft tissues, we scanned an iodine solution treated specimen of a common quail (Coturnix coturnix). We conducted a classical dissection to describe finer structures which were otherwise not visible with micro-CT. We will present our combined dissection results, provide details from our morphometric analysis, and calculations for ligament strain of a potential elastic deformation.

P3-224 KANE, EA; Georgia Southern University; *ekane@georgiasouthern.edu*

On designing and implementing a new course as a new professor

In my 4th semester as an Assistant Professor, I was responsible for creating the course I was hired to teach - a new upper level lecture and lab course in biomechanics. However, I had no experience developing a course from scratch, only had a few hundred dollars for supplies, and did not have the ability to test labs before the semester started. By talking to students, I realized the answer to these problems lay in an authentic science approach that can bridge opportunities available in structured lab courses and independent research projects in faculty labs. Therefore, I structured my new course to emphasize the process of science, providing students an opportunity to gain valuable hands-on research experience without the selectivity and time commitment necessary for independent research. The expectation that experiments may not work as planned allowed flexibility to expand on or condense topics as necessary. Labs creatively utilized the campus wildlife center, departmental teaching specimen collections, previously collected research data, local invertebrate models, collaboration with my research lab or other teaching labs, and freely available software. Emphasis was on students gaining practical experience with research equipment, analyses, software, and communication techniques that could be added to their CV. Students often asked if we could do more and commented that they more fully understood the nature and process of science. Students also increased in knowledge and understanding of comparative biomechanics by 14.5% on average, with up to a 40% increase individually. Therefore, utilizing an authentic science approach to build new lab courses can be an effective way to enhance student learning while minimizing course prep constraints and facilitating overlap between research and teaching interests.

97-6 KANE, EA*; HIGHAM, TE; Georgia Southern University , UC Riverside; *ekane@georgiasouthern.edu*

Apparent modulation of integration with prey type in bluegill is driven by individual differences in performance and its integration

Integration refers to the ability for parts of an organism to work together, often to accomplish a higher-level function. Parts can be defined as covarying performance traits, where integration helps organisms achieve ecologically relevant tasks. Since performance is behavioral, traits or their integration may be able to respond to changing ecological contexts on short time scales, such as capturing alternative prey types. In suction-feeding fishes, integration between approach (locomotor) and capture (feeding) kinematics is broadly supported, but performance in each of these functional systems can also be modulated based on prey evasiveness. Therefore, we ask how modulation of component performance traits to capture evasive and non-evasive prey types affects their integration in bluegill sunfish. As expected, bluegill modulated between relatively slow swimming/high suction force to capture non-evasive prey, and fast swimming/high suction volume to capture evasive prey. Using multivariate partial least squares ordination followed by general linear model regression analyses, we found that reduced integration with evasive prey, likely a factor of gape limitation at fast swim speeds, was driven by individual specialization for relatively evasive/non-integrated and non-evasive/integrated capture strategies, not by flexibility of integration within individuals. Whether specialized performance drives integration, integration constrains the flexibility of performance, or any of these traits may be learned is unclear. Despite this, these results suggest that performance integration is a whole-organism phenotype and selection on integration (if present) acts on individuals rather than behaviors.

P1-154 KANE, SA; XIA, S*; FANG, R; LU, Y; ULZII-ORSHIKH, N; WU, J; DAKIN, R; Haverford College, Haverford PA USA, Carleton University, Ottawa, Ontario, Canada;
samador@haverford.edu

Multispectral imaging reveals the design of iridescent visual signals in peacocks and related pheasants

Indian peacocks (*Pavo cristatus*) and their close relatives, the peacock pheasants (genus Polyplectron) and the Congo peafowl (*Afropavo congensis*) court females using highly ritualized displays of iridescent, elaborately patterned, fan-like feather arrays. In this study, we investigated how the dynamic maneuvers performed by displaying males of these species influence the visual signals perceived by females. Specifically, we tested the prediction that visual signals perceived by females are most salient in the configuration used during display for species with iridescent (changeable) displays and complex behavior. We studied multiple species within the family Phasianidae in order to evaluate the hypothesis that such a match would generally apply. Multispectral imaging, and reflectance spectroscopy were used to determine the variation in feather iridescence due to the ranges of illumination and viewing angles found during these behaviors, as well as to measure whether relative humidity influenced iridescence. To relate these data to actual behaviors, we quantified the dynamic display geometries using images and videos of courtship displays. Computer simulations based on these data were used to model the dynamic visual signals generated by iridescent feathers during these displays. These results were then used to test whether the corresponding signal efficacy is well-matched to the geometry and dynamics of the display behavior for each species studied, compared to alternatives.

P1-97 KANE, SA; WANG, Y*; FANG, R; LU, Y; DAKIN, R; Haverford College, Haverford PA USA, Carleton University, Ottawa Ontario Canada; *wangyuchao1995@gmail.com*

How conspicuous are peacock eyespots and other colorful feathers in the eyes of mammalian predators?

Colorful feathers have long been assumed to be conspicuous to predators, and hence likely to incur costs due to enhanced predation risk. However, many mammals that prey on birds have visual systems with only two types of color-sensitive visual receptors, rather than the three and four characteristic of humans and most birds. Using a combination of multispectral imaging, reflectance spectroscopy, color vision modelling and visual texture analysis we compared the visual signals available to conspecifics and mammalian predators from multicolored feathers from the Indian peacock (*Pavo cristatus*)and parrots. We also model distance-dependent blurring due to visual acuity. When viewed by birds against green vegetation, most of the feathers studied are estimated to have color and brightness contrasts similar to values previously found for ripe fruit. On the other hand, for dichromat mammalian predators, visual contrasts for these feathers were only weakly detectable and often below detection thresholds for typical viewing distances. We also show that for dichromat mammal vision models, the peacock's train has below-detection threshold color and brightness contrasts and visual textures that match various foliage backgrounds. These findings are consistent with many feathers of similar hue to those studied here being inconspicuous, and in some cases potentially cryptic, in the eyes of common mammalian predators of adult birds. Given that birds perform many conspicuous motions and behaviors, this study suggests that mammalian predators are more likely to use other sensory modalities (e.g., motion detection, hearing, and olfaction), rather than color vision, to detect avian prey.

S8-12 KANO, T.*; ISHIGURO, A.; Research Institute of Electrical Communication, Tohoku University; *tkano@riec.tohoku.ac.jp*

Decoding Decentralized Control Mechanism Underlying Adaptive and Versatile Locomotion of Snakes

Snakes have lost their limbs and acquired the ability to move in various environments by using a simple one-dimensional body structure through long-term evolutionary process. Specifically, snakes have various locomotion patterns and change them in response to the environment. For example, on an unstructured terrain, snakes actively utilize terrain irregularities and move effectively by actively pushing their bodies against "scaffolds" that they encounter. In a narrow aisle, snakes exhibit concertina locomotion in which the tail part of the body is first pulled forward with the head part anchored, and this is followed by the extension of the head part with the tail part anchored. This ability has attracted attention to roboticists and many snake-like robots have been developed thus far. Most of these robotic studies aim for engineering applications such as search-and-rescue operation, yet our approach is different: our standpoint is "robotics-inspired biology" rather than "bio-inspired robotics". Namely, we are motivated to understand the decentralized control mechanism underlying adaptive and versatile locomotion of snakes by developing robots. In the presentation, we will introduce our results for these ten years.

39-7 KANWAL, J.K*; DE BIVORT, B.L; SAMUEL, A; Harvard University; *jkanwal@fas.harvard.edu*

Early integration of multisensory information in the Drosophila larva

The brain integrates information from different sensory modalities in order to enhance detection and perception of external stimuli and to respond in the most efficient manner. For a *Drosophila* larva, this means detecting chemosensory cues to locate the most nutritious food source in its environment. How the larva integrates olfactory and gustatory cues, at both the neuronal and behavioral levels, remains largely unknown. To assess the larva's behavioral strategy for chemosensory integration, we compared its navigation behavior on attractive olfactory or gustatory gradients alone to that on simultaneous presentations of both gradients in parallel or in conflict. Larvae show multisensory enhancement in their navigation efficiency towards the most attractive region of their chemosensory environment when both gradients are in parallel compared to either one alone. Placing the two gradients in conflict reveals that neither sensory system gates the other. Using in vivo calcium imaging to record neural activity, we identified several local and projection neurons within the antennal lobe, the first olfactory processing center in the larval brain, that respond to both odors and tastes or are modulated by odor-taste mixtures. To our knowledge, these results indicate for the first time that neurons in the antennal lobe have multisensory responses. Our findings support the idea that multisensory integration occurs at early stages of sensory processing and begin to address how this convergence enhances perception and shapes foraging behavior.

S4-7 KARACHIWALLA, Z; DECARVALHO, T; BURNS, M*; Department of Biological Sciences, University of Maryland, Baltimore County, Keith R. Porter Imaging Facility and Department of Biological Sciences, University of Maryland, Baltimore County; *burnsm@umbc.edu*

Spermathecal Variation By Mating System in Temperate Harvestmen

As in mammals, most arachnid fertilization occurs internally, allowing for a variety of post-copulatory mechanisms to take place. Females are expected to exert some level of control over sperm fate when 1) the the point of fertilization is particularly distant from the point of oogenesis, 2) the time of fertilization is occurs significantly later than the time of mating, 3) sperm are non-motile, and/or 4) the morphology of females allows for selective containment of sperm. Many of these conditions are met in Opiliones. Fluorescent microscopy of spermathecae from Opiliones of the suborder Eupnoi has revealed a variety of morphologies that may have critical function in controlling seminal movement, and we have evidence of polygynandrous mating and delayed oviposition in a number of species. Preliminary data on spermathecal morphology in temperate genera *Hadrobunus* and *Leiobunum* has deviated from initial expectations that more complex spermatheca would be found in species with conflict-based mating systems, as females of some species with high sexual antagonism have relatively simplistic spermatheca, while females of some species with low antagonism have multi-chambered organs with apparent valvular openings. These findings will have significant implications for the study of reproductive mode maintenance in facultatively parthenogenetic species that may use spermathecal mechanisms to withhold or bias paternity.

P2-65 KARACHIWALLA, Z*; DECARVALHO, T; BURNS, M; UMBC, Baltimore, MD, Keith R. Porter Imaging Facility, UMBC, Baltimore, MD; *zkarach1@umbc.edu*

Three-dimensional Visualization of Harvestman Spermathecae using Confocal Microscopy

Confocal laser scanning microscopy is an imaging technique that provides detailed optical sectioning of samples. We used this form of fluorescent microscopy to obtain three-dimensional images of harvestmen ("daddy-longlegs") spermathecae, structures within the genitalia of female arthropods that store and maintain sperm after copulation. We examined spermathecal morphology in seven species of *Leiobunum* and one species of *Hadrobunus*, which were collected from North America and Japan and stored in 99% ethanol. Ovipositors were dissected and stained for 24 hours with DAPI to enhance the anatomical structures within the tissue. Although harvestmen spermathecae are naturally fluorescent, the use of DAPI was found to improve visualization of weakly sclerotized tissues. Z-stack images of the paired spermathecae were taken with a Leica SP5 confocal and three-dimensional representations were rendered in Imaris software using the contour surface tool. These are the first reported images of harvestmen spermatheca and we found that morphology varies among species, including differences in size, shape, and internal complexity. The method we developed allowed us to visualize internal structures difficult to interpret with two-dimensional brightfield microscopy, which could be applied to the characterization of internal structures in other arthropods.

S3-6 KARAGIC, N*; MEYER, A; HULSEY, CD; University of Konstanz, Konstanz, Germany; *nidal.karagic@uni-konstanz.de*

Plasticity of Vertebrate Dentition

Vertebrate teeth and how they respond to environmental challenges play a crucial role in organismal prey capture and food processing. However, the morphology of teeth is not completely genetically determined as phenotypic plasticity in response to environmental conditions can heavily influence tooth anatomy in various vertebrate species. Plasticity is also highly important in structuring how the dentition, or the entire array of teeth an individual exhbits, function together. For instance, since most vertebrates are polyphydont (e. g. fish) the forces that food items exert on teeth can change during the replacement of old teeth. Some cichlid species are known to adapt to hard food items by increasing the size of replacement teeth for greater force resistance. Other di- or monophydont vertebrates use plasticity seemingly adaptively without replacing their dentition. Monophydont rodents are adapted to the high wear their incisors are subjected to by constantly growing those teeth and effectively sharpening them. Human dentition is also exposed to high degrees of plasticity for example during tooth development where environmental factors such as malnutrition can impact traits such as the timing of tooth eruption. I will discuss these examples as well as general patterns and processes involved in the plasticity of vertebrate teeth. As in few other traits, a better understanding of the plastic nature of teeth and the forces generating these induced phenotypic differences should allow us to better integrate studies of development, evolution, and behavior in both extinct and extant vertebrate taxa.

44-3 KARASOV, WH*; DEHNERT, GK; University of Wisconsin, Madison; *wkarasov@wisc.edu*

Non Target Impacts of the Herbicide 2,4,-D on Early Life Stages of Fish

2,4-dichlorophenoxyacetic acid (2,4-D) is contained in many systemic herbicides used worldwide for selective weed control of invasive plants in agriculture and aquatic ecosystems. The US Environmental Protection Agency (EPA) permits aquatic 2,4-D amine applications up to 2ppm for whole-lake treatments with a follow-up treatment 21 d after initial application. For multiple native WI fish species, we exposed early life stages (embryos and/or larvae) and juvenile fish to environmentally relevant concentrations of 2,4-D (0-2ppm) as the active ingredient alone and as the commercial formulations that are applied in the field. Survival was depressed by 2,4-D exposure for at least one early life stage in 78% of species tested (n=9); there were no impacts on juvenile fish survival in 5 species tested. In functional studies, 2,4-D interacted with neurobehavioral and endocrinological physiological systems. For example, in larval zebrafish, exposure to a 2,4-D commercial formulation reduced neural activity within the optic tectum and decreased prey capture ability, and this essential survival behavior was also depressed in larval yellow perch (Perca flavescens). In one type of endocrine study with juvenile fathead minnows (Pimephales promelas) raised in 0.05 ppm 2,4-D, whole-body cortisol rise following a stress challenge (momentary removal from water) was reduced >50%. These multiple lines of evidence underscore previously unappreciated risks associated with current 2,4-D application practices. Although designed to act against plant biochemical/physiological systems as a cell growth deregulator, 2,4-D joins other major herbicides such as atrazine and glyphosate as having surprising, significant non-target effects on function and survival of aquatic vertebrates. Work supported by the WI Dept. Natural Resources.

4-6 KASOJU, VT*; SANTHANAKRISHNAN, A; Oklahoma State University; *askrish@okstate.edu*
Bristled wings in fling: aerodynamic importance of initial inter-wing spacing
Tiny flying insects of body lengths under 2 mm, such as thrips and fairyflies, possess bristled wings and use wing-wing interaction via the 'clap and fling' mechanism to augment lift generation at chord-based Reynolds number (Re) on the orders of 1-10. When compared to solid wings, bristled wings have been shown to decrease drag required to fling wings apart. We used a dynamically scaled robotic platform fitted with physical bristled wing models to examine the aerodynamic importance of initial inter-wing spacing of bristled wings during fling. Three sets of motion profiles were considered: 1) wings purely rotating about their trailing edges; 2) pure translation of each wing at a fixed angle of attack (AOA); and 3) overlapping rotation and translation of each wing, all at Re=10. The results show that (i) average drag coefficient increased during pure rotation and pure translation with increasing AOA (relative to horizontal), (ii) decreasing initial inter-wing spacing increased the lift coefficient due to formation of weaker trailing edge vortices, resulting in asymmetric leading and trailing edge vortices. Previous studies have shown leakiness of flow through bristles to aid in decreasing drag. However, we found that both peak drag and leakiness increased with decreasing initial inter-wing spacing during pure rotation. We observed large negative pressure distribution along the chordwise direction within the cavity between the two wings, which we suspect causes fluid to leak through the bristles. This suggests that increasing leakiness does not necessarily decrease drag during pure rotation in early fling. The contribution of leakiness to pressure and viscous drag reduction will be presented.

30-5 KATIJA, K*; GOVINDARAJAN, A; LLOPIZ, J; WIEBE, P; BREIER, J; HOBSON, B; RISI, M; ROBISON, B; ROCK, S; YOERGER, D; Monterey Bay Aquarium Research Institution, Moss Landing, CA, Woods Hole Oceanographic Institution, Woods Hole, MA, Stanford University, Palo Alto, CA; *kakani@mbari.org*
Mesobot: Toward autonomous observations of organismal behavior in the ocean's midwaters
Animals in the ocean's midwaters are some of the least understood organismal systems due to the technological challenges of non-invasively observing behavior in an exceedingly remote place. To address this need, we developed a new hybrid (remotely and autonomously operated) underwater vehicle called the *Mesobot*. Rated to 1000 m, this vehicle is designed to track and observe slow-moving midwater animals (e.g., salps, jellies, crustaceans) with minimal disruption. After acquiring animal targets under teleoperated control through a tether, the tether is released and the vehicle autonomously tracks targets for up to 24 hrs. While the *Mesobot* had its first deployments in 2019, we will present preliminary results from field trials that utilized the *Mesobot*'s stereo imaging hardware and *JellyTrack* algorithms on ROV *MiniROV* in Monterey Bay. Long duration observations of an amphipod (*Phronima sedentaria*) in a salp barrel and a feeding siphonophore (*Lychnagalma utricularia*) clearly illustrate the challenges and highlight the potential a vehicle like *Mesobot* will have on our understanding of midwater inhabitants.

60-3 KATZ, HR*; MCCARTHY, NA; FOUKE, KE; MORGAN, JR; Marine Biological Laboratory, Woods Hole, MA, Carthage College, Kenosha, WI; *hkatz@mbl.edu*
Functional Recovery of Burrowing Behavior in Sea Lampreys After Spinal Cord Injury
Following a complete spinal cord transection, larval sea lampreys (*Petromyzon marinus*) are able to regenerate their spinal cords in 10-12 weeks post-injury (WPI), and consequently undergo functional recovery of swimming. However, larval lampreys are generally found burrowed in the substrate of their home environment (e.g. sand). While recovery of swimming is robust and well-established, the lampreys' ability to recover burrowing following spinal cord injury is largely unknown. Burrowing behavior has two components. The initial component resembles swimming with propagated undulations, while the final component involves large body flexions that pull the tail under the sand. Here, we evaluated the lampreys' ability to burrow by examining these two components from video recordings at multiple post-injury time points during recovery from spinal cord injury, spanning from 1 to 11 WPI. Control (uninjured) animals completed the initial component in 1.82 ±1.24 seconds (N=16) and the final component in 21.13 ±15.95 seconds (N=15). Transected animals did not attempt to burrow until 2 WPI and most animals from 2 to 8 WPI were unable to burrow completely, leaving a portion of the tail exposed. Burrowing coverage improved over time with most animals burrowing completely by 9-11 WPI. The duration of the initial component did not differ between control and spinal-transected animals across the entire recovery period, but the duration of the final component in 9-11 WPI transected animals (94.93 ±81.76 seconds, N=15) was significantly longer than in controls. These data indicate that, similar to swimming behavior, lampreys are able to recover burrowing behavior after spinal cord injury, though moderate deficits may persist.

15-8 KATZER, AM*; WESSINGER, CA; HILEMAN, LC; University of Kansas; *a681k477@ku.edu*
Nectary size is a pollination syndrome trait in Penstemon
Individual trait adaptation can influence the evolution of complex phenotypes such as floral pollination syndromes. In *Penstemon*, hummingbird-adapted flowers have evolved many times from bee-adapted ancestors. We examined the definition of *Penstemon* pollination syndromes in context of nectar volume and nectary development. Across 19 *Penstemon* species, we tested the evolutionary association of nectar volume and nectary area with pollination syndrome where we found both traits having an association with pollination syndrome. Then, we assessed the cellular-level processes shaping nectary area by measuring the width of 5 nectary cells in selected species, where we found a combination of cell expansion and cellular proliferation. Lastly, we assessed trait correlations in a segregating population from an intersyndrome cross and found that nectary area, nectar volume, and stamen length were all correlated with one another. These results show independent origins of hummingbird syndrome in *Penstemon* have parallel developmental processes in nectary patterning.

62-7 KAWANO, SM*; BLOB, RW; George Washington Univ., Clemson Univ.; *smkawano@gwu.edu*
Evaluating limb bone stresses of early tetrapods in the context of the evolutionary invasion of land
Becoming terrestrial was a pivotal event in vertebrate evolution that placed new physical demands on the musculoskeletal system. Increased gravitational loads on land can make bones more prone to injury, but how stressful was terrestrial locomotion for early tetrapods? We used a computational model to estimate the magnitude of peak bone stresses, across limb postures ranging from hyper-sprawling to upright, by integrating experimental data from live animals with morphological data from fossils. Although salamanders are often used to model some of the earliest tetrapods due to their generalized tetrapod Bauplan, they may better represent stages that occurred later in the transition to land. Our laboratory studies show that a semi-aquatic salamander (*Pleurodeles waltl*) had a hyper-sprawled limb posture compared to the terrestrial tiger salamander (*Ambystoma tigrinum*), with ground reaction forces intermediate between semi-aquatic mudskipper fish and terrestrial *A. tigrinum*. When these data were used in our computational model of a crownward early tetrapod (*Greererpeton burkemorani*) using a salamander-like gait, femoral stresses decreased as the limbs became more sprawled. Moreover, stresses were lower when *Greererpeton* was modelled with limb mechanics resembling those of salamanders rather than alligators, supporting salamanders as a reasonable model for *Greererpeton*. Our results also indicate that the estimated peak stresses on the *Greererpeton* femur never exceeded typical values of ultimate bending strength for amphibian limb bones, suggesting appendicular bones were likely well suited for terrestrial locomotion relatively early in their evolution. These analyses set the stage for further evaluations of limb posture and terrestrial locomotor capacity across the water-to-land transition.

35-5 KAY, DI*; GIGNAC, PM; O'BRIEN, HD; Oklahoma State University Center for Health Sciences, Tulsa; *david.kay@okstate.edu*
Do sockets shape teeth in non-mammalian thecodonts? A case study in Alligator mississippiensis
In heterodont mammals, the alveolus mechanically shapes and adds complexity to the developing crown (e.g. rodents). In crocodylians, which are also thecodont but with pseudoheterodont crown shapes (i.e. two broad categories: caniniform, molariform) it is unclear if alveolar form similarly determines crown morphologies. Here we examine alveolar shape alongside crown type to test for a relationship between sockets and crowns in *Alligator mississippiensis* for the first time. From CT data, we digitally reconstructed alveoli of the most procumbent caniniform and molariform teeth, as well as ambiguously shaped intermediate teeth. Alveolus outlines were quantified using elliptical Fourier transformation, standardizing for location, orientation, and size. Principal components analysis (PCA) ordinated patterns in the Fourier coefficients, and linear discriminant analysis (LDA) was run on the PC scores to determine consistency of crown categories: caniniform, molariform, and intermediate. The first two PCA axes captured ~87% of shape variance (PC1 = relative mesio-distal alveolar length, PC2 = alveolar curvature). Crown-shape categories fell into largely separate convex hulls. The LDA had high classification rates for caniniform (80%) and molariform (90%) teeth, but middle teeth were less well-defined (60% accurate identification, with the remaining 40% mis-classified as caniniform). These preliminary results suggest a significant relationship exists between alveolar and crown morphologies in crocodylians. Intriguingly, each new tooth in these polyphydont reptiles contributes tissue to the socket wall (e.g. interalveolar bone), thus potentially shaping subsequent crown generations and resulting in a mechanism inverted from the mammalian pattern (e.g. crown-first vs. alveolus-first).

P2-142 KAZMI, JS*; BUKOWSKI-THALL, GL; TSANG, RH; MILLER, AI; CHRISTIE, AE; DICKINSON, PS; Bowdoin College, Brunswick, ME, University of Hawaii Manoa; *pdickins@bowdoin.edu*
The role of behavioral diversity in determining the extent to which neural patterns are modulated
The crustacean stomatogastric nervous system (STNS) requires the input of neuromodulators to enable behavioral flexibility. The pyloric circuit is one of four central pattern generators (CPGs) in the STNS; its outputs control food processing by foregut muscles. The sensitivity of the pyloric circuit to various neuromodulators has previously been examined in two crab species. One species, *Cancer borealis*, is an opportunistic feeder, while the other, *Pugettia producta*, is a dietary specialist. Since neuromodulation enables variation in the movements of pyloric muscles without altering STNS circuitry, the modulatory capacity is predicted to reflect the need for diversity of feeding patterns and thus the diversity of diet in each species. In contrast, we predict no relationship between diet and modulatory capacity of other CPGs, such as the cardiac ganglion, which controls the crab heart. Previous data have shown that the *Cancer* STNS is sensitive to a wider array of neuromodulators than that of *Pugettia*. However, these species are not closely related phylogenetically. To examine the relationships between diet, phylogeny, and modulatory capacity, we recorded the responses of two members of the same superfamily as *Pugettia*, the opportunistic-feeding crabs *Chionoecetes opilio* and *Libinia emarginata*. The responses of the isolated STNS and whole heart preparations to six endogenous neuromodulators and an acetylcholine agonist were measured. Initial results suggest that, in contrast to *Pugettia*, the STNSs of the two opportunistic feeders are sensitive to all tested modulators. Preliminary data also suggest that the cardiac ganglia of specialist feeders and opportunistic feeders respond to the same neuromodulators.

6-3 KéVER, L*; BASS, AH; PARMENTIER, E; CHAGNAUD, BP; Liège University, Liège, Belgium , Cornell University, Ithaca, U.S.A. , Liège University, Liège, Belgium, Ludwig-Maximilian University, Munich, Germany;University of Graz, Graz, Austria; *loic.kever@uliege.be*
Conserved Neural Circuitry among Mochokid Catfish despite Morpho-Functional Diversity of Sonic and Electric Organs
The Elastic Spring Apparatus (ESA), composed of the protractor muscle (PM) and a modified process of the fourth vertebra (i.e. Müllerian ramus), evolved independently in several catfish families. In most taxa, its function is sound production, but the PM of some synodontid mochokids has been modified to produce electric discharges. Here, we compare the ESA behavioral phenotype, morphology, and associated neural circuit between three synodontid species producing sounds (*Synodontis grandiops*), electric discharges (*S. nigriventris*), or both (*S. eupterus*) and representative members of two sister genera - *Microsynodontis batesii* and *Mochokiella paynei*. *Microsynodontis batesii* and *M. paynei* produce only sounds suggesting that electric signaling evolved only among synodontids. Together, the ESA of the five species shows large interspecific differences in size and shape including intergeneric differences in the PM insertion points, while *S. nigriventris* has the thinnest PM and a Müllerian ramus with the longest stem and shortest plate. Despite some quantitative differences, tract tracing after labelling of the PM with neurobiotin or dextran biotin reveals similar organizational patterns in the ESA neural circuit for the five species. In every case, paired motor and premotor nuclei are positioned at the same location in the caudal hindbrain. Despite dramatic differences in the behavioral phenotype and anatomy of the ESA, the central ESA neural circuit of these five species seems highly conserved. Research support from the NSF (IOS-1656664 to AHB), DFG (BPC), and F.R.S-FNRS (LK).

P2-165 KEAVENY, EC*; DILLON, ME; University of Wyoming; *ekeaveny@uwyo.edu*

Brood Incubation May Provide Reciprocal Thermal Benefits for Worker Bumble Bees

Bumble bees are well-known heterotherms, able to regulate high body temperatures by taking advantage of heat generation from highly active thoracic muscles. Facultative shunting of heat between thorax and abdomen not only allows bumble bees to regulate their own body temperature, but also allows them to regulate temperatures of the developing brood clump, even in extreme cold. Although the benefits of incubation for brood have been actively explored, little attention has been paid to the potential reciprocal benefits for individual workers of a colonially heated brood clump with high heat storage capacity by virtue of its size and composition. We established microcolonies of adult *Bombus impatiens* workers and tracked temperatures of the developing brood, nest chamber, and individual workers in response to cold challenge. As expected, workers consistently incubate brood at low temperatures, with the effectiveness of brood incubation depending on number of workers and brood clump size. Workers in microcolonies that maintain high brood clump temperature are also better able to maintain body temperatures at low ambient temperatures: previous investment of heat may directly benefit the workers as they re-absorb the heat from the brood clump as temperatures fall. These findings uncover an additional thermoregulatory strategy facilitating bumble bee persistence in extreme climates.

P3-63 KECK, CMT*; EARLEY, RL; GRESHAM, JD; The University of Alabama; *ckeck@crimson.ua.edu*

How Do Males Reproduce When Prospective Partners Prefer to Mate with Themselves?

The mangrove rivulus fish (*Kryptolebias marmoratus*) is one of only two self-fertilizing vertebrates. Populations consist of predominantly self-fertilizing hermaphroditic fish, with varying proportions of males (androdioecy). Outcrossing occurs between hermaphrodites and males and rates of outcrossing vary among populations, but is rare in most populations. It is unknown how relatively few males find infrequently laid unfertilized eggs while they are still viable. We hypothesized that males prefer to associate with hermaphrodites that routinely lay a greater proportion of unfertilized eggs. We predicted that males would exhibit a stronger preference for younger hermaphrodites because they are more likely to lay unfertilized eggs; ovarian tissue matures before spermatogenic tissue. To test this hypothesis, two hermaphroditic fish from the same genetic lineage, but at least 150 days different in age, were placed in clear fish brooding boxes on opposite sides of a behavior arena. A male was placed in the middle of the arena, and his movements recorded digitally and scored for thirty minutes. This was repeated with the same trio, but with hermaphrodite positions reversed. The brooding boxes permitted water to freely flow throughout the arena while keeping the hermaphrodites inside the boxes, allowing males access to visual and chemical cues. Contrary to our predictions, preliminary data suggest that the males prefer to associate with older hermaphrodites. This preference was even stronger during the second trial. These results indicate that males actively seek hermaphrodites with higher probabilities of laying unfertilized eggs, which another experiment showed to be older hermaphrodites. Such a preference might explain how males, in a predominantly selfing species, obtain non-trivial reproductive success in wild populations.

P1-225 KEHL, C E*; NEUSTADTER, D M; CHIEL, H J; University of North Carolina at Chapel Hill, Cardiac Success Ltd, Yokneam 20692, Israel, Case Western Reserve University; *cekehl@email.unc.edu*

A 3d Model for Validating Hypotheses in Feeding Behavior in Aplysia californica

The mechanics of grasping soft or irregular materials is challenging for both living and designed systems. Many animals have evolved solutions to this challenge. The feeding system of the marine mollusk, *Aplysia californica*, for example, allows it to grasp and ingest seaweeds of a great variety of shapes, textures and toughness. Recent work suggests that the opening of *A. californica's* grasping surface, the radula, is largely mediated by the newly characterized sub-radular fibers (SRFs). A 3d computational model has been built to test our understanding of this hypothesis. To this end, a high-resolution static magnetic resonance image was segmented and combined with anatomical studies to produce a simplified 3d computational model using the Blender modeling environment and Bullet Physics Engine. The rigid segments of this computational model were then fit to the frames of a magnetic resonance movie of an intact feeding animal. The model of the surface was bound to the edges of these rigid structures. The properties of the model surface corresponding to the SRFs were then changed over time to mimic the muscle activation. Simulations were also run with no muscle activation in the areas that were lesioned in *in vivo* studies. The model results compared well to what was seen *in vivo*.

99-3 KEHL, C E*; WU, J; LU, S; DRUSHEL, RF; SMOLDT, R K; CHIEL, H J; University of North Carolina at Chapel Hill, Case Western Reserve University, 1973; *cekehl@email.unc.edu*

Effect of the Sub-radular Fibers on Grasper Opening in Aplysia californica

The mechanics of grasping soft, and irregular material is challenging for both biological and designed systems. Many animals have evolved to meet this challenge. In particular, the feeding system of the marine mollusk *Aplysia californica*, an herbivore generalist, allows it to grasp and eat seaweeds of different textures, toughness and shapes. The surface of the grasper is known of as the radula, a cartilaginous sheet with fine teeth. Previous *in vitro* studies suggested that the I7 muscles, deep in the grasper, were responsible for the opening of the radula. Lesions to these muscles do not prevent animals from grasping and ingesting food. New *in vivo* studies demonstrate that a previously uncharacterized set of fine muscular fibers - the sub-radular fibers (SRFs) - mediate openings even in the absence of the I7 muscles. Both *in vivo* and *in vitro* studies show very large deficits in opening when the SRFs are lesioned. A theoretical biomechanical analysis of the actions of the SRFs suggest that they reverse the folding of an anatomical crease to create an arched shape that can conform to irregular structures.

P1-113 KELLEY, MD; KA, C; MENDONCA, MT*; Auburn University; *mdk0014@auburn.edu*

The Importance of Olfactory Cues from Male Chin Glands & Multimodal Signal Use in Gopher Tortoises Gopherus polyphemus

Multimodal signalling can reinforce messages in communication. In gopher tortoises, the enlarged chin gland (CG) may serve as a visual signal during mating, but chemical signals may also occur in secretions providing information about species, sex, or individual recognition. The sensory drive hypothesis suggests transmission of signal may influence selection, and the signal that travels the furthest distance (e.g., CG olfactory cues) can be prioritized over other signals (e.g., CG visual signals) that occur at closer range. Here, we used both sexes of gopher tortoises in 2 experiments to examine chemical-only presentations of CG secretions vs. distilled water (DI) on cotton swabs and also, chemical and visual signals, with CG secretions vs. DI water on resin tortoise models in paired-choice experiments. We assessed behavior to ask if chin secretions are a social cue recognized by tortoises and we assessed the interplay of chemical and visual presentation of cues. Tortoises of both sexes spent more total time ($p=0.001$) and performed a higher number of behaviors ($p=0.001$) with the CG-treated model, relative to the negative control (DI-model). But, although tortoises individually performed the same numbers of behaviors in both swab and model experiments (e.g. approximately 3 behavior types per trial of either experiment; $p=0.29$), only the visual + chemical experiment showed a significant difference in numbers of behaviors towards the CG-model vs. DI-model. The preferences of the CG-treated model was also supported by multivariate analyses. Our results suggest that although visual cues may be necessary for some types of behaviors to occur, the presence of the CG chemical treatment ultimately drove behavioral patterns in tortoises, hence, tortoises may prioritize chemical cues but use both modality types in intraspecific communication.

12-2 KELLY, JB*; THACKER, RW; Stony Brook University, Stony Brook, NY; *joseph.b.kelly@stonybrook.edu*

Ecological divergence in the sponge genus Ircinia

Microbiomes can have substantial impacts on the ecological identities and evolutionary histories of their hosts. In the sponge genus *Ircinia*, evolutionary responses to host-microbial symbioses abound, evidenced through several hallmarks of metabolic integration including microbial genome streamlining, the translocation of nutrients between the microbes and hosts, and the heritability of endosymbionts. Previous work has shown that several incipient *Ircinia* species from Panama are divergent in the compositions of their microbiomes (2bRAD, 16S rRNA data). However, the ecological ramifications of these microbiome differences are largely unknown due to the inherent limitations of 16S rRNA data and the lack of ecophysiological information for the vast majority of these microbes. Our study sought to fill this gap in knowledge by using shotgun-metagenomic data to delineate the metabolic consequences of *Ircinia* microbiomes.

P1-62 KELLY, A.P*; MADDUX, S.D; UNT Health Science Center, Dept. of Anatomy & Physiology; *alexa.kelly@my.unthsc.edu*

The interaction of climatic and energetic factors on human nasal morphology

Physiological climate adaptability is of growing concern given the dramatic increase in human migration over the last two decades. While a narrower nose enhances inspiratory air-conditioning in cold-dry climates, such environments are also metabolically expensive, requiring greater oxygen intake than tropical environments. Accordingly, it has previously been hypothesized that volumetric restriction of oxygen intake due to nasal narrowing may necessitate an increase in nasal height to meet energetic demands. To test this, we employed 17 linear measurements from the nasal skeleton of modern humans from 10 climatically diverse geographic areas (Arctic Circle, Europe, Iran, Australia, North Africa, South Africa, East Africa, West Africa, Papua New Guinea). Femoral head diameter (FHD) was further employed to estimate body size and basal metabolic rate (BMR). In conjunction with climatic data, these morphological data were employed in multivariate analyses to examine the relationship between nasal dimensions, climate, and metabolic demand. Our results indicate that most breadth measurements of the nasal aperture and internal cavity are significantly correlated with climate, but not FHD. Conversely, height and length measurements of the aperture and cavity were found to be more strongly correlated with FHD compared to climate. Further, overall nasal passage area was found to be positively associated with FHD, while nasal passage shape retained a significant relationship with climate. Collectively, these results support the assertion that airway height represents a compensatory mechanism for ensuring a metabolically sufficient intake of oxygen. Additional studies employing more direct measures of metabolic demands are accordingly warranted.

23-2 KELLY, PW*; PFENNIG, DW; PFENNIG, KS; UNC Chapel Hill; *patk@live.unc.edu*

Sexual Selection and Adaptive Evolution in Variable Environments: Phenotypic Plasticity as a Good-Genes Effect

What is the role of sexual selection in adaptive evolution? Theory, modeling, and data tell us that sexual selection can facilitate adaptive evolution by favoring specific traits that are also favored by natural selection, by purging deleterious mutations, and by favoring high-condition individuals that can achieve high fitness in a range of environmental conditions. These scenarios are complicated, however, by variable or novel environments, in which sexual selection can fail to track changes in natural selection, thereby becoming an impediment to adaptive evolution. We propose another route whereby sexual selection can facilitate adaptive evolution. In particular, we present observational and experimental data that suggest that offspring plasticity can function as an indirect benefit of mate choice and that sexual selection can thereby facilitate adaptation in variable or novel environments by promoting the evolution of adaptive plasticity.

101-8 KELLY, TR*; BOYER, A; MACDOUGALL-SHACKLETON, EA; MACDOUGALL-SHACKLETON, SA; Louisiana State University, Western University; *trkelly@lsu.edu*

Experimental acute-phase immune activation in migratory sparrows has host-antigen specific effects on body mass and migratory restlessness

How birds contribute to the global spread of disease depends inherently on the physiological and behavioral responses of the host to pathogenic invasion. This is particularly critical during migration when birds traverse large geographic barriers and interact with con/hetero-specifics. Observational studies of how pathogens affect migrating birds are limited in that captures of migrants at stopover provide a single snapshot of the subject in time. These can rarely distinguish the costs of infection from the costs of mounting an immune response, nor can they ascertain the effects of pathogen exposure without subsequent infection. Understanding host-specific responses to antigen exposure is important in modeling super-individual scales of host-pathogen dynamics. We experimentally challenged song sparrows (n=28; *Melospiza melodia*) and white-throated sparrows (n=27; *Zonotrichia albicollis*) in autumn migratory condition with non-infectious antigens, then monitored body composition and nocturnal migratory restlessness. Whole body mass of both species increased the day after birds were challenged with lipopolysaccharide (LPS) or keyhole-limpet hemocyanin (KLH), substances that induce an acute-phase immune response. Migratory activity of all sparrows, including sham controls, was reduced the night after receiving treatments. White-throated sparrows, but not song sparrows, challenged with LPS had increased lean mass one week after exposure and KLH-challenged white-throated sparrows exhibited reductions in migratory activity during the week of recovery. Our results suggest that short-term activation of the acute immune response may have effects on migratory condition and activity, specific to certain combinations of hosts and antigens.

81-7 KEMP, ME; The University of Texas at Austin; *mkemp@austin.utexas.edu*

Extinction, persistence, and resiliency in the Caribbean fossil record

The Caribbean is one of the most well-studied biodiversity hotspots, regions that in total cover less than 3% of the Earth's surface yet host the majority of the planet's endemic species. But the diversity of today's Caribbean is only a fraction of what once existed there, as climate, sea-level fluctuations, and multiple human colonization events have restricted the ranges of many species, or worse, contributed to their extinction. Given this past history of environmental perturbations, paleobiology is well-suited to inform ongoing conservation needs in this system. Such perspective from the past is essential now more than ever before, as continued habitat degradation, non-native species introductions, and ongoing range contraction, extirpation, and extinction threaten to erode the remaining biodiversity. My research explores how one seemingly successful group of Caribbean vertebrates, the lizards, have been impacted by environmental perturbations throughout the Pleistocene, Holocene, and into the Anthropocene. I unveil extinction biases within the Caribbean that have transformed how we understand lizard extinctions globally. I also report on the excavation of a paleontological site in Puerto Rico that encompasses the past 20,000 years. Data analyzed from the site are concordant with overarching trends in the Caribbean fossil record: most notably, the large-scale extinction of terrestrial non-volant mammals and fewer losses in other taxonomic groups, such as lizards. Detailed stratigraphic records provide evidence of long-term site occupation for many *Anolis* species, although preliminary data suggest an instance of turnover in this genus. This newly described paleontological data highlights both the vulnerability and resiliency of lizards and Caribbean vertebrates more broadly, with relevance to regional conservation management.

64-6 KEMP, AK; Duke University; *addisonkemp@gmail.com*

Effects of binocular field size on leaping performance in small bodied primates

It has long been argued that a number of distinguishing features of primates, including their forward-facing eyes and large binocular visual field, improve the effectiveness of arboreal leaping locomotion, especially in a thin branch setting. This remains an area of intense debate, especially in regards to primate origins, yet this study is the first to directly test the relationship between binocular field size and leaping performance in primates experimentally. The effect of restriction of the binocular field on leaping locomotion was evaluated in five captive *Cheirogaleus medius*, a small bodied (~175g) nocturnal primate species considered a reasonable morphological and ecological analogue of early primates. Binocular field restriction was achieved using a helmet-mounted blinder that obstructed the medial portion of the visual field of one eye. Subjects were recorded leaping between narrow vertical substrates both with the full use of their binocular field and with a restricted binocular field. Restriction of the binocular field did not increase the subjects' probability of either missing or failing to reach a landing substrate. Restriction of the binocular field did, however, increase the probability of adverse landings, the number of grasp adjustments individuals made between consecutive leaps, and the lag time between landing and subsequent take-off. These results suggest that increases in binocular field size during early primate evolution may have provided an important advantage in leaping by facilitating more precise landings.

114-6 KENALEY, CP*; KRAEMER, K; KUNKLE, H; Boston College; *kenaley@bc.edu*

Revisiting the Kinematic Parameters that Define Eel-like Swimming

The kinematics of aquatic locomotion in elongate, eel-like vertebrates has received considerable attention since the pioneering work of Sir James Gray in 1933. In recent decades, the body of research focusing on eel-like locomotion suggests collectively that this mode of locomotion is highly variable with respect to midline kinematic parameters. In this study, we summarize these patterns and add new insights concerning propulsive wavelength and wave speed. Synthesizing data from previous work with new kinematic analysis of hundreds of thousands of waveforms over a range of routine, steady swimming speeds from two eel-like swimmers, the American eel (*Anguilla rostrata*) and ropefish (*Erpetoichthys calabaricus*), and one subcarangiform swimmer, rainbow trout (*Oncorhynchus mykiss*), we show that there may be novel canonical patterns of eel-like swimming that set this mode apart from other modes of aquatic undulatory locomotion. Specifically, our dataset and data from previous studies of eel-like swimmers, indicate that eel-like swimming may be defined by rostocaudal gradients of increasing propulsive wave speed and decreasing propulsive wavelength. In contrast, a subcarangiform mode, as represented by the rainbow trout, is defined by a rostrocaudal gradients of decreasing wave speed and increasing wavelength.

9-2 KENNEDY, J.R*; MAHADEVAN, L; NAGPAL, R; Harvard University, Harvard Unisersity; *jokennedy@g.harvard.edu*
Mapping spatiotemporal changes of North American beaver (L. Castor canadensis) damming complexes
Beavers construct structurally complex and dynamic damming networks.In many cases, it is difficult to understand the building process of beavers because it happens over many years and satellite imagery does not provide sufficient spatial or temporal resolution to track beaver damming network growth. In mountainous regions snow melt annually washes out the previous year beaver builds. Here, beaver colonies thrive by recapitulating the entire dam building process over a period of three to five months. This provides a unique opportunity to study the building process from "scratch". We hypothesize that beavers build locally and are driven to do so by hydraulic triggers at the dam scale. We present a study of beaver colony damming network construction in the foothills of the Rocky Mountains in northwestern Montana. Using hydraulic measurements and aerial imagery we observed the construction activities of beaver during their active building season. To observe dam building at high enough spatial and temporal resolution we used a DJI Phantom 4 Pro drone to conduct weekly scans of four sites from May 2018 to August 2018, covering approximately 103 hectares, 13 beaver colonies responsible for the construction of 76 dams over a three month period following snow melt. Using Agisoft Photoscan high resolution orthomosaics were built and then annotated with ArcMap to create shapes files in order to track dam network formation and growth. A beaver damming network contains a multitude of features; including dams, ponds, trails, canals, lodges, and scent mounds. Our results suggest that the initiation of building corresponds to the measured volumetric flow rates at each site. The final damming complex is many times larger than any one individual beaver and likely taking place in many locations simultaneously, suggesting beavers engage in distributed building activities.

P3-47 KENNY, E*; HOWEY, CAF; The University of Scranton; *elizabeth.kenny@scranton.edu*
Ambient Light at Night and Effects on the Immune Response of Anoles
Urban areas present many challenges to resident organisms. With natural light during the day and artificial light at night, urban organisms are more exposed to ambient light compared to their natural habitat. Ambient light at night (ALAN) is a chronic stressor that greatly affects anoles as these organisms are commonly found in urban environments. Chronic stressors are known to affect glucocorticoid levels of organisms, and have cascading pathological effects on immune systems. Our objective was to study the effects that ALAN had on the immune response of green anoles *(Anolis carolinensis)*. We housed 24 male *A. carolinensis* for six weeks in two separate treatments. The Control Treatment was housed in a 12:12 Light:Dark cycle, and the ALAN Treatment was housed in 24-hour ambient light. Both treatments were housed in similar temperature, humidity, and UV light conditions. After six weeks, we used a PHA (phytohemagglutinin) test to measure the T-cell immunocompetence of anoles in both treatments. The results collected from this study will help scientists studying ecoimmunology to determine the effects that a chronic stressor, like ALAN, has on the immune system of an organism.

P2-25 KEOGH, SM*; SIETMAN, BE; JOHNSON, NA; SMITH, CH; RANDKLEV, CR; HARRIS, JL; SIMONS, AM; University of Minnesota, MN Depart Nat Resources, US Geological Survey, Baylor University, Texas A&M , Arkansas State University; *keogh026@umn.edu*
Species delimitation, phylogeography, and morphology of the North American Mapleleaf (Quadrula) freshwater mussels (Bivalvia: Unionidae)
The genus *Quadrula* has long been a source of frustration for North American malacologists. This frustration stems from substantial interspecific morphological and distributional overlap which has created confusion over the validity of taxa. The most recent analysis (2019) proposed a decrease in species from five to three. No study has examined putative species across their geographic ranges sampling both mitochondrial and nuclear characters. We used multilocus molecular phylogenetics (COI, ND1, ITSI) to evaluate the taxonomic identity of all putative *Quadrula* taxa: *Q. apiculata, Q. fragosa, Q. quadrula, Q. rumphiana* as well as closely related species *Tritogonia verrucosa* and *T. nobilis*. We used >200 specimens from >50 localities to construct a robust phylogenetic hypothesis. We recovered monophyly of all but one species, *Q. quadrula*, which was paraphyletic in the ND1 gene tree analysis. Additionally, *Q. apiculata, Q. rumphiana*, and *Q. quadrula* clades 1 & 2 exhibited no differentiation at the nuclear locus. To test the hypothesis that mtDNA cladogenesis is indicative of speciation we integrated our Sanger-sequence dataset with nuclear wide restriction-site associated DNA sequencing (RADseq). We used micro-CT scanning and three-dimensional geometric morphometrics of *Quadrula* shells to quantify inter and intraspecific shell variation and compare this to our molecular results. We plan to leverage these results with museum shell material to infer the historic ranges of *Quadrula* species in North America, which is necessary for developing effective conservation strategies, especially for wide-ranging, highly variable species like those in the genus *Quadrula*.

24-1 KERNBACH, M.E*; UNNASCH, T.R; MARTIN, L.B; University of South Florida; *Kernbach@mail.usf.edu*
Differential Effects of Spectral Composition of Nighttime Lighting on West Nile Virus Resistance and Mortality in House Sparrows
Artificial light at night, or ALAN, has become a pervasive anthropogenic stressor for both humans and wildlife over the past century. Although many of the negative impacts of ALAN on health have been documented, the consequences for infectious disease dynamics are largely unexplored. With the recent implementation of broad-spectrum and energy efficient light-emitting diodes (LEDs), the effects of spectral composition of ALAN have also come into question. Previous studies have shown that exposure to low levels of incandescent ALAN extends the infectious period of house sparrows infected with West Nile virus (WNV) without affecting mortality rates. Here, we asked whether altering the spectral composition of ALAN would exacerbate or ameliorate these consequences for house sparrows infected with WNV. We found that exposure to broad-spectrum (3000+5000K) LED ALAN did not affect viral resistance (i.e. inverse of viremia), but this light form increased WNV-induced mortality. As these same individuals died earlier and lost more body mass over time than expected from their viremia, higher mortality under broad-spectrum ALAN may be due to disproportionately higher pathogen-induced damage and/or immunopathology. Conversely, birds exposed to amber-hue (1800K) LED ALAN had significantly lower viremia, and mortality rates similar to natural light exposed controls. This study demonstrates that the spectral composition of ALAN can affect infection outcomes and thus provides insight into utility of particular nighttime lighting methods.

69-4 KHALIL, S*; ENBODY, ED; WELKLIN, JF; SCHWABL, H; WEBSTER, MS; KARUBIAN, J; Tulane U, Uppsala U, Cornell U, WSU, Cornell U; *skhalil@tulane.edu*

Testosterone Regulates Gene Expression Associated with Carotenoid-Based Plumage Ornamentation in the Red-backed Fairywren

For many animals, testosterone (T) activates ornamentation in males. However, our mechanistic understanding of the relationship between T and ornamentation is limited in two main ways: 1) T does not impact all tissue types in the same manner, and 2) sex-specific coloring is likely mediated by polygenetic interactions, rather than simple genetic variation. As a consequence, transcriptional differences—and how hormones may regulate them—are critical to understanding the link between genotype and phenotype. In this study, we investigate the role of testosterone in mediating gene expression across tissues associated with a sexual signal in wild Red-Backed Fairywrens (*Malurus melanocephalus*). In this species, males exhibit flexible reproductive phenotypes: some individuals have high circulating T and breed in red/black plumage, and others have low circulating T and breed in female-like brown plumage. Previous work has shown that females prefer mating with red/black males over brown males, and redder males have higher reproductive success, suggesting the red back is an important sexual signal. To assess how the endocrine system impacts gene regulation and red plumage production, we experimentally manipulated T levels in males and sequenced the transcriptome of both the liver and feather, two important tissues for red carotenoid coloration. We identified genes involved in generating variation in plumage color by comparing the transcriptome of control brown males, T-implanted brown males, and naturally red/black males. We found that testosterone regulates the expression of CYP2J19 in the liver, which is essential for carotenoid metabolism, while also mediating carotenoid transport into feathers. To our knowledge, this is the first study to demonstrate a causal link between testosterone and carotenoid metabolism in a wild population.

3-3 KHANDELWAL, P C*; HEDRICK, T L; UNC Chapel Hill; *pranavk@live.unc.edu*

Gliding through clutter – obstacle-avoidance and path-planning in the flying lizard Draco dussumieri

Gliding animals frequently traverse complex spatial habitats to perform ecologically relevant behaviors. However, unlike flapping flyers, gliders are constrained in their ability to negotiate obstacles and cover longer distances by a fixed energy budget (takeoff height) and a relatively simpler wing anatomy. In this context, it is unclear how gliders achieve collision-free flight on a day-to-day basis. We address this question by quantifying voluntary glides in a naturally behaving, wild population of the flying lizard *Draco dussumieri*, inhabiting the Agumbe rainforest nature preserve in India. We digitized 25 glide trajectories of varying distances in 3D and found that *Dracos* executed non-equilibrium glides involving a steeper takeoff, shallower mid-glide and a sharper pitch-up landing maneuver to cover longer glide distances. Furthermore, we digitized the location of all trees in the recording environment and found that for a given glide distance, *Dracos* selected a target tree with less surrounding clutter and jumped away from an obstacle in line with the target tree. During flight, *Dracos* navigated their cluttered environment using a vision-based obstacle-avoidance model with up to 0.5g turns. Finally, to land on the target tree, *Dracos* initiated deceleration consistent with a visual trigger model and progressively increased their braking while approaching the landing tree. In summary, we used a biologically relevant framework of the environment, sensory input and the biomechanical capability of *Dracos* to show how gliders execute collision-free flight in a natural habitat.

P2-138 KHAWAJA, Y*; HUSAK, J; University of St. Thomas; *khaw4895@stthomas.edu*

Effects of Triiodothyronine on Metabolism in Lizards

Thyroid hormones play a key role in regulating metabolic rates in mammals and some non-mammal species. Thyroid hormones, especially triiodothyronine (T3), also play a role in altering mitochondrial number and function, as well as oxidative phosphorylation pathways, in skeletal muscle after exercise or increased activity. However, research concerning the role T3 plays in whole-body and muscle metabolism via mitochondrial biogenesis in nonmammals has mixed results. In our study, we experimentally manipulated 40 male green anole lizards split into two treatment groups, with the first group assigned saline injections, and the second group assigned T3 injections. We expected T3 to elevate both whole-body metabolic rate as well as oxygen consumption rate of skeletal muscle fibers. However, we discovered that T3 did not elevate whole-body metabolic rate or oxygen consumption rate of skeletal muscle tissue compared to controls. Our results suggest that either thyroxine (T4) may be the biologically active form for eliciting specific physiological responses in ectotherms instead of T3, or thyroid hormones have fundamentally different roles in lizards compared to mammals.

P2-108 KHOJA, A*; KWITNY, M; STAPLES, AE; SCHÜRCH, R; Virginia Tech; *staplesa@vt.edu*

Development of an Open Source Implementation of Automated Honey Bee Waggle Dance Decoding Using Particle Image Velocimetry

In honey bees, a worker bee that returns from a foraging trip will indicate to her nestmates in the hive where she has found food by performing a stereotypical behavior, the waggle dance. In this waggle dance bees encode the direction and the distance to the food source. Researchers can eavesdrop on these dances, extract the vectors from hive to food resource, and assess the landscape for its ability to feed pollinators. In other words, we can use bees as bioindicators for landscape health. Up to now, researchers have decoded these dances by hand from video. However, recently a group in Japan (Okubo *et al.* (2019) *Apidiolgie* 50:243–252) has published a method for decoding dances from video automatically using particle image velocimetry (PIV). This method of dance decoding has the potential to use waggle dance data on a large scale. Unfortunately, the researchers used proprietary software for the PIV. Here we show how we re-implemented the method using free and open software. Our implementation using OpenPIV and Okubo *et al.*'s scripts works well at identifying waggle runs from video recorded waggle dances. Furthermore, we show that the automatically decoded waggle runs are largely concordant with the gold-standard of manually extracting the vector information. This open and free implementation should provide a useful resource for researchers studying bee foraging.

30-7 KHURSIGARA, AJ*; ESBAUGH , AJ; The University of Texas at Austin; *akhursigara@utexas.edu*

Does crude oil exposure alter behavior in fish?

Crude oil is a common environmental toxicant of concern in aquatic environments, and the impact it has on marine fishes has been well studied. A majority of these studies have focused on cardiotoxicity and its downstream ecological effects. However, recent work has demonstrated that neurological function and behavior may be just as sensitive as the cardiotoxic endpoints. Transcriptomic work from larval red drum (*Sciaenops ocellatus*) has shown significant alteration in pathways related to neurological and cognitive function following oil exposure; this was accompanied by a reduction in brain size. Based on this information, several follow up studies sought to examine the influence that oil exposure may have on fish behavior and performance. In open field tests, acutely exposed larval red drum showed a reduction in thigmotaxis or "wall hugging" behavior and increased area explored compared to control conspecifics. Similarly, small shoals of Atlantic croaker (*Micropogonias undulatus*) in an open field test also demonstrated a reduction in thigmotaxis while increasing mean neighbor distance, suggesting a decrease in sociability. While these studies examined specific personality behaviors, recent work on zebrafish (*Danio rerio*) has examined the effect of oil on behavioral syndromes. Interestingly, preliminary data does not suggest a shift in behavioral syndromes following oil exposure, however there is a shift in the correlation between behavioral traits. These findings suggest that more research is needed to understand how sub-lethal exposure can impact fish behavior and the downstream ecological significance this can have for populations.

S9-3 KIENLE, SS*; POWERS, J; CACANADIN, A; KENDALL, T; RICHTER, B; COSTA, DP; MEHTA, RS; UCSC; *skienle@ucsc.edu*

Linking Functional Morphology, Behavior, and Ecology to Understand Foraging Strategies in an Endangered Marine Mammal

Successful animals integrate morphology and behavior to produce diverse feeding strategies to consume prey in a variety of environmental contexts. Different strategies represent trade-offs between morphological specialization, prey choice, and energetic expenditure, and comparing strategies and their trade-offs is important for understanding individual and population level foraging success. Here we examined the underwater feeding strategies used by the endangered Hawaiian monk seal (*Neomonachus schauinslandi*), as poor foraging success seems to be driving the decline of some populations. Seven Hawaiian monk seals were fed five prey types of different sizes presented in three contexts (surface, midwater, benthos). Hawaiian monk seals used two strategies: suction feeding and biting, and these strategies involved specific behaviors and kinematics. Despite having a skull and dentition specialized for biting, Hawaiian monk seals used suction feeding most frequently (91% of all feeding trials), regardless of prey type and feeding context. However, biting was used most frequently when seals targeted larger prey (>70% of the seal's head length), demonstrating that prey size influences the transition between strategies. In terms of trade-offs, suction feeding was 2.3 times faster than biting and involved a smaller gape and fewer jaw movements, allowing seals to quickly consume numerous small prey; biting was slower but resulted in 1.5 times more energy gained per time spent feeding. Maintaining both strategies results in increased behavioral flexibility, which is important as Hawaiian monk seals feed in an increasingly spatially and temporally dynamic marine environment.

76-7 KIKEL, M*; GECELTER, R; THOMPSON, NE; NYIT College of Osteopathic Medicine; *mkikel@nyit.edu*

Evolutionary origins of human pelvic list, hip adduction, and step width

Human bipedal walking entails unique frontal plane balance strategies compared to other primates. Compared to bipedal chimpanzees, humans walk with step widths that are proportionally three times narrower, utilize stance-phase hip adduction rather than abduction, and use a pattern of pelvic drop on the swing side rather than swing-side pelvic elevation. Here we sought to determine if and how the human-like pattern of pelvic and hip motion is related to step width. To investigate pelvic and hip motion during walking, ten human subjects walked on a treadmill at narrow, normal, and wide step widths. Full body kinematics were measured using the Plug-In Gait marker set with a 12-camera Vicon motion capture system. Our results suggest that neither wide steps (~3 times normal width) nor narrow steps (~0 cm) lead to major differences in pelvic list. Narrow and wide steps do lead to an increase and decrease, respectively, in overall hip adduction (+3° for narrow steps, -6° for wide steps). These results suggest that the human-like pattern of pelvic list is not dependent on step width, though hip adduction is. The change to pelvic drop on the swing side in humans and perhaps some early hominins was therefore likely an evolved trait, and not a direct result of the emergence of valgus knees and narrow step widths.

16-4 KILLION, KD; Blinn College District, Brenham, TX, Blinn College; *karen.killion@blinn.edu*

Getting Undergrads to Write the Something

Getting undergraduates to take notes is a struggle. They either write nothing or attempt to write every word. I have a background in teaching 6-12 science and have done professional development for K-12 classroom teachers for a several years. I constantly try methods and strategies from secondary levels in my classroom. One thing I've recently tried is making study tools that seem more like an activity that actually learning the content or taking notes. In lower grades "foldables" are often created and kept in a composition book using lots of construction paper, colored paper and markers, etc. I call the ones we make in my classes, grown-up foldables. White paper and a pencil or pen do just fine unless the student wants to "decorate" theirs. I let them know they are not graded, they are their creations and their study tools. Sometimes we make the foldable as a class as we go through the lecture and sometimes I put pictures of a sample on our digital platform and encourage them to make a foldable on their own as a way to study. I tried this with my 2019 Summer I Non-Majors Biology class and when the students came in for the final, they had all their foldables to continue reviewing for the exam. Students in that class even suggested other topics that would be good in a foldable. I'm not a research scientist. I have no data. I am a hand-on, brains on, non-majors, community college biology educator trying to make students realize they need to know some basic biology. If they have a little fun, make a "flappy thing" as one student called it, and learn something, it's a success!!

35-6 KIM, SL*; YEAKEL, JD; EBERLE, JJ; ZEICHNER, SS; University of California, Merced, University of Colorado - Boulder, California Institute of Technology, Pasadena, CA; *skim380@ucmerced.edu*

Impacts of Environmental Gradients on Shark Body Size: a Comparison from Fossil Evidence and Demographic Modeling of Sand Tigers

Fossil shark teeth serve as biological proxies for numerous environmental and climatic variables but, geochemical records are not often correlated to ecological factors. For example, the oxygen isotope composition of shark enameloid ($\delta^{18}O$) acts as an indicator of water temperature and salinity. In addition, tooth crown height correlates to body size and the vast number of fossil teeth in museum collections can be used to provide estimates of body size distributions for extinct populations. Changes in body size distributions over space and time are, in part, a consequence of changes to shark life history in response to shifting environmental conditions. We determined body size and $\delta^{18}O$ values for Eocene Sand Tigers (*Striatolamia macrota* syn. *Carcharias macrota*) from two high latitude (Arctic and Southern Ocean) and two mid-latitude (Gulf of Mexico) localities to compare the effects of latitude, temperature, and salinity on life history. We found significant differences in body size distributions across sites differing in environmental conditions as well as function, as some locations are suggested nurseries. We created a demographic population model to evaluate how temperature likely constrained growth and reproduction of a population straddled between spatially separate nursery and adult sites. By comparing the body size distributions of empirical fossil data with results from our demographic model, we are poised to assess the role of environmental plasticity in the long term evolutionary success of Sand Tigers.

P2-34 KIM, LN*; CAPANO, JG; MAYERL, CJ; BLOB, RW; WYNEKEN, J; BRAINERD, EL; Brown University, Northeast Ohio Medical University, Clemson University, Florida Atlantic University; *leila_kim@brown.edu*

XROMM analysis of pectoral girdle motions during locomotion and ventilation in the loggerhead sea turtle

In turtles, the position of the limb girdles deep to the shell presents functional challenges between locomotion and ventilation. Without mobile ribs or a diaphragm, turtles ventilate by contracting a muscular sling inside the rigid shell. Previous studies of semiaquatic turtles indicate that this sling mechanism enables breathing during locomotion. However, respirometry and flume observations suggest that sea turtles cannot breathe during their most intense locomotor style, powerstroking. We hypothesize that species-specific locomotor behavior may explain these differences: semiaquatic turtles row their limbs craniocaudally, whereas sea turtles use a synchronous dorsoventral flapping motion to powerstroke. We used XROMM to quantify the skeletal kinematics of lung ventilation and flapping locomotion in loggerhead sea turtles, *Caretta caretta*. Rotations and translations were measured relative to the plastron, about anatomical dorsoventral (DV), craniocaudal (CC), and mediolateral (ML) axes. We found that sea turtles rotate their pectoral girdle substantially more during lung ventilation (~5-18° DV) than during powerstroking locomotion (~3-5° DV). These rotations are small compared to those previously described for the semiaquatic river cooter, *Pseudemys concinna* (~30° DV). Our findings suggest that despite the potential for pectoral girdle rotations demonstrated by movements during ventilation, the evolution of flapping locomotion in sea turtles resulted in smaller rotations of the pectoral girdle, a functional specialization that may inhibit their ability to breathe while powerstroking.

92-2 KIMBALL, MG*; GRANT, AR; CHRISLER, A; JOHNSON, E; MALISCH, JL; Louisiana State University, Baton Rouge, LA, University of Nevada, Reno, NV, St. Mary's College of Maryland, St. Mary's City, MD, St. Mary's College of Maryland, St. Mary's City, MD; *mkimba6@lsu.edu*

Acute Stress Mobilizes Glucose and Free Fatty Acids in Mountain Dark-eyed Juncos (Junco hyemalis)

Resource mobilization and reallocation is a major endpoint of the physiological response to acute stress. However, energy metabolites have not been the focus of most field studies. Here we characterized the glycemic and free fatty acid (FFA) 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 the early nesting period. Blood samples were collected at 0, 15 and 30 min post-capture. Blood glucose levels were higher than baseline at 15 min (43% increase) and 30 min post-capture (67% increase). FFA levels were also higher than baseline at 15 min (29% increase) and 30 min post-capture (22% increase). Predictors of energy 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 and FFA in response to acute handling stress, and these responses are best modeled when scaled mass, abdominal fat, and initial glucose response from baseline to 15 min are included as predictor variables. These results suggest that energy mobilization capacity is influenced by measures of body condition.

P2-211 KIMBALL, D*; MINICOZZI, M; GIBB, A; Northern Arizona University, Flagstaff, Arizona, Minnesota State University, Mankato, Minnesota ; *dsk55@nau.edu*

Bonytail, the Arizona tuna, convergence in muscle and tendon anatomy in scombrids and Gila cypha

Bonytail (*Gila elegans*) are an Arizona native endangered species that have unusual morphology thought to have evolved for high flow riverine environments. The shallow peduncle and crescent shaped tail appear to allow them to reduce drag and increase swimming efficiency. We describe the anatomical features associated with body shape in the caudal peduncle region. We compared the peduncle morphology of two closely related native species, Roundtail (*Gila robusta*) and Humpback chub (*Gila cypha*), to that of Bonytail. We cleared and stained ten individuals from each species to measure the neural and hemal vertebral spine angles (angle the spine creates with the vertebral centra) and size normalized spine lengths (spine length/standard length of fish) of the last twelve vertebrae. Bonytail have more acute spine angles in the caudal peduncle compared to Humpback and Roundtail. We also examined the soft tissues (muscle and tendon) of the caudal peduncle. Using a tendon-tension test and histological examination, we found evidence for paired lateral tendons in Bonytail that appear to be present in Humpback but absent in Roundtail. The total volume of muscle in the peduncle region of Bonytail appears to be reduced but stronger (tension test) when compared to Roundtail. Loss of musculature and lateral tendons are also seen in scombrid (tunas) fishes, where their long lateral tendons transmit force from the anterior musculature to the tail. Bonytail appear to be converging on this morphology which is likely beneficial during historic seasonal flooding events, where they can maintain position in the flow with relatively low energy expenditure.

S4-8 KIMMITT, AA*; SINKIEWICZ, DM; KETTERSON, ED; Texas A&M University, Indiana University; *akimmitt@bio.tamu.edu*

Female Songbirds that Differ in Migratory Strategy Also Differ in Neuroendocrine Measures in Early Spring

Most studies of reproductive timing and the underlying mechanisms have used only male subjects, despite the critical role females play in determining breeding phenology. To better understand how animals shift into the reproductive state, more knowledge of hormonal mechanisms in the brain underlying the transition is necessary, especially in females. Closely related populations found in the same environment in early spring that differ in reproductive timing provide an opportunity to examine differences in these mechanisms. We studied a migrant and resident population of dark-eyed juncos (*Junco hyemalis*) that are found in overlapping ranges during the winter and early spring. Populations differ in reproductive timing, as residents initiate breeding before migrants depart, whereas migrants do not breed until they reach northern breeding grounds. To study differences in the hypothalamic mechanisms of reproduction, we caught 16 migrant and 13 resident free-living females between March 25 and April 11. We quantified expression of mRNA transcripts for genes related to reproduction in the hypothalamus. We found that resident females had higher abundance of gonadotropin-releasing hormone transcripts than migrant females, indicating that residents have greater hormonal top-down stimulation than migrants during this time. Additionally, we found higher transcript abundance of estrogen receptor and androgen receptor in migrant than resident females, suggesting that negative feedback might delay reproductive development in migrants. These differences in hypothalamic mechanisms could help to explain population differences in reproductive timing.

46-5 KIMURA, J*; RICCI, L; LUO, Y; SRIVASTAVA, M; Harvard University; *Julian_Kimura@g.harvard.edu*

Development of the acoel worm Hofstenia miamia and the embryonic origin of neoblasts

Animals that are capable of "whole-body" regeneration are able to replace any missing cell type. Species that are able to undergo whole-body regeneration often do so using a population of adult stem cells that are effectively pluripotent such as the i-cells of cnidarians and neoblasts of planarians. Studying the embryonic origins of these adult stem cells in regenerative species would be the first step in determining the genetic control of stem cell formation. We are studying this question using the new model system Hofstenia miamia, a highly regenerative acoel species that produces experimentally tractable embryos in the laboratory. Hofstenia possess a population of stem cells, also called neoblasts, that are necessary for regeneration and express homologs of piwi. Here, we report an in-depth characterization of embryonic development in Hofstenia miamia. We generated a bulk RNAseq dataset and a developmental atlas by studying gross morphological changes and cellular movements during Hofstenia embryogenesis. A previously undescribed, coordinated cellular movement occurred at about 43-55 hours post laying where the cells on the surface of the animal pole became internalized ("Dimple" stage). in situ hybridization revealed that differentiated cell types and body axes were detectable after the Dimple stage. Finally, to determine when neoblast-like cells emerge during embryogenesis, we performed single cell RNA-seq across developmental stages. Using computational tools, we aim to identify cell lineages and the genes that are required for neoblast formation. The identification of candidate regulators followed by functional studies will enable us to determine the mechanisms for neoblast specification during embryogenesis.

77-8 KING, EE*; STILLMAN, JH; WILLIAMS, CW; University of California, Berkeley, University of California, Berkeley and San Francisco State University; *emily_king@berkeley.edu*

New Zealand Mud Snails Continue Respiring During Severe Oxygen Limitation at Warm Temperatures

Physiological intolerance of environmental stress constrains a species' range by limiting population growth and dispersal to new habitats. Abiotic stress also serves as a barrier to establishment of non-native species. Understanding the interactive effects of temperature and oxygen on aquatic habitats is critical to predicting habitat availability across present and future landscapes. The invasive snail, *Potamopyrgus antipodarum*, tolerates diverse abiotic conditions across its global distribution, but how habitat temperature and oxygen availability interactively affects its distribution is unknown. This study investigated the effect of water temperature and oxygen saturation on respiration rate to discern under what conditions persistence would be limited. We predicted that respiration rates would increase with temperature and that respiration rates would decrease with decreasing oxygen supply. Respiration rates were measured during progressive hypoxia, from 100% O_2 until respiration ceased, at 9 temperatures (7-35°C). As predicted, we found that respiration rates declined with decreasing water temperature and decreasing oxygen availability. At warmer temperatures snails continued respiring under increasingly hypoxic conditions (<1.5mg/L O_2) while they stop earlier at lower temperatures (1.5-3 mg/L O_2). Thus, faster respiration rates were associated with a more complete use of available oxygen. At low temperatures there is still oxygen remaining suggesting that snails have stopped respiring through active regulation rather than conforming respiration rates to the oxygen supply available. However, at high temperatures the only option is to use the remaining oxygen.

10-4 KING, TK*; BROWN, JM; Louisiana State University ; *tking21@lsu.edu*

Identifying Atypical Modes of Continuous Trait Evolution

Phylogenetic comparative methods (PCMs) are used to make comparisons among organisms while considering their shared evolutionary histories. Brownian motion (BM) and the Ornstein-Uhlenbeck (OU) process are the main models of continuous trait evolution utilized in the context of PCMs. However, because PCMs can be applied to a wide range of organisms occupying a number of environments and various spans of evolutionary time, these models may not be able to fully capture all observed patterns of trait evolution. How valid are your biological conclusions if characters of interest do not conform to either mode of evolution? Here we propose a new parametric bootstrapping method using phylogenetic contrast to assess the fit of either BM or OU models to continuous traits. Phylogenetic contrasts were calculated for each trait of interest along the tree and used as a test statistic. We performed simulations using estimated parameters after fitting each trait to either BM or OU. We used effect size to compare phylogenetic contrast between empirical and simulated datasets. We applied this method to data on seven structural, temporal and frequency characteristics of birdsong from the genus Catharus. Surprisingly, comparisons indicate that neither BM or OU models properly characterizes the mode of evolution, as evidenced by high effect size values. Additionally, this method allows for the identification of specific outlier nodes that contrast with what we would expect if the tree where evolving under BM or OU models. To verify our method, we performed a small simulation study to demonstrate that it has a proper Type I error rate. Ultimately, this study highlights the importance of carefully considering other possible modes of evolution.

23-3 KING, RW*; WUND, MA; FOSTER, SA; BAKER, JA; Rich King, Clark University, Worcester, MA, The University of New Jersey, Clark University, Worcester, MA, Clark University, Worcester, MA; *rking@clarku.edu*

Salinity mediated shape plasticity in oceancic threespine stickleback

Adaptive radiations offer unique insights into evolutionary processes and elucidating the processes by which the evolution of new species occur. Parallelism in adaptive radiations could be the result of selection acting on standing genetic variation or via a ‘flexible stem system' that causes the expression of consistently different phenotypes in different environments. Subsequent selection could produce ecotypic differences in adaptive radiations and thus the high levels of parallelism in these radiations. Evaluation of these alternatives is difficult, as comparison of ancestral genetic architecture or patterns of plasticity with those of derived, divergent ecotypes is rarely possible - primarily because the ancestral form is rarely extant. Using the threespine stickleback adaptive radiation, we employ a common-garden design and geometric morphometrics to test degree of plasticity in shape between marine and anadromous (i.e., ancestral) populations based upon salinity of the rearing environment. Our study indicated that the form of plastic responses differs between anadromous and marine G. aculeatus. Moreover, there was clear evidence that some of the shape variation between anadromous and marine fish is due to trait-based genetic differentiation. To the best of our knowledge, this is the first suggestion for any evolutionary system where two, differentially plastic, ancestral stems exist.

70-4 KINGSTON, ACN*; SPEISER, DI; University of South Carolina; *acnahm@gmail.com*

Snapping shrimp see through transparent armor

Snapping shrimp have specialized armor, termed the orbital hood, that covers their head and eyes. It has been proposed that orbital hoods protect the heads of snapping shrimp but impair their visual abilities. To explore the relationship between armor and vision in these animals, we examined the optical properties of the orbital hood, the morphology and physiology of the visual system, and the visually influenced behaviors of the big claw snapping shrimp *Alpheus heterochaelis*. We find that the orbital hoods of *A. heterochaelis* are made of transparent carapace that transmits 80-90% of incident light to their reflecting superposition eyes. Electroretinography (ERG) shows that the eyes of *A. heterochaelis* respond maximally to 500 nm light and demonstrate a flicker fusion frequency of > 40 Hz. Microspectrophotometry (MSP) reveals that the eyes of *A. heterochaelis* have two middle-wavelength sensitive (MWS) visual pigments that maximally absorb light at 501 and 519 nm. Behavioral trials using optomotor assays show that snapping shrimp demonstrate spatial vision with an angular resolution of ~ 8°. After discovering that *A. heterochaelis* has a functional visual system, we tested our hypothesis that the orbital hoods of snapping shrimp protect their heads from the shock waves produced by their snapping claws. To do so, we recorded shock waves produced by *A. heterochaelis* using pressure sensors mounted inside and outside of the orbital hoods of intact individuals. We compared these results to those from trials using individuals from which we removed orbital hoods. From these experiments, we discovered that orbital hoods decrease the magnitudes of shock waves by at least 40%. We conclude that the orbital hoods of snapping shrimp facilitate spatial vision and may protect their neural tissues from shock waves.

P3-133 KINSEY, CT*; BLOB, RW; Clemson University; *ckinsey@clemson.edu*

Predatory selection across stages of limb and tail development in Xenopus tadpoles

Anurans undergo dramatic structural changes during metamorphosis, in which the tail is resorbed, and fore- and hindlimbs emerge. These structural changes cause a shift in locomotor mechanics, from axial to appendicular-based propulsion. Previous studies of species that metamorphose into terrestrial jumpers have shown that tadpoles experience decreased survival against predators when both the limbs and tail are intermediate in development. It is possible that increased limb length is initially detrimental to performance and survival, but that the limbs become the primary source of locomotion during tail resorption, thus increasing survival later in metamorphosis. To test this hypothesis, we conducted selection trials on *Xenopus laevis* tadpoles using a fish predator. This species differs from those studied previously, in that adults use their limbs for swimming rather than jumping on land. Tadpoles (N=15) were spread equally across three developmental stages: NF56 (with tail and newly budded limbs), NF 63 (functional hindlimbs and tail), and NF 64 (fully functional limbs and minimal tail). Predation trials ended after 50% of tadpoles were eaten. Remaining tadpoles were filmed to assess escape performance and photographed to collect morphological data. Survival increased uniformly across ontogeny as the hindlimbs grew and the tail was resorbed, rather than showing an intermediate stage of low survival when both legs and tail were functional. Thus, survival across stages may be driven by a rapid increase in hindlimb development prior to significant tail resorption. These data suggest that contributions of hindlimbs to escape performance may play a larger role in survival than tail length in this fully aquatic frog species, in which the hindlimbs do not need to function in two distinctly different locomotor modes.

P3-117 KINSEY, ST*; COOK, JG; LAITE, C; SECOR, SM; University of North Carolina Wilmington, University of Alabama; *kinseys@uncw.edu*

Muscle growth patterns and implications for energy costs in diamondback water snakes (Nerodia rhombifer)

The bulk of ATP demand in resting skeletal muscle is devoted to maintenance of the sarcolemmal membrane potential, the sarcoplasmic reticulum (SR) Ca+ gradients, and protein turnover. We have previously found that skeletal muscle fibers often grow as large as possible, to the brink of diffusion limitation, which minimizes sarcolemmal surface area:volume (SA:V) and reduces the costs associated with the Na+-K+ ATPase (NKA). The diamondback water snake (*Nerodia rhombifer*) devotes much of its body mass to skeletal muscle, eats infrequently, and is often sessile, making it advantageous to minimize muscle maintenance costs. We tested the hypothesis that fiber size and myofibril size would increase with animal growth, and that the NKA and SR/ER Ca2+ ATPase (SERCA) would be proportional to fiber and myofibril SA:V, respectively. Muscle fiber size increased with body mass, however, the NKA activity did not decrease in proportion to fiber SA:V as hypothesized. Myofibril size also increased with body mass, but the SERCA activity increased, rather than decreasing in proportion to SA:V as expected. Myonuclear density decreased with increasing body and fiber size, suggesting a decrease in the capacity for protein turnover in larger snakes. Further, the nuclei shifted toward a more intermyofibrillar distribution during fiber growth, which is indicative of fibers growing to sizes that induce diffusion limitation. These results suggest that muscle fibers are growing as large as possible, but the lack of a relationship between fiber size and NKA activity does not support the notion that this is a cost saving strategy. The elevated SERCA activity in larger animals may indicate that more SERCA activity is needed to support Ca2+ fluxes over longer diffusion distances.

133-7 KIRKPATRICK, A*; KANATOUS, S; CROCKER, D; TRUMBLE, S; Baylor University, Colorado State University, Sonoma State University; *a_kirkpatrick@baylor.edu*

Fatty acids and Diving Development: Age class and sex differences in skeletal muscle fatty acid compositions the northern elephant seal Mirounga angustirostris

Fatty acid oxidation provides approximately 90% of energetic requirements in northern elephant seals (NES), yet little is known about the composition of their skeletal muscle fatty acids (FAs). Here, we report the skeletal muscle FA composition of NES within different age classes (adults {AD}, 1-year olds {1YR}, weaned pups {WP}) and sex. We analyzed 136 samples, spanning from 2012-2016, via GC-FID. A subset of 15 FAs, accounting for ~96% of FAs, were normalized and transformed. Saturated fatty acids (SFAs, ~65%) dominated muscle tissue in all age classes, monounsaturated fatty acids (MUFAs, ~19%) were the second most abundant and polyunsaturated fatty acids (PUFAs, ~11%) were the least abundant. Muscle tissue was predominantly composed of five FAs, C16:0, C16:1, C18:0, C18:1n9c and C20:2 (81% total FA). Multivariate analysis (MANOVA) of FA groups (SFA, MUFA, PUFA) indicated a significant effect of age class ($F[4,248]= 14.40$ p

P1-167 KIRONDE, E*; FURLAN, F; FUXJAGER, M.J; PREININGER, D; MANGIAMELE, L; Smith College, Université Paris Diderot, Brown University, Vienna Zoo; *ekironde@smith.edu*

Androgens modulate dynamic changes in multimodal display structure in the Bornean rock frog (Staurois parvus)

Multimodal communication often evolves in noisy habitats, where selection favors multiple ways to send messages to conspecifics. Multimodal displays are highly dynamic; however, to date most studies have focused on how signaling behavior varies across behavioral contexts and physical environments. We hypothesize that endocrine state also influences the structure of multimodal displays. To test this hypothesis, we recorded the interactions between two male Bornean rock frogs (*Staurois parvus*) and one female and quantified the behavior of a focal male during aggressive bouts. *S. parvus* uses an array of vocal and visual signals for male-male competition, the most conspicuous of which is an unusual hind limb gesture known as "foot flagging." A bout was defined as a period of short intense activity that was initiated by either a foot-flag or a call. Males were treated either with 1) saline, 2) testosterone + vehicle, or 3) testosterone + flutamide, an androgen-receptor blocker. We used R to create kinematic diagrams that mapped the frequency and sequences of the six main behaviors in the males' multimodal display. Our results show that when flutamide is introduced as an androgen receptor blocker, it decreases the number of bouts that occur. Flutamide also influences display dynamics in S. parvus by decreasing the overall frequency of many behaviors, and reducing the complexity of the entire network of behaviors by increasing repetition.

P3-121 KIRWAN, DJ*; RUDDY, BT; PORTER, ME; Florida Atlantic University, Boca Raton, Fl; *bruddy2018@fau.edu*

Predator-Prey Swimming Kinematics of Sphyrna mokarran and Carcharhinus limbatus

With the commercial availability of aerial drones, we are able to document animal interactions in the wild, including predator - prey interactions, leading to in-depth analyses of swimming kinematics. We quantified swimming kinematics of *Sphyrna mokarran* (great Hammerhead) and *Carcharhinus limbatus (blacktip shark)*, a common prey item for the great hammerhead, prior to and at the point of attempted predation. We predicted that great hammerheads would have reduced average velocity relative to the blacktip sharks, as stalking behavior is documented in the literature as a common predatory tactic during attempts on larger groups. Based on documented escape behavior from laboratory experiments, we hypothesized that after interacting with a nearby hammerhead (within 4 body lengths), blacktip shark tailbeat frequency, velocity, and whole body curvature will increase. We used a DJI Phantom 4 Advanced aerial drone to capture footage of wild predation events between blacktips and great hammerheads nearshore (N = 10 distinct predation events). Using Loggerpro motion tracking software, we derived swimming kinematic variables (amplitude, tailbeat frequency, velocity, and whole body curvature) of individual blacktips and great hammerheads. ImageJ was used to quantify distance of each blacktip to the hammerhead to determine the point of interaction. We found that overall great hammerheads swam with a reduced average velocity when compared to the blacktips prior to interaction, indicative of a stalking behavior. Additionally, blacktips increased their body curvature, velocity, and tailbeat frequency in response to interacting with the great hammerhead. These data validate responses in lab settings and quantify modulations in fish swimming kinematics in response to a predatory stimulus.

136-6 KISHI, Y*; BRÜCKNER, A; THOMAS, IM; PARKER, J; California Institute of Technology, Pasadena, CA, Columbia University, New York, NY; *ykishi@caltech.edu*

Hox-logic of Rove Beetle Chemical Weaponry

In the rove beetle subfamily Aleocharinae (Coleoptera: Staphylinidae) symbiosis with ants (myrmecophily) has evolved independently dozens of times. The predisposition to evolve myrmecophily has been attributed to an abdominal defensive gland in free-living species that equips the beetles for entry and exploitation of ant colonies. In some symbiotic species, the gland has undergone further specialization to synthesize and secrete compounds that manipulate ant behavior. The tergal gland is therefore a substrate for selection that has likely facilitated the repeated emergence of myrmecophily in Aleocharinae. Despite being a pivotal structure for this remarkable convergence towards myrmecophily, the molecular architecture of the gland and its chemical evolvability are poorly understood. We exploited a free-living aleocharine, *Dalotia coriaria*, to ask how this evolutionary novelty arises developmentally. The gland consists of two exocrine cell types: epithelial secretory cells (termed D2) that form a reservoir into which fatty acid derivatives are secreted, and classical glandular units (termed D1), composed of a biosynthetic bulb and duct cell, which synthesize irritant benzoquinones. The benzoquinones are trafficked into the D2 reservoir where they dissolve, creating a defensive secretion. Using RNAi, we find that development of both D1 and D2 cell types requires the cooperative activity of the posterior Hox proteins abdominal A and Abdominal B. Strikingly, we find that the thoracic Hox protein Ultrabithorax is also involved: Ubx knockdown causes loss of benzoquinone-producing D1 cells. Hence, evolution of an unusual Hox code in aleocharines underlies the capacity of these beetles to manufacture defensive chemicals, and consequently, their convergent infiltration of ant colonies.

34-7 KITCHEN, SA*; BRUCKNER, A; KISHI, Y; MILLER, DR; NARAGON, T; WAGNER, J; PARKER, J; California Institute of Technology; *sak3097@caltech.edu*

Genomic insights into gland development of rove beetles

Rove beetles comprise the largest family in Metazoa with nearly 64,000 species. The vast radiation of rove beetles can be attributed in part to their shortened elytra that enhanced abdomen flexibility, thereby allowing occupation of diverse and novel habitats. A second key innovation was the evolution of a defensive tergal gland in the largest subfamily Aleocharinae that can discharge volatiles through abdomen flexing to deter predators. The development of this gland has been proposed as a primary preadaptation for social insect symbiosis and many lineages have convergently evolved into highly social, symbiotic organisms through repeated changes in morphology, glandular chemistry and behavior to assimilate into the complex societies of ants and termites. In this study we investigate the evolutionary "ground state" of aleocharine beetles through genomic, transcriptomic and chemical profiling. We present the near chromosome-level genome assembly of *Dalotia coriaria*, a new genetic model system, and draft genome assemblies of 15 other species. Genomic scans for conservation of genes, gene families and genomic architecture in tergal gland development were assessed within the higher Aleocharinae and the convergently-derived defensive glands of *Tribolium castaneum*. Genes previously characterized to be specific to the gland tissue and volatile production in *T. castaneum* were compared with differential expression of control and gland tissue, targeted RNA interference and quantification of gland volatiles with GC/MS in *D. coriaria*. We highlight common molecular processes underlying the evolution of the defensive gland in beetles and those specific to the aleocharines that were key to their diversification.

3-5 KLEINHEERENBRINK, M*; FRANCE, L A; TAYLOR, G K; Dept. of Zoology, University of Oxford, UK; *Marco.KleinHeerenbrink@zoo.ox.ac.uk*

Modelling the flight envelope for transition to an unpowered perching manoeuvre.

By gliding up to an elevated perch, a bird can convert some of its kinetic energy into potential energy. Besides storing energy that can be used again for take-off, this manoeuvre reduces the requirement for energetically-costly aerodynamic braking during the approach. The most efficient approach to the perch would limit the use of braking to trajectory corrections only. We investigated the constraints on the transition from powered flight to an unpowered perching manoeuvre by simulating constant-lift decelerating glide trajectories towards an elevated perch. We identified several physical constraints that limit the horizontal and vertical distance to the perch by which gliding must be initiated. The requirement to fly faster than the stall speed causes the minimum required vertical distance to increase for smaller horizontal distances. On the other hand, a larger vertical distance requires a steeper pull-up manoeuvre, which leads to two further limits constraining the maximum vertical distance to the perch: the maximum load that the wing can sustain, and the need to avoid an inverted approach. Together, these limits constrain the minimum horizontal distance that a bird needs to perform a successful perching manoeuvre. In an experimental setting, involving four Harris' hawks, we controlled the distance between perches and found that the behaviour of these birds matched the modelled limits: when the perch distance was large, the birds flew near to the floor, with a gliding approach to the perch; for short distances, the birds flew straight to the perch and instead performed a powered braking manoeuvre. As straight, level flight would in principle work for any perching distance, the observed flexibility in strategy demonstrates an implicit awareness of the underlying physical constraints.

2-1 KLEPAC, CN*; BARSHIS, DJ; Old Dominion University, Norfolk, VA; *cklep001@odu.edu*

Decreased thermal tolerance in corals from high-frequency variable environments

Coral bleaching events (i.e., dis-association between coral animals and their dinoflagellate photosymbionts) are increasing in frequency and severity, resulting in widespread losses in coral cover and an urgency to identify resilient populations. Recently, research has found stress-tolerant coral populations that are adapted to highly variable environments and possess greater bleaching resistance than corals from more moderately variable habitats. Using well-studied, environmentally variable backreef lagoons (Ofu Island, American Samoa), we evaluated the thermal tolerance scope of the massive coral *Porites lobata* following a reciprocal transplant experiment between a Moderately Variable (MV) and Highly Variable (HV) pool, as well as transplanting from a Low Variability (LV) pool into the HV pool. Transplanted and native samples were exposed to a controlled acute thermal stress throughout a two-year transplant period. Corals transplanted into the HV pool had reduced growth, decreased photosynthetic efficiency, and greater chlorophyll loss following acute heat stress compared to native back-transplants in their pool of origin. HV corals grew the most yet exhibited the greatest bleaching susceptibility compared to MV and LV natives. Surprisingly, MV native corals were resilient to acute thermal stress. In contrast to previous studies, there was a thermal anomaly in the region where Ofu's backreef thermal regime surpassed historical records – 2017 had up to 9.5 Degree Heating Weeks (DHW), 2016 and 2015 had up to 8 and 5 DHW, respectively (in comparison to ≤ 3 over the last 10 yrs). These results indicate the HV environment greatly exceeded historical variability and could be reaching a tipping point from enhancing coral stress tolerance to potentially overwhelming upper tolerance limits.

109-9 KLOMPEN, AML*; SANDERS, SM; CARTWRIGHT, P; University of Kansas, Lawrence, Thomas E. Starzl Transplantation Institute, University of Pittsburgh School of Medicine, Pittsburgh; *annaklompen@ku.edu*

Hazardous Hydroids of Hydractinia: Variation in venom expression and nematocyte distribution in functionally distinct tissues of a hydractiniid hydrozoan

The role of venom with respect to ecological interactions is an active area of research. For instance, varying ecological conditions can alter the composition and expression of venoms between populations and even within individuals. Some species compartmentalize venoms for specific purposes into distinct structures, such defensive and predatory venoms within the ducts of cone snails or varied venom expression in the competitive structures of sea anemones. Cnidarians (jellyfish, hydroids, corals, etc.) are the earliest diverging venomous animals and display extremely diverse life history characteristics. Yet, little is known about their venom composition with respect to biological or ecological roles. Hydractiniid hydrozoans are an ideal system to study influences of ecological function on venom composition due to their functionally specialized tissue types and complex life cycles. The hydractiniid *Hydractinia symbiolongicarpus* displays a division of labor among the polyps in a colony: gastrozooids (feeding, digestion), dactylozoids (defense, predation), and gonozooids (reproduction). How does venom composition vary between the functionally distinct tissues within *H. symbiolongicarpus*? Using existing RNA-seq data from the different polyp types, we characterized the putative venom composition and expression between these tissues. We also determined the nematocyte (stinging cell) distribution between each polyp. By comparing RNA-seq and nematocyte distribution data between functionally specific tissues of *H. symbiolongicarpus*, we show that different venom arsenals correlate with specific functions and hypothesize that some venoms may be nematocyte-type specific (an ongoing question in cnidarian biology).

39-4 KO, D*; HADDAD, A; LIN, H-T; Imperial College London; *dsk13@ic.ac.uk*

Visual Target Information Encoding Mechanisms in the Dragonfly

Dragonflies perform impressive aerobatics to catch prey in flight, using their acute vision to locate and track prey pre and post take-off. Dragonflies track their prey by keeping it above the dorsal fovea of their eye throughout a hunt. The amount of tracking error is known to be an effective predictor of hunt success. Due to the limited neural information bandwidth in the ventral nerve cord of the dragonfly, efficient encoding of relevant spatial and directional information of the prey is critical. A set of 16 visually responsive neurons called Target Selective Descending Neurons (TSDNs) have been shown to encode the direction of prey motion. However, the full extent of the receptive fields (edge to edge with high resolution) as well as the prey position encoding mechanisms in these neurons are not known. We introduce the full extent of TSDN receptive fields and their implications on the nature of coding of spatial and directional states of visual targets in the TSDNs. The complete receptive field data allow rigorous testing of different coding hypotheses and the construction of a model that incorporates position, direction and the classes of prey trajectories.

P2-241 KOCH, RW*; REICHARD, M; Oklahoma State University; *ryan.koch@okstate.edu*

Using ecological niche modeling to predict the suitable habitat for Trichinella species in cougars (Puma concolor) from Colorado

Little information exists on the occurrence of *Trichinella* species in cougars throughout North and South America. However, species distribution models can be useful to predict the suitable habitat for elusive species with limited occurrence data. Here, we used the occurrence data from a recent study that found larvae of three *Trichinella* species in 44% (17/39) of cougars from five counties in Colorado. Environmental layers were constructed in ArcMap and included elevation, land cover, precipitation, and temperature. Habitat suitability models were created using MaxEnt, and models were projected to the extent of Colorado. The resulting models for infected (AUC=0.67) and uninfected (AUC=0.79) cougars were then combined to refine the final model, yielding distinct areas of presences and absences for *Trichinella* spp. The final model shows areas directly surrounding mountains to be the most suitable for *Trichinella* spp. Future work would benefit from sampling in predicted suitable areas to confirm species presences or absences. To date, this is the first ecological niche model of *Trichinella* spp. in cougars from Colorado.

34-3 KOCOT, KM; The University of Alabama; *kmkocot@ua.edu*

Revolutionizing Biodiversity and Systematics Research on Aplacophora (Mollusca) and Training the Next Generation of Invertebrate Systematists

Aplacophora is an ecologically important and phylogenetically significant clade of worm-shaped marine molluscs. Basic questions about aplacophoran biodiversity and evolution, such as the number of species, evolutionary relationships, and ancestral states of key characters remain unanswered. The number of aplacophoran taxonomists, which has always been small, has declined in recent years. Meanwhile, known but undescribed species and specimens collected in environmental surveys that remain unidentified continue to grow in number. Specimen identification often requires the labor-intensive process of histology, but newer technologies such as micro-CT scanning and DNA barcoding could significantly accelerate this process. I will present on a new project aimed at dramatically accelerating the pace of the study of aplacophoran biodiversity and systematics while training the next generation of malacologists. Specimen identification will employ a novel workflow combining stereo light microscopy, micro-CT, and SEM of whole specimens, DNA barcoding, and compound light microscopy of permanent sclerite mounts - all from the same animal. Goals of this project include identification of thousands of specimens, description of >50 new species, characterization of the faunas of particularly diverse and understudied regions, monographs for select taxa in need of revision, and production of a reference DNA barcode library. Further, the first aplacophoran genomes will be sequenced, enabling target-capture phylogenomics. A well-resolved and broadly sampled phylogenetic framework will make possible a revised classification that accurately reflects the group's evolutionary history as well as ancestral state reconstruction of key traits for Aplacophora, Aculifera, and Mollusca as a whole.

78-3 KOEHL, MAR*; NGUYEN, H; FAUCI, L; University of California, Berkeley, Trinity University, Tulane University; *cnidaria@berkeley.edu*

Effects of Cell Morphology, Attachment to a Surface, and Colony Formation on the Hydrodynamic Performance of Choanoflagellates

Choanoflagellates, eukaryotes that are important predators on bacteria in aquatic ecosystems, share a common ancestor with sponges and are used as a model system to study the evolution of animals from protozoan ancestors. The choanoflagellate *Salpingoeca rosetta*, which has a complex life cycle that includes unicellular and multicellular stages, provides a model system to study within one species the functional consequences of: 1) different cell morphologies (swimming cell with a collar of prey-capturing microvilli surrounding a single flagellum; dispersal-stage cell with a slender body, long flagellum, and short collar), 2) being free-swimming vs. sessile (thecate cell attached to a surface), and 3) being a single cell vs. a multicellular colony. We used high-speed microvideography to measure swimming and feeding currents produced by different life stages, and computational fluid dynamics to study the effects of specific aspects of morphology on the fine-scale hydrodynamics of swimming and feeding. We found that a longer flagellum increases swimming speed, longer microvilli reduce speed, and cell shape only affects speed when the collar is very short. The flux of prey-carrying water into the collar capture zone is greater for swimming than sessile cells, but this advantage decreases with collar size. Stalk length has little effect on flux for sessile cells. Cells tethered to each other in colonies produce faster feeding currents and capture more prey per cell per time than do single cells, but there is a trade-off between feeding performance and predator avoidance because colonies produce larger hydrodynamic signals than do single cells.

140-5 KOLCHENKO, S*; ABDENNUR, N; LOE-MIE, Y; PLESSIER, F; SAUDEMONT, B; FRINTZENWANKER , J; LOWE, C; MIRNY, L; SPITZ, F; MARLOW, H; The University of Chicago and Institut Pasteur, MIT, Institut Pasteur, Institut Pasteur, Stanford University; *kolchenkosergey@gmail.com*

Evolution of Genome 3D organisation in Metazoa

We sought to find how spatial organisation allowed for evolution of increased complexity of gene regulation by comparing the genome 3D organization of species from different clades using chromosome conformation capture techniques. We developed a set of computational tools to identify features associated with TADs and compartments and showed that the characteristic features of loop-extrusion domains are far less prominent in protostomes (such as *Drosophila melanogaster*) than in vertebrates. Accordingly, the drosophila genome appears mostly folded in small compartments, reflecting the nature of the underlying chromatin and transcriptional activity. In contrast, the domains we observed in the hemichordate *S. kowaleskii* and in the lancelet showed features characteristic of loop-extrusion and their boundaries showed significant and strong enrichment for CTCF motifs, indicating that they correspond predominantly to bona fide TADs. Furthermore, by using single-cell RNA-Seq data, we show that in hemichordates, genes located in TADs are more likely co-regulated than genes separated by a TAD boundary. We did not observe such domains in cnidarians, who branched before the evolution of CTCF, or tunicates, such as *Ciona intestinalis*, who has a modified CTCF gene, suggesting that they use different systems for gene regulation. Altogether, our studies underline that the evolution of the 3D genome, and in particular the innovation represented by cohesin-based and CTCF-delimited TADs, may have fueled regulatory innovation by extending the possible genomic space available to store gene regulatory elements.

P1-122 KOLKER GHATAN, M*; BELMAKER, Y; KIFLAWI, M; MEIRI, S; HOLZMAN, R; Tel Aviv University , Ben-Gurion University; *kolkermi@mail.tau.ac.il*

Using a meta-barcoding method for studying population dynamics of larval invasive and native fishes in the Eastern Mediterranean

Accurate species-level identification, along with unbiased quantitative sampling, are the pillars of large-scale community ecology. However, species level enumeration is challenging in planktonic fish larvae, whose species-specific morphologies are often undeveloped, and their identification based on meristic criteria is often impractical. Meanwhile, PCR based identification methods of pooled samples result in biased estimates of species abundance. We present an innovative metabarcoding method for studying population dynamics of fish larvae within the Eastern Mediterranean, a highly disturbed marine habitat, where the number of invasive Indo-Pacific species doubled every 20 years since the beginning of the 20th century. We sampled ichthyoplankton off the Israeli coast monthly during 2018-2019. We sequenced 96 samples containing 5642 larvae using a high-throughput next-generation method, resulting in coverage of the mitochondrial CO1 barcoding gene. We BLASTed CO1 sequences found in our samples against an adult CO1 database containing ~1200 species, including >90% of the native Mediterranean species and the Red Sea species who are likely to have invaded the Mediterranean. We found that the relative fraction of CO1 reads derived from each individual larva was proportional to the relative biomass of that larva from the sample, estimated from silhouette imaging of the sample, and used this relationship to assess the abundance of the species in the sample. This method enables direct species-level identification of the high-volume samples, with robust estimations of species abundances. It thus allows for exploration of species composition and richness as well as identification of invasive species.

89-4 KOLLATH, D/R*; TEIXEIRA, M/M; MILLER, K/J; BRIDGET , B/M; FUNKE, A; Pathogen and Microbiome, Northern Arizona University , University of Brasília Campus Universitário Darcy Ribeiro, Asa Norte, Brasília-DF Brazil, Imaging and Histology Core Facility, Northern Arizona University, Flagstaff, AZ, USA; *drk87@nau.edu*

Investigating the Role of Animal Burrows on the Ecology and Distribution of Coccidioides spp. in Arizona Soils.

The lack of knowledge regarding the ecology of Coccidioides spp. makes both modeling the potential for disease outbreaks and predicting the distribution of the organism in the environment challenging. No single ecological parameter explains the biogeography of the pathogen and the desert mammal association hypothesis has some support, but should be reexamined using modern molecular techniques. Therefore, the ecology and biogeography of Coccidioides spp. in Arizona was assessed by using molecular tools to analyze soils associated with animal activity (i.e. burrows). Soils were collected from locations outside of the established endemic regions to better understand the ecological niche of the organism in this state. Our central hypothesis is that soils taken from within animal burrows will have a higher abundance of Coccidioides spp. when compared to soils not directly associated with animal burrows. Results show that there is a positive relationship with Coccidioides spp. and animal burrows. The organism was detected in two locations in Northern Arizona at sites that are not known previously to harbor the fungus. Moreover, this fungus is able to grow on keratinized tissues (i.e. horse hair). These results provide additional evidence that there is a relationship between Coccidioides spp. and desert animals, which sheds new light on Coccidioides' ecological niche. These results also provide evidence that the geographic range of the organism may be larger than previously thought, and the concept of endemicity should be reevaluated for Coccidioides.

73-1 KOLMANN, MA*; HUGHES, LC; EVANS, K; HUIE, JM; ORTI, G; HERNANDEZ, LP; George Washington University, Brown University, University of Washington; *mkolmann@gmail.com*

Carnivorous grazers? How to build scale-feeding and fin-feeding fishes from less egregious relatives

The tropics are home to some of the most nuanced examples of ecological specialization: from frogs that raise their young in puddles formed on only certain plants (phytotelmata), to fish species that subsist by parasitizing close relatives, some actively mimicking their sister taxa. The tropics are rife with a myriad of animals that parasitize, clean, compete or prey on co-occurring taxa, be they confamilials, conspecifics, or organisms not closely related at all. What, if anything, do these taxa share in common? This is especially clear in Neotropical freshwater fishes, where a notable number of scale-feeding, fin-feeding, and mucus-feeding taxa occur (and some cleaners too). The best examples of these sorts of behaviors occur in the characiform fishes: tetras, payara, tambaqui, and others - otophysan fishes which comprise the vast majority of freshwater fish diversity worldwide. We examined feeding and body shape morphology among diverse Neotropical characiform ectoparasites with micro-computed tomography scanning in order to answer whether there are any traits in particular that are shared among these particularly belligerent fishes. We find that few characters distinguish ectoparasitic fishes from their confamilials - i.e., it appears rather easy to make an ectoparasite in sheep's clothing. However, robust teeth and elongate lower jaws may be important for feeding performance, perhaps for leveraging scales and mucus from prey. Some manner of ectoparasitism has evolved at the family-level at least eight times in characiforms, and some four times within characoids alone. We discuss whether these strategies constitute evolutionary 'dead ends' and why such specialized niches may not beget specialized morphologies.

85-1 KONOW, N*; PANESSITI, C; SCHWARZ, D; BOUVIER, C; MARBELT-RODRIGUEZ, C; HEISS, E; ROSS, CF; RULL, M; UMass Lowell, U. Jena, U. Jena, U. Chicago; *Nicolai_konow@uml.edu*

Food processing across the fish-tetrapod split

Food processing, or cyclic application of dentition-clad surfaces to ingested food, is rhythmic among mammals (grand mean CV; Coefficient of Variation = 15%) and basal bony fishes (25%) and less so among lepidosaurs (lizards and their allies; 53%). This phylogenetic shift in rhythmicity from aquatic-feeding anamniotes to terrestrial amniotes is not readily explained by variation in the proprioceptive capabilities of the jaw closers. However, the shift might be influenced by changes in fluid properties (water to air) as vertebrates move from aquatic to terrestrial chewing. We examine variation in chewing rhythmicity across the fish-tetrapod transition using data from basal actinopterygians (*Polypterus sp.*), lungfishes (*Neoceratodus fosterii*; *Protopterus annectens*), and salamanders (*Ambystoma mexicanum, Siren intermedia, Amphiuma means, Plethodon sp., Ichthyosaura alpestris*, and *Triturus carnifex*). Among ancestral gnathostomes, processing rhythmicity rivals that of mammals (*Polypterus*, CV = 17%) and rhythmicity is generally high in aquatic-feeding sarcopterygians (*Protopterus*, 14%; *Neoceratodus*, 34%). The grand average CV for processing rhythmicity among lissamphibians (28%) is not statistically significantly different from that of other anamniote chewers. However, CV is consistently higher for terrestrialized than aquatic salamander morphs. These data suggest an ancestral state for gnathostomes of high processing rhythmicity, which is somewhat perturbed by transitions to terrestriality. However, to explain the uniquely arrhythmic chewing behavior of lepidosaurs we might need to invoke behavioral attributes, such as inertial food handling.

28-8 KORNEV, K*; APRELEV, P; BRASOVS, A; ADLER, P; BEARD, E; Clemson University; *kkornev@clemson.edu*

Probing viscosity of insect blood at different spatial and time scales

When studying insect biomechanics, it is crucial to understand the materials properties of blood at different time and length scales. Insect blood is a suspension of adherent and non-adherent micron-sized cells suspended in plasma. Even though at the macro-scale the suspension may behave as a single-phase liquid, it has been a long-standing challenge to measure its materials properties at the micro- and nano-scales, where the effects of cells can be significant. Magnetic Rotational Spectroscopy allows one to probe these multi-scale rheological properties in real time. We quantitatively study nucleation of cell aggregates that occurs within fractions of a second. Using larvae of Manduca sexta, we discovered that clot nucleation is a two-step process whereby cell aggregation is the time-limiting step followed by rigidification of the aggregate. Clot nucleation and transformation of viscous blood into a visco-elastic aggregate happens in a few minutes, which is hundreds of times faster than wound plugging and scab formation. In contrast, hemolymph of adult lepidopterans is a Newtonian viscous fluid. Hemolymph of Monarch and Painted lady butterflies and Manduca sexta moth still shows surprises: a threefold difference in viscosity between these species suggests an important physiological implication of hemolymph constituents most likely related to the flight fuel. 1. Aprelev, P., Bruce, T.F., Beard, C.E., Adler, P.H., Kornev, K.G. Nucleation and formation of a primary clot in insect blood, Scientific Reports, 9, 3451(2019)

54-2 KOVACS, JL*; WERREN, J; Spelman College, University of Rochester; *jkovacs@spelman.edu*

Horizontal Gene Transfer as a Mechanism for Convergent Evolution in Arthropods

"How do organisms acquire new traits?" is a central question in evolutionary biology. We know that new traits can arise a number ways including mutations, gene duplications, and chromosomal inversions. We also know that prokaryotes, such as bacteria, can acquire traits from other bacteria or from their environment through a process known as horizontal gene transfer (HGT). These horizontally transferred genes can allow their new host to rapidly adapt to their environment. Until recently, it was thought the HGT happened only in prokaryotes, but multiple cases of functional HGT have been documented in a wide range of eukaryotes, including a variety of arthropod species. We currently have a very limited understanding of how widespread HGT is in eukaryotes and how it has contributed to the evolution and diversification of eukaryotes. The goal of this project is to identify, validate and characterize HGTs in fifteen species of blood-feeding and herbivorous arthropods. We are particularly interested in the role that HGTs play in allowing organisms to exploit new environments, therefore we will pay special attention to HGTs that are shared across multiple species that share a similar ecological niche, but are absent in more closely related arthropods that have a different feeding behavior. We hypothesize that HGT has repeatedly allowed for the independent acquisition of similar novel phenotypic traits in multiple distantly related arthropod species and has allowed for niche invasion and novel resource exploitation in these species. This work will test the prediction that HGTs will be shared by multiple niche-sharing species, either blood-feeders or herbivores, while being absent from more closely relates, but non-niche sharing species.

17-5 KOZMA, MT*; NGO-VU, H; SENATORE, A; BOBKOV, Y; ACHE, BW; DERBY, CD; Georgia State Univ., Univ. of Toronto, Mississauga, Whitney Lab, Univ. of Florida; *mtottempudi1@gsu.edu*

Single Cell Transcriptomics Reveals Expression Patterns of Chemoreceptor Genes in Olfactory Receptor Neurons of the Caribbean Spiny Lobster, Panulirus argus

Crustaceans express several classes of putative chemoreceptor proteins. These include variant ionotropic glutamate receptors (IRs) that have co-receptor IRs and tuning IRs that confer response specificity by forming heterotetrameric ion channels, Transient Receptor Potential (TRP) channels, Gustatory Receptors, and possibly others. The Caribbean spiny lobster, *Panulirus argus*, expresses over 200 IRs, 15 TRP channels from all TRP subfamilies, and 1 GR. However, the combinatorial expression pattern of these proteins in single chemoreceptor cells is not known for this or any crustacean species, limiting our understanding of how crustacean chemoreceptor systems encode chemical quality. We generated and analyzed seven single cell transcriptomes to provide a first view of the expression patterns of chemoreceptor proteins in olfactory receptor neurons (ORNs) in spiny lobsters. We found that all seven single-ORN transcriptomes contained two co-receptor IRs (IR25a, IR93a) and one TRP channel (TRPA1). In addition, single ORNs expressed 1–2 tuning IRs and also TRP channels belonging to subfamilies TRPA, TRPM, and TRPC. Tuning IRs included arthropod-conserved IRs, IR40a and IR75, as well as species-specific IRs. We did not detect two other co-receptor IRs, IR8a or IR76b, in the single-ORN transcriptomes despite their presence in the transcriptome of the olfactory organ. Our results yield an initial view of combinatorial expression of co-receptor IRs, tuning IRs, and TRP channels in ORNs from this decapod crustacean, where ORNs may express different subsets of receptor molecules compared to other types of chemoreceptor neurons.

P2-44 KRAMER, L*; COLLINS, C; GIGNAC, P; O'BRIEN, H; Holland Hall High School, Tulsa, Sacramento State University, California, OSU Center for Health Sciences, Tulsa, OSU Center for Health Sciences, Tulsa; *haley.obrien@okstate.edu*

Convergence can you hear me? A Phylogenetic Comparative Study of the Conductive Hearing Apparatus of Desert-Adapted Rodents

Mammals living in deserts are often considered well-adapted to the unique ecological pressures of their arid environments. Often, these strong selective pressures drive convergent morphological evolution between distantly related and geographically isolated species, such as the large ears of hares and fennec foxes. As bipedal hoppers with long hindlimbs, kangaroo rats (Heteromyidae) and jerboas (Dipodidae) are often discussed as examples of convergence in desert rodents. Such convergence is thought to extend to the auditory apparatus, as enlarged tympanic bullae amplify low-frequency signals used to avoid predators and detect prey. Here, we test for convergence in the conductive auditory system for five species each of heteromyids and dipodids. We use microCT scans and linear measurements to examine trait evolution for external pinna length and tympanic bulla volume. Phylogenetic trait mapping and ancestral character estimation reveal different tradeoffs for each group: bullae are relatively large and pinnae are small in heteromyids, whereas the inverse is seen in dipodids. We then use evolutionary allometry to model the relationship between pinna length vs. ear volume, finding the PGLS regression lines to be orthogonal (m_{jerboa}= -0.178; m_{krat}= 4.58). We therefore reject the hypothesis that the auditory system is broadly convergent in these two groups of desert rodents, instead identifying inverse tradeoffs in the conductive hearing apparatus in response to similar selective pressures.

P3-89 KRANTZ, J*; DALY, M; MACRANDER, J; Florida Southern College, The Ohio State University; *jkrantz@mocs.flsouthern.edu*

Identifying Convergence of ShK Toxins in Sea Anemones

Toxins and other naturally derived products synthesized for predatory defense or prey capture can often be harmful to humans, but in some cases they may also present pharmaceutical potential. One toxin in particular, commonly referred to as ShK, has been isolated from the sea anemone *Stichodactyla helianthus* and is currently being tested to treat multiple sclerosis in humans. The currently existing ShK toxin as well as its analogs are not ideal in their target and treatment, exhibiting some flaws regarding effective transport and binding to the Kv1.3 channels. Toxins containing this domain are ubiquitous across sea anemones as they target potassium ion channels, potentially being used to immobilize prey or deter predators. We hypothesized that there may be variations of the toxin that are naturally produced by other species that may serve as better pharmaceuticals to combat multiple sclerosis or other autoimmune diseases. Our bioinformatic approach has found hundreds of other ShK toxins in other sea anemone species and tested hypotheses regarding ShK evolution by identifying homologous or convergent ShK products. Our results are the first step towards identifying toxin candidates similar to ShK proteins that could combat various types of autoimmune or even neurological diseases.

P3-37 KRATOCHVIL, LB*; SMALL, TW; THOMPSON, RR; Bowdoin College, Brunswick, ME, Oxford College of Emory University, GA; *lbkratoc@bowdoin.edu*

Rapid effects of androgens on olfaction in the zebrafish, Danio rerio

Steroids are molecular messengers that regulate a variety of bodily functions, including behavioral responses to stimuli. Classically, steroids have been thought to act in the body through so-called genomic mechanisms, which can take hours to weeks to influence behavior. More "rapid" non-genomic mechanisms of steroids have since been discovered, which can modulate behaviors in seconds to minutes. However, research surrounding rapid effects of steroids on sensory systems is lacking. We took advantage of the sex pheromone system in zebrafish to investigate rapid effects of androgens on olfactory sensitivity. In goldfish, we have observed that testosterone (T) rapidly modulates the male approach response to the postovulatory pheromone prostaglandin F2α (PGF2α), but the same rapid modulation has not been investigated in male zebrafish, who also approach the pheromone. We pre-treated mature male zebrafish with vehicle, T, or 11-ketotestosterone (11-KT; the most potent androgen in fish brains) for 40 minutes, and then immediately measured their responses to vehicle and then PGF2α being pumped into their tanks. Initial data suggests that T-treated fish spend more time near the pheromone, indicating that T may rapidly modulate this response in zebrafish.

80-3 KRAUSE, JS*; REID, AMA; PEREZ, JH; BISHOP, V; RAMENOFSKY, M; WINGFIELD, JC; MEDDLE, SL; UN Reno and UC Davis, U. Edinburgh, Roslin Institute, Roslin Institute, UC Davis; *jskrause@unr.edu*

The reduction in negative feedback sensitivity underlies seasonal changes in corticosterone in free-living migrant white-crowned sparrows

The CORT-Flexibility Hypothesis proposes that seasonal changes in corticosterone can fine tune the onset of breeding. Circulating corticosterone is mediated by the hypothalamic pituitary adrenal (HPA) axis in response to environmental challenges. Corticosterone is regulated by negative feedback through mineralocorticoid (MR) and glucocorticoid (GR) receptors, although glucocorticoid levels that reach the receptors are regulated by 11β-Hydroxysteroid dehydrogenase (11βHSD1) which reactivates and 11βHSD2 which deactivates the hormone. We sampled plasma corticosterone in free-living male and female migratory white-crowned sparrows (*Zonotrichia leucophrys gambelli*) across their annual cycle and collected tissues during breeding, pre-basic molt, and winter stages to quantify gene expression in the hippocampus, hypothalamus, pituitary, and adrenal gland. Peak corticosterone production occurred during the territoriality and egg laying stages of the annual cycle. GR and MR mRNA expression were downregulated during breeding compared to winter in the hippocampus (not MR), hypothalamus, pituitary, and adrenal gland (not GR). 11βHSD2 mRNA was higher during breeding compared to winter in all tissues except the adrenal gland, and was the only gene to differ between sexes during breeding. While 11βHSD1 mRNA was unaffected by life history stage in any tissue measured. We found no change in mRNA for cholesterol esterase, side chain cleavage enzyme, or steroid acute regulatory protein in the adrenal gland. These data suggest that the seasonal peak in corticosterone is mediated through reductions in negative feedback sensitivity at multiple levels within the HPA axis.

130-3 KRIDER, L; HALSEY, L; YAP, KN; WILLIAMS, TD*; Simon Fraser University, Burnaby, University of Roehampton, UK; *tdwillia@sfu.ca*
Humans Get Fat on Fat Diets, Why Don't Birds?
Obesity is a major issue in modern human societies, in part linked to diet. Humans consuming more calories through eating highly-processed foods or high fat diets gain weight. Although some birds show marked seasonal fluctuations in body (fat) mass, e.g. migrants, many birds appear to tightly regulate body mass and don't get fat. Yet studies on the underlying mechanisms of mass regulation in these non-migrant birds are scarce. We attempted to make captive zebra finches fat by providing them with a high fat diet ad lib for 3 weeks. Birds consumed the high-fat food, and they had elevated plasma triglyceride levels, but there was no associated change in body mass. Birds had mean plasma triglyceride levels ~6-8 mmol/l but three apparently-healthy individuals had triglyceride levels > 60 mmol/l perhaps indicating an interesting "high-fat" phenotype. Body mass was highly variable among individuals, even controlling for structural size, and was highly repeatable at all stages of the experiment. However, birds showed little diurnal variation in body mass, which is common in free-living birds. The only major perturbation of body mass occurred when all birds were blood sampled (-3%), but individual birds returned to pre-sampling mass within 4-5 days, with high repeatability – again suggesting tight regulation of body mass. Zebra finches did show a significant reduction in body mass when exposed to visual and audio cues from a model barn owl – suggesting they retain the potential for ‘strategic' regulation of mass in relation to certain cues (here a predator). Despite their unnatural habitat captive zebra finches might provide an interesting model to explore mechanisms that prevent some birds from getting fat.

56-4 KRIEFALL, NG*; MATZ, MV; KANKE, M; DAVIES, SW; Boston University, UT Austin, Cornell University; *nicfall@bu.edu*
Symbiotic partners diverge across reef environments in a panmictic coral population
Corals from more variable environments tend to fare better under thermal stress when compared to their counterparts from more stable environments. Marine environments exhibiting more or less thermal variability are ubiquitous and even reef zones within the same reef can display divergent thermal profiles. These reef zones offer an opportunity to investigate the role that thermal variability plays in coral resilience and may shed light on how best to manage reefs under climate change. Studies have demonstrated that multiple members of the coral holobiont (the coral host and its associated microorganisms) play a role in a coral's capacity to cope with reef zone differences, however, few studies have contrasted more than two holobiont partners across these environments. Here, we profiled the genetic structure of the coral host, *Acropora hyacinthus*, along with the community compositions of its resident algal symbionts and microbiome from three paired inshore (more variable) and offshore (more stable) reef zones in French Polynesia. 2b-RAD sequencing determined that this broadcast spawning coral exhibited complete panmixia across all reefs regardless of environmental characteristics. In contrast, using ITS2 metabarcoding, we consistently found that algal symbiont communities within offshore corals had higher alpha diversity. In addition, 16S metabarcoding revealed subtle differences in microbiome taxa between reef zones. Our results from investigating this tripartite symbiosis support previous findings suggesting that microbial partners play a role in the ability of their coral hosts to cope with environmental variation. As oceans continue to warm, contrasting how different holobiont partners vary across reef environments may help illuminate coral resilience in a changing world.

P1-159 KRIEG, CA*; GETTY, T; WADE, J; The University of Scranton, Michigan State University, University of Connecticut ; *cara.krieg@scranton.edu*
Sex Differences in Morphology of the Song Control Circuit in House Wrens, a North Temperate Species with Female Song
Bird song has historically been considered a male endeavor. Compared to tropical species where duetting is common, female song in temperate-zone species has been considered rare. In the last decade, however, the number of species with previously undocumented female song has expanded rapidly. In house wrens (*Troglodytes aedon*), females in several North temperate populations sing. Female house wren song structure is highly variable, ranging from a single syllable to songs nearly indistinguishable from male songs. The acquisition and production of bird song is controlled by a series of discrete brain regions that collectively form the song control circuit. We asked whether sexual dimorphism in the song circuit reflects the sexual dimorphism in singing behavior. We caught 18 male and 18 female house wrens from a wild population in Michigan and quantified the volume, cell number, cell density, and average cell (soma) size in three regions of the song control circuit (HVC, RA, Area X). Unlike some species that lack female song entirely, we found regions comparable to the male HVC, RA, and Area X for 94% of the females in the study. For all three regions, the volumes were larger, more cells were present, and the average soma sizes were greater in males than females. For HVC and RA, males also had lower cell densities. In contrast, the nucleus Rotundus (Rt), a visual processing center, showed no sexual dimorphism. This is the first study to examine the song control circuit in either sex in the house wren. Follow-up work will explore whether intrasexual variation in the morphology of song control regions reflects intrasexual variation in song structure.

S6-8 KRISHNAMOORTHY, K; CAPUANO, F; GURKA, R*; BALARAS, E; Coastal Carolina University, University of Naples Federico II, George Washington University; *francesco.capuano@unina.it*
Numerical and experimental study of owls flapping flight
The fluid dynamics of the flapping flight of owls is studied experimentally and numerically. We analyzed a great horned owl, a tawny owl, and a Harris hawk. The latter was chosen to carry out a comparative analysis with the similarly-sized great horned owl. We conducted high-speed, long-duration time-resolved PIV experiments in an open wind tunnel. A perch-to-perch flight style was chosen, and multiple flights were performed for all the birds. High-speed cameras synchronized with the PIV were utilized to capture the kinematics of the birds from different views during flight. The kinematic images display a similar flight path for the three birds, while a comparison of the wake characteristics shows similarities between the two owls and a distinct difference for the hawk in terms of wake flow patterns and turbulence features (intensity and kinetic energy). In conjunction to the experiments, we performed direct numerical simulations (DNS) of the flow generated by an owl in the flapping flight. The wing geometry was extracted from the planform image of the owl wing and a triangulated 3D model was reconstructed. The kinematics were extracted from the trajectories of a set of markers placed along the wing span, which were recorded during the wind tunnel flight. The motion of the markers was transferred to the triangulated surface model by means of an image-registration technique based on the large deformation diffeomorphic metric mapping (LDDMM) framework, allowing alignment of the surface meshes at various phases of the flapping cycle. The derived position and velocity of each point were used as a boundary condition for the computations. The latter were conducted utilizing an immersed boundary (IB) method, which is a cost/efficient approach to conduct DNS with large boundary displacements.

P1-266 KRISHNAN, A*; SINGH, A; FABER HAMMOND, JJ; RENN, SCP; Reed College; *anagkrish@reed.edu*

Effect of Social Stress on Gut Microbiome in Astatotilapia burtoni

The gut microbiome is a community of microbes living within the intestine of a host organism. These microorganisms play important roles in host physiology, metabolism and behavior, yet their community is also sensitive to abiotic, biotic, and social factors in host environments. We use the strong social hierarchies among male *Astatotilapia burtoni* cichlid fish to observe the microbiome response to stressful changes in social rank. Building on previous work in the Renn lab that demonstrated increased beneficial microbes in dominant animals, increased pathogenic microbes in subordinate animals, and an intermediate composition in animals that transitioned in social rank, we present a protocol in which the experimental animals are known to have maintained constant dominant or subordinate ranks prior to the experiment. We increase the sampling frequency to a weekly measure to observe the dynamics of the gut microbiome as animals transition in social rank. We use fecal samples as a non-invasive and repeatable measure of gut microbiome, to allow for tracking this transition over four weeks. Samples were processed for 16S sequencing and analyzed for operational taxonomic units (OTUs), indicating the diversity and distribution of microbial species in an individual. Results will show different OTUs in different experimental fish, according to alpha- and beta-diversity and specific microbial taxa. Furthermore, we can better describe and explain the expected time lag in changes to the microbiome following disruptions in social hierarchies due to controlling for the long term social status of each individual. This link between an organism's microbiome community and highly stressful changes in the organism's environment provides another avenue to explore the possibilities of multi-directional effects between behavior, environment, and physiology and metabolism linked to the gut microbiome community.

S6-7 KRISHNAN, K; BEN-GIDA, H; GUGLIELMO, CG; GURKA, R*; CCU, Technion, UWO; *rgurka@coastal.edu*

Wake Flow Mechanisms and Aerodynamic Forces of Owls During Flapping Flight

The mechanisms associated with the owls' silent flight have been an active scientific research for decades as an inspiration to find solutions for noise reduction applications. Aerodynamic noise generated during flight is associated with the fluid-structure interaction phenomena and the turbulent nature of the flow. When turbulent airflow past the owl wing it is constantly interfered with the wing. During flapping, this interaction results in a more complex three-dimensional unsteady wake. The formed wake is shed downstream and carries the history of the flow affected by the bird. The interaction between the turbulent wake and the wing motion governs the aerodynamic forces acting on the owl and attenuating the noise at the interface region. Understanding the downstream wake-flow dynamics of owl flight can possibly elucidate the aerodynamic mechanisms employed by owls during flight and provide insight to the reduction of the aeroacoustics noise. We focus on the role of turbulence as a noise source and its impact on the aerodynamic performances of owl during flapping flight. We chose three owl species: boobook owl, great horned owl and Tawney owl. The owls were freely flown in a climatic wind tunnel. The wake flow field was measured using long duration high-speed PIV and the owls' kinematics were characterized using high-speed imaging, simultaneously. Large lift and drag variations over the wingbeat cycle were observed, demonstrating the unsteady effects of the flow on lift. The owls' wakes were populated by relatively small turbulence scales. Turbulent energy budgets at the wake depicted high levels of dissipation compared to turbulent production. By estimating the vorticity-strain relations at the wake, we have calculated the pressure gradients at the wake which are proportional to the aerodynamic noise. These appeared to be suppressed, indicating a passive control mechanisms through turbulence dissipation.

P3-231 KRUMM, JL*; SHEA, EK; WOODS, JL; Widener University, Chester, PA, Delaware Museum of Natural History, Wilmington; *jlkrumm@widener.edu*

Integrating Digitized Natural History Collections into Course-based Undergraduate Research Experiences

Undergraduate research in biology is effective in increasing student engagement, retention, and long-term success. Embedding research experiences in biology coursework can increase participation in undergraduate research, especially for minority and first generation college students. To help increase student engagement in undergraduate research, Biological Collections in Ecology and Evolution Network (BCEENET) is developing a community of undergraduate educators, natural history collections experts, education experts, and data experts to support the development and implementation of Course-based Undergraduate Research Experiences (CUREs) using digitized natural history collections. BCEENET will explore how ecology and evolutionary biology classes can mine the hundreds of millions of data records being curated and served on web-based data portals such as iDigBio.org. We will discuss how digitized natural history collections research has been implemented in an upper division biology CURE and opportunities for educators and researchers to get involved in the BCEENET research coordination network.

111-5 KRUPPERT, S*; CHU, F; STEWART, MC; SCHMITZ, L; SUMMERS, AP; Friday Harbor Laboratories, University of Washington, University of Washington, Scripps College, Claremont, Scripps College, Claremont; *skrupp@uw.edu*

En Garde! The poachers' body armor is no show-off but a heavy defensive trait.

Many vertebrates are armored over part or all of their body. The armor can serve several functional roles including defense/protection, offense, visual display, and communication of capability. Different roles imply different tradeoffs, for example defensive armor often trades resistance to attack for maneuverability. The poachers (Agonidae), 47 species of Scorpaeniform fishes, are a useful system for understanding the evolution and function of armor due to their high variety in extent of armoring. We report on an assessment of the amount of mineral in the armor compared to endoskeleton in a diversity of poachers, and an assessment of the damage type in armor across a growth series of one species of poacher. Using publically available CT scan data from 27 species from 16 of 21 genera of poachers we compared the armor to skeletal mineralization for a body region starting at the posterior end of the (first) dorsal fin going two times the body depth. The average material density (a measure of mineralization) of the armor in comparison to the skeleton ranged from 0.77 to 1.17, but the more impressive data is in the total mineralization (volume * average density). In some small, smooth scaled species, like *Aspidophoroides olrikii*, there was 10 times the material expenditure in the armor as in the endoskeleton. With 34 *Agonopsis vulsa* we carefully categorized the extent and type of damage to each of 35+ scales in the eight rows along the body. The ventral rows begin to show abrasive damage along the entire length of the fish. Impact damage to head and tail scales gets more severe and occurs at higher rates with age, suggesting the armor is not just for show.

P2-196 KUBICEK, KM*; BRITZ, R; CONWAY, KW; Texas A&M University, College Station, TX, Natural History Museum, London, UK; *kole_135@tamu.edu*

Ontogeny of the Pectoral-fin Radials in Catfishes

Catfishes (Siluriformes) are characterized by a number of skeletal autapomorphies including the modification of several elements of the pectoral-girdle. In particular, the pectoral-fin radials of catfishes differ markedly from the condition found in other otophysan fishes by possessing fewer proximal radials (2-3 vs. 4), of which one is an enlarged element that is commonly referred to as the "complex" pectoral distal radial. Despite numerous anatomical studies on the skeleton of catfishes, the homology of this element remains unresolved. Additionally, most previous studies have only focused on describing the adult condition, while comprehensive information on ontogeny remains scarce. In order to further our understanding of the identity of the supporting skeletal elements of the pectoral fin in catfishes, we document and describe the earliest stages of pectoral-fin radial formation in cleared and double stained representative siluroid (*Noturus gyrinus* and *Ictalurus punctatus*) and loricarioid (*Megalechis personata*, *Corydoras panda* and *Ancistrus sp*.) catfishes. We also compare the formation of the pectoral-fin radials in these five species to each other and to *Danio rerio* in order to determine homology of these elements.

P3-219 KUDLA, AM*; NIJHOUT, HF; Duke University; *anna.kudla@duke.edu*

Sources of Treehopper Pronotal Variability: An Exploration of Evolutionary Potential in Entylia carinata

Treehoppers (family: Membracidae) are well-known for their impressive pronotal outgrowths that have reached a level of morphological diversity that far exceeds that found in any other insect taxon. Membracid pronota have evolved to look like ants and wasps, leaves, petals, and twigs, and still others do not appear to mimic anything in particular at all. This tremendous diversity of forms may arise from the developmental flexibility of the pronotal tissue, which could lead to an increased evolutionary potential to extend into a novel morphospace. This study investigates the genetic and environmental effects on the size and shape of the *Entylia carinata* pronotum. Specifically, to elucidate the degree to which the *Entylia carinata* pronotum varies, we measured pronotum, wing, leg, and body size of adult treehoppers raised on either a low or high nutrient host plant within a full-sib quantitative genetic experiment. We found that relative to other parts, the pronotum does show a higher degree of variability. Further, within the pronotum, there seem to be at least two developmental modules that vary with relative independence to one another. Our results shed light on the role of host plant quality on pronotal variability and organization, revealing aspects of developmental plasticity that could be the foundation of its diversity in Membracidae.

12-6 KUHN, BF*; SALESA, MJ; MAURICIO, A; ARGANT, A; RANDOPH-QUINNEY, P; KGASI, L; GOMMERY, D; University of Johannesburg, South Africa, Departamento de Paleobiología, Museo Nacional de Ciencias Naturales-CSIC, Madrid, Spain, Aix Marseille Univ, LAMPEA, Aix-en-Provence, France , School of Forensic and Applied Sciences, University of Central Lancanshire, Preston, UK, Hope Research Unit, Plio-Pleistocene Palaeontology Section, Ditsong National Museum of Natural History, Pretoria, South Africa , Hope Research Unit, Plio-Pleistocene Palaeontology Section, Ditsong National Museum of Natural History, Pretoria, South Africa and Palaeo-Research Institute, University of Johannesburg, South Africa and Sorbonne Université, Paris, France ; *kuhnbf@gmail.com*

Evidence for an African Cave Lion (Panthera sp): Multiple Panthera individuals from Bridge Cave, Bolt's Farm, South Africa

Recent excavations at the Bridge Cave location within the Bolt's Farm system have yielded an unprecedented number of Pantherine fossils. To date in excess of 1600 fossils have been recovered from the constrained deposit which measures 1.5 meters across, half a meter high and half a meter deep. Of these fossils, over 600 have been attributed to Panthera. With examples of nearly every bone in the body recovered, and multiples of many elements, we can say with confidence that we have at least eight individuals represented in this assemblage. These individuals are made up of six adult male African lion (Panthera leo) size individuals, a seventh individual noticeably larger than these and a very young juvenile. Taphonomy suggests that a latrine was present inside the cave, lending support for the theory that these 'lions' were in fact denning inside of the cave. Other recovered fauna includes mega fauna such as Equus capensis, Phacochoerus modestus, Metridiochoerus andrewsi and class five bovid remains. The presence of Phacochoerus modestus as well as Metridiochoerus andrewsi indicates an age of approximately 1.8 million years.

32-8 KUNKEL, E L*; DALE, A S; FULLER, N W; MCGUIRE, L P; Texas Tech University, Lubbock, TX; *Emma.Kunkel@ttu.edu*

Partial Migration in Mexican free-tailed Bats: Ecology and Bioenergetics of Winter Residents

Migration evolves when the benefits of migrating outweigh the costs of remaining sedentary. However, migration is a characteristic of individuals and the costs and benefits of migration can vary among individuals. Such variation can result in partial migration where some individuals migrate and others forego migration. Previous investigations of partial migration have focused on homeothermic species where costs of foregoing migration are driven primarily by energy availability. However, heterothermic species can reduce energy expenditure in response to varying energy availability. We investigated the energetic strategies of Mexican free-tailed bats overwintering in Texas. We hypothesized overwintering bats would exhibit flexibility in maintaining energy balance by maximizing energy intake via foraging on warmer nights and reducing energy expenditure by decreasing activity and using torpor while inactive, with multi-day torpor bouts during longer periods of harsh weather. We regularly captured bats between September 2018-May 2019 and measured plasma triglyceride concentration of 137 individuals and deployed an acoustic monitor to continuously record bat activity. In February 2019 we attached temperature-sensitive radiotransmitters to 30 bats to continuously record their skin temperature. Bat activity was strongly affected by weather, with reduced activity on colder nights. Bats regularly used torpor during the day and were able to extend torpor bouts over multiple days during extended periods of harsh weather. Surprisingly, plasma triglyceride levels were extremely low during all winter capture events indicating bats rarely forage during winter. These sub-tropical mammals withstand winter via regular torpor use but despite being active do not capitalize on winter foraging opportunities.

P1-29 KYLE, OM*; GIBB, AC; MINICOZZI, MR; BRAGA, A; Northern Arizona University ; *omk22@nau.edu*

Can Air Breathing Ability in Teleost Fishes be Used to Predict Terrestrial Behavior?

Terrestrial locomotion is a common behavior observed in littoral fishes that can be used to avoid predation or move between aquatic habitats. When stranded, some fishes are capable of producing a coordinated, stereotyped behavior, termed the tail-flip jump, while others "flop" and fail to produce directed movements We conducted stranding trials in which individuals representing seven species of teleost fish were artificially stranded on a damp substrate on land. Following stranding, we filmed the behavioral response for two minutes. Based on the jump distance produced by the fish (relative to body length) and how often they moved during the two minutes, fish were categorized as effective (long jumps) vs. ineffective (short "flops") and active (many movements) vs. inactive (few movements). Following the stranding trials, individuals representing these species were then placed respirometer to measure their terrestrial oxygen consumption and carbon dioxide production. Somewhat surprisingly, that the ability to breathe air did not predict jumping performance (as quantified by jump distance). However, fishes that cannot respire air are more active while stranded (that is, they produce more frequent movements) on land, while fishes that can respire air are relatively inactive while stranded. These findings suggest that the ability to breathe air is not related to terrestrial locomotor performance and is likely not required for the evolution of terrestriality in many lineages.

P3-60 L'ECUYER, Z*; SHARP, S; TODD, K; Westminster College, Salt Lake City Utah; *zml0219@westminstercollege.edu*

Hormonal circuits responsible for reproductive behavior

A long standing hypothesis in neuroscience assumes that closely related species that perform identical behaviors are thought to also share the same neural circuits to produce said behavior. However, recent research in the leech species Hirudo verbana and Macrobdella decora has shown that despite showing the same reproductive behaviors, their neural connections may differ. During reproductive behavior, electrophysiology was previously used to show that motor neuron patterns between the two closely related annelids, Hirudo verbana and Macrobdella decora were significantly different. The identical behaviors appear to be induced by an oxytocin/vasopressin analog synthesized in the two Leydig cells within each ganglion. We have found this hormone analog in both species by using immunohistochemical staining, and in intact animals, injection with the hormone analog has been shown to induce reproductive behavior. The progression of reproductive behaviors was then quantitatively shown to be identical through behavioral assays. The potential differences in neural connectivity and circuit organization will be further explored by using intracellular and extracellular electrophysiology on the Leydig cells. The electrophysiology assays will be performed on Macrobdella decora and compared to data previously collected on Hirudo verbana. The results are expected to show potentially different number of spikes, latencies, or patterns between the two species.

134-5 LABONTE, D; Imperial College London; *d.labonte@imperial.ac.uk*

Dynamic biological adhesion: mechanisms for controlling attachment during locomotion

The rapid control of surface attachment is a key feature of natural adhesive systems used for locomotion, and a property highly desirable for man-made adhesives. Here, we describe the challenges of adhesion control and the timescales involved across diverse biological attachment systems and different adhesive mechanisms. The most widespread control principle for dynamic surface attachment in climbing animals is that adhesion is `shear-sensitive' (directional): pulling adhesive pads towards the body results in strong attachment, whereas pushing them away from it leads to easy detachment, providing a rapid mechanical `switch'. Shear-sensitivity is based on changes of contact area and adhesive strength, which in turn arise from non-adhesive default positions, the mechanics of peeling, pad sliding, and the targeted storage and controlled release of elastic strain energy. The control of adhesion via shear forces is deeply integrated with the climbing animals' anatomy and locomotion, and involves both active neuromuscular control, and rapid passive responses of sophisticated mechanical systems. The resulting dynamic adhesive systems are robust, reliable, versatile and nevertheless remarkably simple.

P3-6 LACY, BD*; RAHMAN, MS; RAHMAN, MS; University of Texas Rio Grande Valley; *brittney.lacy01@utrgv.edu*

Interactive Effects of Heat Stress and Pesticide Co-exposure on Osmoregulation and Antioxidant System in Gill and Kidney of Goldfish

Aquatic ecosystems are becoming increasingly inundated by noxious chemicals, such as pesticides, through human activities. These chemicals combined with other stressors like heat stress (through global climate change, heat pollution, or natural seasonal variation) create volatile environments that negatively affect the physiological functions of aquatic organisms. Through this research, we observed the dose-dependent effects of pesticide cocktail combined with elevated temperatures (32°C for 1-month exposure) on morphology of gills and kidneys, and expression of catalase (CAT, an antioxidant), superoxidase dismutase (SOD, an antioxidant), and renin in kidney tissues of goldfish (*Carassius auratus*, a model teleost species). Histopathological analysis showed wide-spread damage to both gill and kidney tissues in higher temperature and pesticide co-exposure groups, including extensive fusion of secondary lamellae, club-shaped primary lamellae, rupture of epithelial layer, loss of normal architecture, glomerular shrinkage, hemorrhaging, and degeneration of tubular epithelium. Immunohistochemical analysis demonstrated a decrease of CAT and SOD expressions in kidney tissues in combined exposure to pesticide and higher temperature compared to control (22°C). Expression of renin in kidney tissues was also altered with varying doses of pesticides and elevated temperature. Collectively, our results suggest that the combined effects of heat stress and pesticides cause cellular damages, as well as down-regulate the osmoregulatory and antioxidant enzyme activities in gill and kidney tissues of common goldfish.

135-6 LAD, SE*; CORTESE, SA; DANISON, AD; RAVOSA, MJ; University of Notre Dame, Notre Dame, IN, College of Wooster, Wooster, OH; *slad@nd.edu*

Bone Remodeling and Cyclical Loading in the Maxilla of White Rabbits (Oryctolagus cuniculus)

Processing mechanically challenging (e.g., tough or stiff) foods alters feeding behaviors in mammals, requiring larger bite forces or prolonged mastication. The bony response to high bite forces in the mammalian skull is well known, but osteogenesis due to protracted chewing (i.e., cyclical loading) is more poorly understood. Prior studies indicate greater bone formation in mandibles of rabbits raised on mechanically challenging foods, and a stronger link between bone remodeling and cyclical loading vs. high-magnitude strains. Here we assess the relationship between cyclical loading and remodeling, the repair of microdamage due to mechanical deformation and fatigue loading. Ten male white rabbits (*Oryctolagus cuniculus*) were obtained at weaning (4 weeks) and raised on one of two diets until mature (52 weeks). Five subjects ate pellets (E=29Mpa, R=1031Jm^{-2}), and the other five processed pellets and hay (E=3336Mpa, R=2760Jm^{-2}). Mastication of hay results in higher chewing investment (475 vs. 161 chews/g) and prolonged chewing duration (568 vs. 173 sec/g). Remodeling was measured as osteon population density (OPD) and percent Haversian bone (%HAV) in 100μm coronal sections of left maxillae between P2 and P3. An outlier was excluded from analysis due to sectioning error. Mean OPD and %HAV were greater in the hay group, but Mann-Whitney U tests revealed no significant difference between treatments (P=0.111, both). This finding suggests that elevated cyclical loading does not result in greater remodeling in rabbit maxillae. Future analyses will examine additional subjects as well as other cranial sites to more fully characterize mechanisms of adaptive plasticity in bone quantity and quality.

S11-3 LADAGE, LD; Penn State Altoona; *ldl18@psu.edu*

Reptiles: an evolutionarily important link in comparative cognition and neurobiology

In the 1960's, MacLean's concept of the triune brain and its coevolution with cognitive abilities embedded itself into the fabric of psychology and the minds of the general public. For decades, it was assumed that reptiles possessed little to no complex cognitive abilities, with a brain that subserved basic survival functions. While the triune brain model has since been discredited, the bias has been subtly perpetuated, despite reptiles engaging in a diverse repertoire of behaviors including extraordinary navigational feats, social learning, and higher cognitive learning abilities. To determine if these behaviors are indeed cognitively-based requires an ecologically-relevant testing paradigm; correlating these behaviors with the neural architecture typically associated with cognitive abilities lends further support that these behaviors have a cognitive basis. In fact, recent studies have demonstrated that many of the reptilian behaviors that appear to require complex cognitive abilities are associated with areas of the brain that are homologous to those underlying complex cognitive processing in mammals (e.g., the hippocampus). Thus, reptiles represent a relatively understudied yet evolutionarily important group in comparative cognition. Examining the cognitive basis of reptilian behaviors as well as the neural underpinnings underlying those behaviors illuminates the evolutionary trajectory of cognition and the functional and structural similarities and dissimilarities between the reptilian and mammalian brain.

P1-221 LAMMERS, AR*; GOULD, FDH; DING, P; GERMAN, RZ; Cleveland State University, Cleveland, OH, Rowan University, Stratford, NJ, John Hopkins University, Baltimore, MD, Northeast Ohio Medical University, Rootstown, OH; *a.Lammers13@csuohio.edu*

Hyoid kinematics during swallowing: effects of different vagus nerve lesions in infant pigs

Swallowing is an important and complex activity, requiring precise coordination between sensory fields, muscles, and bony and cartilaginous structures. When mammals swallow, coordinated muscles move the hyoid bone anteriorly and dorsally. This movement, which occurs just before or early during the swallow, is one way that the airway is protected from penetration by or aspiration of a bolus. Furthermore, the hyoid movement opens the esophagus, lowering the air pressure and drawing the bolus into it. We examined the kinematics of the hyoid in nine infant pigs. Animals drank milk mixed with contrast agent while fluoroscopy allowed visualization of hyoid position and movement. Then, during aseptic surgery, we located and transected either the right-side superior laryngeal nerve or recurrent laryngeal nerve. We digitized the hyoid and other structures, and also scored the extent to which the airway was protected from bolus penetration or aspiration. The effect of nerve transection on the distance traveled by the hyoid was significant (p=0.01). However, the effects were different between the superior laryngeal and recurrent laryngeal nerves. Hyoid speed was not affected by any treatments. Airway protection was worse after the nerve transection, regardless of which type. However, hyoid travel distance or speed did not differ with airway safety. We conclude that protection of the airway is a multifaceted phenomenon, and that other factors such as bolus velocity and closure of laryngeal valves are also important. Control of hyoid movement is influenced by multiple nerves, either directly through innervation of muscles that attached to the hyoid, or indirectly via vagus and other cranial nerves that interconnect in the brainstem.

S2-3 LANCASTER, LT*; MCCAW, B; ARESHI, S; LEONARD, A; MOORE, B; STEVENSON, TJ; University of Aberdeen, Aberdeen, United Kingdom, University of Glasgow, Glasgow, United Kingdom; *lesleylancaster@abdn.ac.uk*

Epigenetic effects on thermal tolerance and resource use shifts in insects, with implications for range shift potential and life history syndromes

Many species are shifting and expanding their geographic ranges under anthropogenic environmental change. These expanding species include native species which are taking advantage of warming climates to settle in previously inhospitable areas beyond their previous range margins, and invasive pest species which are rapidly colonizing novel industrial / agricultural landscapes. Many studies now show that as these colonizing species shift to new regions, they also adapt very rapidly to novel climate and resource conditions encountered there. Such rapid adaptation presents somewhat of an evolutionary paradox, as genetic variation is often depleted during colonization events. In this talk I will present recent work done by my group on how epigenetic mechanisms contribute to rapid life history transitions, resource use shifts, and rapid thermal adaptations within two insect study systems, the seed beetle *Callosobruchus maculatus* (an expanding global pest on stored legumes), and the damselfly *Ischnura elegans* (which is rapidly expanding northward its native range in Europe under warming climates). The presented studies explore the role of DNA methylation in rapid adaptation to novel niches, but also highlight a central role of epigenetic mechanisms in shaping life history syndromes. The results are discussed in light of wider concepts of niche conservatism and life history theory.

P3-53 LANE, ZM*; DARNELL, MZ; The University of Southern Mississippi; *zachary.lane@usm.edu*

A Home Worth Fighting For: Burrows as a Thermoregulatory Resource in the Fiddler Crab Uca pugilator

In the face of climate change, adaptability and plasticity of thermoregulatory traits may determine whether a species survives long term. Although thermoregulation is largely a physiological phenomenon in many endothermic species, for many ectotherms the maintenance of body temperatures between their critical thermal maximum and minimum is achieved through a complex suite of behaviors. The fiddler crab *Uca pugilator* lives on sandy beaches and on tidally influenced sandflats within marshes from the Caribbean to the northeastern coasts of the United States, and during the summer months the daily temperatures experienced by *U. pugilator* in these habitats can well exceed its critical thermal maximum. Despite this fact, *U. pugilator* retains high fitness throughout its habitat range via thermoregulatory behaviors, many of which center around building, maintaining, owning, and retreating into their sandy burrows. This study focuses on burrows as a thermoregulatory resource in *U. pugilator*, addressing several questions concerning burrows and borrow-ownership. A survey of burrow metrics along the east coast of the United States from New York to Florida has recently been conducted to quantify changes in burrow size and shape that may be correlated with temperature variation across this latitudinal gradient. Additionally, the DNA of cohabitating males and females and those females's offspring will be sequenced and paternity analyses will be performed to better understand how mated pairs share or do not share burrows. In the future, the time, effort, and thermal stress associated with burrow building and maintenance will be assessed via controlled field experiments to shed light on the costs of burrow ownership as well as the antagonistic interactions observed between males in *U. pugilator* and may other fiddler crabs species.

69-5 LANE, S/J*; EMMERSON, M/G; VANDIEST, I/J; HUCUL, C; BECK, M/L; DAVIES, S; GILBERT, E/R; SEWALL, K/B; Virginia Tech, Rivier University, Quinnipiac University; *samjl89@vt.edu*

Urbanization lowers hippocampal glucocorticoid receptor expression but not clearance of glucocorticoids in male Song Sparrows.

Individuals in urban habitats experience frequent disturbances and are expected to respond efficiently and recover quickly from challenges to persist in these habitats. The glucocorticoid (GC) stress response is a physiological response to a stressor during which GC concentration increases in order to activate behavioral and physiological mechanisms to recover homeostasis. Differences in the duration of GC secretion are modulated by the efficiency of negative feedback mechanisms, which is achieved primarily through the binding of glucocorticoid receptors (GRs) in the hippocampus by GC's. Efficient termination of the GC stress response could protect birds in urban habitats from chronic GC exposure. We investigated if male song sparrows (*Melospiza melodia*) in urban habitats show more efficient negative feedback of the GC stress response than their rural counterparts. Song sparrows from each habitat were exposed to restraint stress to increase corticosterone (CORT), the primary avian GC, then injected with either saline or a synthetic GC (dexamethasone, DEX), to induce a negative feedback response. Additionally, we quantified GR mRNA in the hippocampus using qPCR in a separate cohort of birds. Our results show that DEX suppressed CORT concentration below that of saline, but no habitat differences in response to DEX were detected. Urban song sparrows did have lower hippocampal mRNA levels of GR than rural song sparrows. Urbanization therefore does not affect the GC stress response, but can cause structural changes in the hippocampus, the functional effects of which remain to be elucidated.

P2-192 LANG, KL*; GIFFORD, ME; University of Central Arkansas; *klang2@cub.uca.edu*

Multivariate analyses of performance tradeoffs and phenotypic integration in the prairie lizard (Sceloporus consobrinus)

Natural selection acts on phenotypic variation within a population. Phenotypes are highly integrated, so selection for or against a trait can indirectly select for or against integrated traits. Integration of physiological and morphological traits results in and constrains performance traits in animals. Since performance forms an interface between the animal and its environment, it is ecologically relevant and can be under direct selection. Knowing how the physiology and morphology of an animal integrate to form a performance trait is critical to understand how selection works in that animal. Investment in one performance trait can lead to decreased performance elsewhere, a tradeoff. Variation among these traits can provide insight into how selection has worked in the past. Phenotypic variation exists at multiple levels of organization, and studying variation at multiple levels (within organisms, within populations, between populations) can reveal relationships which could be overlooked if only analyzed at one of these levels. For this study, we captured prairie lizards (*Sceloporus consobrinus*) from sites in central Arkansas and southern Missouri. We took repeated laboratory measurements of morphological, physiological, and performance traits associated with locomotion on each animal to account for variation both within and among the lizards. We analyzed the data using multivariate mixed-effects models, which allowed us to identify any correlations or tradeoffs that exist between traits both within and among individuals and whether relationships that existed within individuals were masked when studied in the population. This study will lay the groundwork for future research on how these traits are actively selected in the field.

P3-184 LANGAGER, MM*; HAWLEY, DM; Virginia Tech; *mlangager42@vt.edu*

Effects of Mycoplasma gallisepticum infection on juvenile sociality in house finches (Haemorhous mexicanus)

Acute pathogen infections are energetically demanding events that can induce substantial behavioral changes within hosts and thus influence pathogen spread. To date, few studies of vertebrates have examined how infection with a directly-transmitted pathogen influences host sociality. Juvenile house finches are highly gregarious after reaching nutritional independence, forming large feeding flocks. In part due to this sociality, juveniles are particularly susceptible to infection by the bacterial pathogen *Mycoplasma gallisepticum* (MG). Therefore, any changes in sociality during active infection are likely to have consequences for the transmission of disease throughout these majority-juvenile flocks. However, it remains unknown how infection early in the juvenile stage (<3 months post-hatch) influences behavior and sociality in house finches. To test this, we inoculated 33 wild-caught juvenile house finches with MG or media alone (sham control) within 3 months post-hatch. At the peak of infection, all birds were run through a modified partner choice assay, where they were given the choice to feed and perch adjacent to a small flock or alone. Preliminary data from a subset of house finches suggest that they show heterogeneity in their behavioral preference which relates to the severity of MG-induced disease. Birds with more severe disease exhibited the lethargy seen in prior studies of MG-infected adults, and thus these birds appeared indifferent to flock presence or absence. In contrast, individuals with less severe disease appear to preferentially feed or perch near the flock. Our results have important implications for the spread of MG among hatch-year birds, which make up the largest proportion of both infected and susceptible hosts in natural populations.

27-5 LANZA, AR*; SEAVER, EC; Whitney Laboratory for Marine Bioscience, University of Florida; *alexislanza@gmail.com*
Activin/Nodal signaling is required for establishing the dorsal-ventral axis in Capitella teleta
TGF-beta 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. The spiralians are a large bilaterian clade that exhibit enormous body plan diversity. Members of this superclade share a highly stereotypic early development program called spiral cleavage, and signals emanating from single cells during early cleavages are critical for patterning the dorsal-ventral body axis. Studies in the mollusks *Crassostrea gigas* and *Tritia obsolete*, as well as the annelid *Helobdella robusta* have suggested the BMP pathway plays a crucial role in dorsal-ventral axis patterning. However, previous pharmacological inhibition studies in the annelid *Capitella teleta* suggests that signaling via the ALK4/5/7 receptor, an Activin/Nodal pathway receptor, patterns the dorsal-ventral axis. In this study, we further determine the role of the Activin/Nodal pathway as it functions in *C. teleta* axis patterning. Antisense morpholino oligonucleotides were designed to target *Ct-Smad2/3* and *Ct-Smad1/5/8*, receptor signal transducers specific to the Activin/Nodal and BMP pathways, respectively. Morphants were raised to larval stages and scored for phenotypic anomalies in body axes formation. Our findings confirm that axial patterning in *C. teleta* occurs at the 16 cell stage, 1-2 cleavage divisions before their spiralian counter parts, the mollusks, and utilizes the Activin/Nodal branch of the TGF-beta superfamily, but not the BMP pathway. Furthermore, these findings highlight an important molecular difference in the induction of axes between annelids and mollusks.

84-6 LAPSANSKY, AB*; TOBALSKE, BW; University of Montana; *anthony.lapsansky@umontana.edu*
The biomechanics of multi-functional wings in diving birds
While water and air are fundamentally different media, diverse species locomote effectively in both. As a prominent example, 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. During aquatic flight, these species flex the wrist and elbow joints of their wings, substantially reducing the effective span and area of their wings relative to in aerial flight. To elucidate the function of this behavior, we investigated the aero- and hydrodynamic performance of the flexed and extended wing postures on pairs of wings from ten common murres (*Uria aalge*). We used a propeller model to emulate flapping in air and water and a wind tunnel to emulate gliding. We hypothesized that the flexed posture would produce greater ratios of vertical-to-horizontal force (an efficiency metric) across all conditions, but that the total vertical force produced by this posture would be insufficient for weight support. During emulated gliding, flexed wings did achieve greater ratios of vertical-to-horizontal force when all angles of attack (0-60 deg) were considered. However, during emulated flapping, extended wings achieved greater ratios of vertical-to-horizontal force and greater coefficients of vertical force at both aerial and aquatic Reynolds numbers. Extended wings produced 1.5-6X more vertical force than flexed wings, but even extended wings were insufficient for weight support -- consistent with the poor slow-flight performance of murres. It is therefore unclear why birds use a flexed wing during flapping of aquatic flight. Perhaps steady-state models fail to capture the performance of the flexed-wing posture or the use of a flexed wing for aquatic flight is compulsory due to limitations on factors outside of propulsor shape (e.g. structural or muscular constraints). (NSF IOS 1838688).

82-5 LARK, R; SHARABI, L; LEVY, O*; Tel Aviv University, Israel; *levyofi@gmail.com*
The use of remote sensing and models to understand behavioral thermoregulation in dogs
Behavioral thermoregulation is crucial for avoiding thermal stress. Hence, understanding when and how animals might utilize microhabitats for thermoregulation may enable a better risk assessment and conservation planning for animals. However, data on animal location are usually analyzed based on topography, land cover, and other biotic factors, while ignoring microclimate conditions, which may have substantial importance for thermoregulation. Here we integrated microclimate modeling and empirical observations to study how the movement patterns of a searching mammal are affected by thermal conditions, using search-trained dogs as our model animal. In particular, we used GPS tracking to measure how microclimate conditions affected the movement of dogs during their training sessions in a natural forest with nearly 50% vegetation cover, and analyzed the dogs' selection of particular microclimates. To estimate microclimates in the study area, we developed a model that calculates ground temperatures based on meteorological variables obtained from a weather station, the topography and land-cover of the area obtained from a drone. To validate the model, we also used the drone to map the ground temperature under different weather conditions. Interestingly, we found that the dogs' thermoregulation efforts varied between movement and standing. In particular, dogs did not show a preference for a particular microhabitat during movement, but often chose a cooler microhabitat when standing. Our findings highlight the importance of movement analysis and microclimatic mapping when seeking to understand the thermoregulation behavior of animals.

P1-5 LAROCCA-STRAVALLE, Z; KAUFFMAN, J; GILLEN, K*; Kenyon College; *gillenk@kenyon.edu*
Labial A and Post-1 Hox Gene Expression in Lumbriculus variegatus
Hox genes encode transcription factors that help specify anterior-posterior positional information during animal development. They are also expressed in adult and regenerating tissues (Barucca et al., 2016). Among animals, many annelids show remarkable regenerative abilities. The annelid *Lumbriculus variegatus* demonstrates posterior and anterior regeneration, involving both epimorphosis and morphallaxis (Özpolat and Bely, 2016), but the expression of Hox genes during *L. variegatus* regeneration has not been reported. To provide context for Hox expression patterns in regenerating tissue, we first analyzed expression in non-regenerating tissue. Here we present the expression pattern of two Hox genes, Labial A and Post-1, in anterior and posterior portions of mature *L. variegatus* (clade I). After determining that either 18s rRNA or actin are acceptable housekeeping genes for our qRT-PCR studies, we found that the labial A and Post-1 Hox gene mRNAs are found in both anterior and posterior regions of bisected *L. variegatus*. Researchers have noted the utility of studying the development of annelid segment formation (Kuo and Lai, 2019; Balavoine, 2014) and Hox gene expression (Barucca et al., 2016) in a wide variety of taxa. To our knowledge this is the first report of Hox gene expression patterns in the Lumbriculidae family of annelids.

42-2 LAROUCHE, O*; FRIEDMAN, ST; CORN, KA; MARTINEZ, CM; WAINWRIGHT, PC; PRICE, SA; Clemson University, University of California, Davis; *olivierlarouche7@hotmail.com*

Does Habitat Complexity Affect the Direction of Body Shape Evolution in Marine Fishes?

Marine habitats vary widely in structure, from incredibly complex coral reefs through to less complex deep water and open ocean habitats. Hydromechanical models suggest that optimal morphologies differ between these habitats. Simple habitats are predicted to select for sustained efficient swimming, which can be achieved by fusiform body shapes. In contrast, complex habitats are predicted to select for maneuverability, which can be achieved by deep-bodied and laterally compressed forms. To look for a signature of these processes at a broad macroevolutionary scale, we tested for differences in body shapes between fishes living in complex and more simple habitats. We quantified body shapes across 3658 species of ray-finned fishes using a series of linear measurements informative to swimming kinematics. We scored each species for whether they lived in reefs, the most complex marine habitat, or not and tested for morphological differences in a phylogenetic framework. Our results confirmed significant overall shape differences between fishes living in complex and less complex marine habitats. Consistent with our predictions, reef species have on average deeper bodies, lower fineness ratios and higher depth/width ratios, while non-reef species are more streamlined with more tapering tails. Despite the numerous evolutionary forces that may influence body shapes at such a broad macroevolutionary scale, our results support the expected morphological differences predicted from hydromechanical models of swimming kinematics.

P3-110 LARSON, A M*; KANATOUS, S B; Colorado State University; *spashley@rams.colostate.edu*

Temporal Examination of Myoglobin and Myosin Heavy Chain Expression Patterns in Skeletal Muscle Cells

Myoglobin is a hemoprotein expressed in vertebrate muscle that has been shown to ameliorate the effects of tissue ischemia experienced by mammalian divers during diving. Typically, myoglobin expression is known to follow 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 changes in myoglobin expression without a change in fiber type. This indicates that myoglobin expression may not always be fiber type dependent and could be regulated by different stimulatory pathways. Our lab has shown that mixed lipid supplements, and hypoxia coupled with muscle contraction 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, hypoxia, and/or caffeine to stimulate contraction. Cells were then harvested each day after differentiation initiation. Western blots were conducted to determine the expression of myoglobin and various myosin heavy chains. With these methods, we have found myoglobin expression prior to that of myosin heavy chain I and IIA. This data reveals conditions under which there are pathways to myoglobin expression independent from slow fiber type expression. Examination of alternate routes of myoglobin expression that are independent of fiber type could yield potential therapeutic benefits to combat ischemic diseases seen in humans and animals.

P1-73 LARSON, TR*; JACOBS, JL; SMITH, EN; University of Texas at Arlington; *thornton.larson@mavs.uta.edu*

Sexual dimorphism in the fanged-frog genus Limnonectes (Anura: Dicroglossidae): skull differences between males and females

In the fanged-frog genus *Limnonectes*, males are larger than females at maturity, with the size discrepancy accredited to their large heads. Big headedness is often attributed to sexual selection arising from male-male fighting for appropriate egg laying habitat, that attracts more females to it. Intrasexual selection driven sexual dimorphism in amphibians has contributed to the hyper diversity of frogs found in tropical regions. Previous morphological descriptions are focused on species level descriptions, demonstrating that skull morphology can differentiate between *Limnonectes* species, further attributed to differences in mating behavior of species in the genus. However, no osteological description currently exists between male and female individuals within a species. Our goal is to identify differences in the skull morphology between males and females in Sumatran *Limnonectes kuhlii*, through the study of high-resolution computed microtomography (CT) scans of skulls. Three-dimensional geometric morphometric analyses were used to quantify the variation between males and females using fixed landmarks. Our findings show a suite of sexually dimorphic traits in skull morphology, some likely related to male-male combat. Specific trends in skull sexual dimorphism may be species specific and we also highlight environmental drivers of speciation within the genus.

79-6 LASALA, JA*; HUGHES, C; WYNEKEN, J; Florida Atlantic University; *jlasala321@gmail.com*

Leatherback Turtle Breeding Sex Ratios are 1:1

As temperatures increase, marine turtles are at risk of a feminization skew within populations due to temperature dependent sex determination. While hatchling sex ratios can be estimated because they are accessible, adult sex ratios remain unknown because breeding females and males are not equally accessible. A functional metric is the breeding sex ratio (BSR), which is estimated from maternal sampling and paternity of clutch samples. Previous estimates of BSR for leatherback turtles (*Dermochelys coriacea*) nesting along Florida's southeastern coast, were not significantly different than 1:1. This estimate did not account for females laying multiple nests per season or that they might may mate between nesting events. We reassess the 1:1 adult sex ratio estimate by analyzing samples from turtles that returned to nest multiple times (2016-2019). We sampled 27 different returning females and a subset of their subsequent nests (n=62 , 760 hatchlings). Females typically did not mate between clutches. Of the females that mated with multiple males, loss of sperm contributions across time was detected. We confirm that females mate at the beginning of the breeding season, and likely do not mate between nests. In Florida, the 1:1 BSR was supported. This leatherback population appears to be decreasing, hence characterizing the mating system is important to population structure now, before extreme environmental effects are evident.

80-1 LATTIN, CR*; KELLY, TR; Louisiana State University, Baton Rouge, LA; *christinelattin@lsu.edu*
Method matters: Considerations for calculating glucocorticoid negative feedback
Because of its critical role in reducing glucocorticoids after exposure to stressors, many researchers have become increasingly interested in assessing hypothalamic-pituitary-adrenal (HPA) negative feedback. Although assessing negative feedback in a standardized way using injections of the synthetic glucocorticoid dexamethasone is a straightforward procedure, there are several defensible ways to quantify negative feedback efficacy, each of which incorporates various aspects of HPA physiology. Here, we report seven different methods for reporting HPA negative feedback and their prevalence in the comparative endocrinology literature, and reanalyze a dataset of wild house sparrows (*Passer domesticus*; n=58) caught during six different times of year to show that even though most of these approaches give values that are correlated with each other, they yield distinct (and even opposing) statistical results. Because the approach used to quantify negative feedback matters so much for the end results, we encourage researchers to converge on a common method for reporting HPA negative feedback, report multiple measures, or at the very least, make their raw data available so alternative measures can be calculated. We also advise caution in comparing results among studies using different approaches to assess HPA negative feedback.

P3-205 LAU, E*; OAKLEY, TH; University of California, Santa Barbara; *emily.lau@lifesci.ucsb.edu*
A light meal: dietary acquisition and metabolism of bioluminescent compounds in the midshipman fishes
Many organisms acquire, sequester, and use necessary biological molecules from their diet that they cannot produce themselves. Numerous bioluminescent organisms rely on dietary acquisition of substrates for bioluminescence, called luciferins. Luciferins are highly unstable molecules that are oxidized by enzymes called luciferases to produce light. Due to the instability of luciferins, bioluminescent organisms such as fireflies, the sea pansy, and ostracod crustaceans have evolved a luciferin storage mechanism to preserve the substrate until it is needed. We hypothesize that organisms that share luciferin via dietary acquisition have the same luciferin storage form. *Porichthys*, commonly known as midshipman fishes, produce their own luciferase but obtain luciferin from their diet of bioluminescent ostracods. A recent study on ostracods identified a more stable sulfated luciferin derivative that can be enzymatically converted into the active form of luciferin. Although previous work identified luciferin in its active form in various midshipman fish tissues and blood, the presence of luciferin derivatives has not yet been thoroughly investigated. Here, we use biochemical assays and liquid chromatography coupled with mass spectrometry to detect luciferin derivatives in midshipman fish tissues and eggs. Preliminary data indicate that, in midshipman fish eggs, a derivative of luciferin can be chemically converted into an active form of luciferin. Identifying luciferin derivatives in midshipman fish sets the stage for future studies on the convergent evolution of luciferin storage systems in these phylogenetically distant organisms.

120-1 LAUDER, G V*; WAINWRIGHT, D K; DISANTO, V; WHITE, C; ZHU, J; BART-SMITH, H; Harvard Univ., Univ. Virginia; *glauder@oeb.harvard.edu*
Tuna Robotics: Exploring the High-frequency Performance Space of Swimming Fishes
Tuna and related scombrid fishes are high performance swimmers that often operate at high frequencies, especially during behaviors such as escaping from predators or catching prey. This contrasts with most fish-like robotic systems that typically operate at low frequencies (< 2 Hz). To explore the high-frequency fish swimming performance space, we design and test a new platform based on yellowfin tuna (Thunnus albacares) and Atlantic mackerel (Scomber scombrus). Body kinematics, speed, and power are measured at increasing tail beat frequencies to quantify swimming performance, and to study flow fields generated by the tail. Experimental analyses of freely swimming tuna and mackerel allow comparison with the tuna-like robotic system. The Tunabot (255 mm long) can achieve a maximum tail beat frequency of 15 Hz, which corresponds to a swimming speed of 4.0 lengths per second. Comparison of midline kinematics between scombrid fish and the Tunabot shows good agreement over a wide range of frequencies, with the biggest discrepancy occurring at the caudal fin, primarily due to the rigid propulsor used in the robotic model. As frequency increases, cost of transport (COT) follows a fish-like U-shaped response with a minimum at ~1.6 BL/s. The Tunabot has a range of ~9.1 km if it swims at 0.4 m/s or ~4.2 km at 1.0 m/s, assuming a 10 Wh battery pack. These results highlight the capabilities of high frequency biological swimming and lay the foundation to explore a fish-like performance space for bio-inspired underwater vehicles.

85-5 LAURENCE-CHASEN, JD*; JUNOD, RM; HATSOPOULOS, NG; ARCE-MCSHANE, F; ROSS, CF; University of Chicago; *jdlc700@gmail.com*
Geometric morphometric analysis of tongue shape dynamics during feeding in Macaca mulatta
The tongue plays a crucial role in feeding, but is notoriously difficult to study. Most attempts to quantify the tongue's contribution to chewing and swallowing have been limited to single-plane X-ray video, and thus fail to capture its dynamic shape changes in three dimensions. Here, we use XROMM to measure and quantify 3D tongue shape dynamics during feeding. Two Rhesus macaques (*Macaca mulatta*, both male), were surgically implanted with 24 tantalum markers in the cranium (4), mandible (4), hyoid (1), and tongue (15). Biplanar videoradiographic data were collected while the monkeys fed on grapes, gummy bears, and almonds. Using a new machine learning workflow, at least 1000 gape cycles per individual were tracked, and the motion of the mandible, hyoid, and tongue markers relative to the cranium was reconstructed. A Procrustes superimposition was performed on the tongue marker positions to isolate shape. We then performed a principal component analysis on the transformed data and found that 80% of the variance in the data was explained by the first six principal components. After scaling to percent of gape cycle duration, we compared tongue shape within and across gape cycle types and feeding sequences. As predicted, tongue shape differed significantly between chews and swallows. Notably, these differences emerged as early as the first 10% of the cycle, during the fast-close phase. Finally, the mean variation in tongue shape decreased consistently over the duration of a feeding sequence, reaching a minimum at the terminal swallow. These geometric morphometric analyses reveal global changes in tongue shape independent of tongue or jaw position; our future analyses will quantify the impact of these factors on tongue shape.

P2-28 LAW, CJ; American Museum of Natural History, UC Santa Cruz; *cjlaw9@gmail.com*

Evolution of carnivoran body plans

Body shape diversity is one of the most prominent features of phenotypic variation in vertebrates and can lead to increased diversification, niche specialization, and innovations within a clade. Biologists, however, still lack a full understanding of the underlying morphological components that contribute to body shape diversity, particularly in endothermic vertebrates such as mammals. Consequently, little is known about the morphology, ecology, and evolution of mammalian body shapes as well as the underlying traits that contribute to different body plans. In this study, I generated the first quantitative database of mammalian body shapes using osteological specimens within the mammalian order Carnivora. I then test hypotheses pertaining to the relationships between the cranial, axial, and appendicular morphologies and examine how these relationships contribute to the evolution of body plans found across carnivorans. This work fills a critical gap in our understanding of vertebrate evolution by elucidating the evolutionary similarities and dissimilarities across vertebrate body plans and the underlying processes that drive their phenotypic diversity.

21-6 LAW, CJ*; TINKER, MT; FUJII, JA; NICHOLSON, T; STAEDLER, M; TOMOLEONI, J; YOUNG, C; MEHTA, RS; American Museum of Natural History, Nhydra Ecological Consulting, Monterey Bay Aquarium, Monterey Bay Aquarium, US Geological Survey, California Department of Fish and Wildlife, University of California Santa Ccruz; *cjlaw9@gmail.com*

Tool use increases mechanical and bioenergetic foraging success in southern sea otters

Although it is well documented that tool use can facilitate the exploitation of resources, the fitness benefits associated with this innovative behavior are difficult to test. Using longitudinal data from 196 radio-tagged southern sea otters, we examined how variation in tool use frequency contributes to differences in foraging success (both biomechanically and energetically) and longer-term fitness between individuals. We found that individuals, particularly females, with high tool use frequency consumed harder prey items. Furthermore, we found a bi-modal relationship between tool use frequency and caloric income, revealing that not only does frequent tool use lead to greater caloric income but that non-tool using behavior serves as a viable strategy to maintain sufficient caloric requirements. Interestingly, these foraging advantages do not translate to long-term health gains as tool use frequency neither prevented tooth injury nor increased body condition. These results indicate that frequent tool users exhibit greater foraging success by gaining access to relatively harder prey, resulting in greater caloric intake.

P2-42 LAWSON, AB*; ECHOLS, MS; HEDRICK, BP; SCHACHNER, ER; Louisiana State University HSC, Echols Veterinary Services, Salt Lake City, UT; *Adam.B.Lawson@gmail.com*

Anatomy of the Respiratory System of the African Grey Parrot (Psittacus erithacus erithacus)

Over the past century, the avian respiratory system has received considerable interest, with numerous studies describing morphological variation between and within species. While gross dissections and casts of the lower respiratory tract have permitted qualitative descriptions of variation in some avian taxa, there has not yet been a systematic quantitative analysis of these differences. Advances in imaging, such as x-ray computed microtomography (microCT), permit non-destructive visualization and quantification of pulmonary structures *in situ*. Six deceased African grey parrots (*Psittacus erithacus erithacus*) were microCT scanned, and the air sacs, lung surfaces, and airways were segmented to produce 3D surface models. These structures were qualitatively analyzed to characterize overall shape, branching pattern, and left-right symmetry. Quantitative metrics were taken from multi-planar reconstructions of the microCT scans and include: 1) distances to the ventrobronchi and dorsobronchi from the carina; 2) the area of the primary bronchus where each major secondary bronchus branches; and, 3) the area of the ostium for each of the large secondary bronchi (ventrobronchi, laterobronchi, and first four dorsobronchi). Qualitatively, the air sacs demonstrated the most intraspecific variation, with marked differences in the caudoventral extension of the cervical sacs along the internal aspect of the sternum. Additionally, quantitative metrics demonstrated reduced variability in structures more closely associated with the aerodynamic inspiratory valve. This work advances our understanding of the avian respiratory system, providing both a novel methodology and a baseline for evaluating interspecific variation in future studies.

108-6 LEAHY, AL*; FISH, FE; KERR, SJ; LEFTWICH, MC; West Chester University, George Washington University; *al916349@wcupa.edu*

Value of the California Sea Lion (Zalophus californianus) Hindflippers during Porpoising and Turning Maneuvers

California sea lions (*Zalophus californianus*) are a highly maneuverable species of marine mammal. They possess four control surfaces in the form of paired foreflippers and hindflippers. Unlike the foreflippers, whose wing-like morphology is fixed, the hindflippers are adjustable in which the digits of the hindflipper can be collapsed (adducted) with a low drag profile or spread (abducted) with a shape similar to a delta wing. During uninterrupted, rectilinear swimming, sea lions oscillate their foreflippers to propel themselves forward without aid from the collapsed hindflippers, which are passively trailed. Sea lions utilize the spread hindflippers during maneuvers, including turning and leaping (porpoising) behaviors. Little has been done to define the role of the hindflippers as a control surface when maneuvering. To examine hindflippers during maneuvering, trained sea lions were video recorded underwater through viewing windows performing porpoising behavior and banking turns. Anatomical points of reference (nose, ankle, and hindflipper tip) were digitized from videos to measure velocity and angle of attack. During porpoising bouts, the average hindflipper angle of attack through the submerged lift-producing phase was 14.6 deg. However, while performing small-radius banking turns, the angle of attack of the hindflippers was much higher, ranging from 25.6 to 35.3 deg. The high angle of attack measured when turning supports the assertion that the hindflippers act as a delta wings to help provide a centripetal force from hydrodynamic lift without stalling to achieve high-performance maneuvers.

S11-6 LEAL, M*; POWELL, JB; University of Missouri, Columbia; *lealm@missouri.edu*

A Comparative Study of Behavioral Flexibility in AnolisLizards

There has been a recent rebirth of comparative cognition. Using such a comparative approach, wherein closely related species that experience different ecological conditions are presented with the same cognitive tasks, can help untangle the strong interaction between environmental pressures and evolutionary history. We evaluated the problem-solving abilities, including behavioral flexibility, of three species of *Anolis* lizard (*A. evermanni*, *A. pulchellus*, and *A. cristatellus*) belonging to three distinct ecomorphs. We found significant differences in cognition between species that correspond to differences in habitat complexity. In particular, a greater frequency of *A. evermanni* and *A. pulchellus*, which inhabit relatively complex three-dimensional environments, solved a novel motor task than *A. cristatellus*, which are often found in structurally simple habitats. Additionally, individuals of *A. evermanni* and *A. pulchellus* completed multiple reversal tasks, but did not exhibit a decrease in the number of trials required for successive reversals. These findings suggest that interspecific variation in problem-solving ability might be driven by variation in habitat preference, and that ecology might even contribute to general intelligence in anoles. Furthermore, we found that at least some individuals of each species were able to complete all tasks, which indicates that anoles as a clade are behaviorally flexible and supports the hypothesis that evolutionary history can also contribute to cognitive ability.

45-4 LEARY, CJ; University of Mississippi; *cjleary@olemiss.edu*

Hormonal Regulation of Alternative Mating Tactics in Anuran Amphibians: A Tribute to Rosemary Knapp

Rosemary Knapp was an incredibly influential figure in behavioral endocrinology. Her meticulous work on hormonal regulation of alternative mating tactics set the stage for research in this area and guided many studies in this and other realms. Her knowledge, insight, wit and charm drew admiration from countless students and established scientists alike. Her passing is a major loss. As a PhD student in her lab, Rosemary and I developed some of the first work on hormonal regulation of alternative mating tactics in anuran amphibians. Here I compare our earlier work on toads (*Bufo cognatus*) to current work in treefrogs (*Hyla cinerea*). These two species differ in their ecology and behavior, especially in terms of temporal patterns of reproductive activity and aggression. I discuss how these differences relate to hormone production and conditional adoption of satellite behavior. A common theme that emerges from this work is that circulating glucocorticoid levels play a central role in mediating changes in both mating tactic expression and vocal attractiveness, implicating glucocorticoids as important modulators of sexually selected traits.

P1-147 LEAVITT, HE*; ADRIENNE, C; AMANDA, NN; FORD, M; Eckerd College , NOAA Office of Ocean Exploration and Research, NOAA Fisheries Marine Ecosystems Division; *heleavit@eckerd.edu*

Investigating Remotely Operated Vehicle Avoidance Behavior and Distribution of Mesopelagic Fauna

Mesopelagic fauna are known to follow distinct vertical distribution patterns, ubiquitously concentrating in one or more layers between 300-1000 meters throughout the open ocean. This high density of midwater fauna, known as the deep scattering layer (DSL), consists of a variety of hard and soft-bodied organisms that contribute to the DSL's characteristic acoustic backscatter. Most DSL backscatter is attributed to midwater fish; however, gelatinous scatterers like gas-containing physonect siphonophores also play a role. Exploratory remotely operated vehicle (ROV) transects of the midwater environment allow us to gain insight into the distribution of a wider breadth of midwater organisms than traditional trawling studies, which struggle to recover delicate gelatinous fauna. Exploratory midwater transect video footage and active acoustic data collected during the Windows to the Deep 2019 expedition (EX1903), which focused on the EEZ off the Southeastern coast of the United States, were used to study the distribution of mesopelagic taxa relative to the DSL and quantify the ROV avoidance of midwater taxa during visual surveys. Sighting frequencies of most groups of mesopelagic fauna, with the exception of physonect siphonophores, were greater during transects within the DSL compared to transects outside of it. There was evidence of ROV avoidance on several transects, determined by measuring local acoustic backscatter before and after transects occurred. Quantification of ROV avoidance is crucial to further contextualizing visual surveys, but data collected during EX1903 points towards faunal distribution patterns that aid in our understanding of community structure in this enigmatic ecosystem.

17-6 LEBOW, CL*; BURT, DB; TAYLOR, J; Stephen F. Austin State University; *clebow@tds.net*

Glare Reduction Properties of Dark Avian Facial Markings

Avian facial plumage, bill coloration, and feather microstructure may serve one or more adaptive functions. Several researchers have proposed that dark eyestripes, bills, and facial masks aid in reducing glare, however, there have been relatively few tests of this hypothesis. Dark facial markings have been shown to have an adaptive glare-reduction function in recent field studies of a few species, but this hypothesis has never been tested in a broad multispecies analysis. It is likely feather microstructure influences feather brightness and has an effect on the efficacy of glare reduction properties of feathers. We tested the hypothesized link between dark facial markings and glare reduction, under natural lighting conditions, in several bird species using a spectrometer probe placed in the eye-position of museum specimens. Reduction in irradiance in full, natural sunlight, used as a measure of glare, was quantified for specimens varying in bill and head plumage coloration and pattern. Each specimen was tested with the head held at various angles to mimic natural foraging positions. We also quantified the brightness of bills and plumage surrounding the eye of these same specimens using reflectance spectroscopy. Correlations between irradiance measurements and the bill and plumage brightness were analyzed. Facial feather microstructure, barbule density, pith and cortex size were examined using scanning electron microscopy. These characteristics were then compared to plumage brightness of both light and dark patches. We show a significant relationship with average head darkness and reduction in irradiance values when the head was held at 45 degrees from horizontal. Dark patches in the anterior and posterior dorsal quadrants are most important in this reduction in irradiance. Preliminary findings on feather microstructure will be discussed.

37-5 LEDESMA, D*; KEMP, M; University of Texas, Austin; *ledesma-david@utexas.edu*

Changes in central Texas fossil herpetofauna

In the face of modern climate change and worldwide biodiversity loss, it is imperative that we work to better understand the impacts that environmental changes can have on extant populations over long timespans. The study of Quaternary fossils represents an important bridge to the past that grants us insight into how past biota responded to environmental fluctuations and how extant species may respond to future change. I use fossils from Hall's Cave, located on the Edward's Plateau in Kerr County, Texas, to reveal demographic and taxonomic variation in the herpetofauna during the late Quaternary. A reexamination of fossil herpetofauna from Hall's Cave using apomorphic and diagnostic morphology resulted in a different list of herpetofauna taxa than had been previously reported. This result speaks to the merit of using these identification methodologies to provide strong support for fossil classifications and subsequent paleoecological interpretations. I determined the minimum and maximum number of individuals within 5-centimeter intervals for different reptile and amphibian taxa. The two abundance metrics exhibit similar trends through time with changes in abundances of frogs, snakes, and lizards occurring concurrently. Around 1,500-2,000 years ago, there are peaks in abundances of these taxa which coincide with wetter and cooler conditions as reconstructed from previous north-central Texas paleoclimate proxies. Herpetofauna abundances decrease after 1,500 and between 2,500-3,500 years ago, which correspond to warmer and drier time intervals according to published speleothem records. These preliminary results suggest that changes in herpetofaunal abundances from Hall's Cave may be a consequence of past climatic change and provide a glimpse into changes in central Texas' herpetofaunas during the late Quaternary.

86-4 LEE, MA*; DENSMORE III, LD; Texas Tech University, Lubbock, TX; *mark.a.lee@ttu.edu*

Past, Present, and Future Distributions of Agkistrodon contortrix

Changes between past, present, and future climates have noticeable effects on species distribution. For example, temperate reptiles occupy areas today that would have been far too cold in the geologically recent past, and their distribution will likely change as the world becomes warmer. However, species distribution models are usually built using current climatic conditions. While this may give a decent approximation of their current distribution and suitable habitat, it does not elucidate their potential distribution in past climates, nor does it predict changes in their future distribution brought on by climate change. Copperheads (*Agkistrodon contortrix*) are temperate pit vipers that can be found in deserts, forests, prairies, and mountains from southwestern Texas to New England – thriving in varied climatic conditions throughout their range. Due to this adaptability to varied climatic conditions, they may serve as a reference point for changes in temperate reptile distribution brought upon by warming temperatures. Here we used approximately 1,000 geolocations from two citizen science databases, iNaturalist and Herpmapper, to model past, present, and future distributions of this species using non-correlated bioclimatic variables and investigate the rate and extent of change between them. Our results illustrate that copperheads have undergone noticeable changes in their distribution due to climatic change in the past and will likely continue to do so in the face of man-made climate change, albeit at an unprecedented pace. Understanding the effects of climatic variation on temperate reptile distribution can help us understand their evolutionary history and aid in future conservation management plans.

30-1 LEFAUVE, MK*; HERNANDEZ, LP; George Washington University; *mlefauve@gwu.edu*

Invasive Behavioral Syndrome in Cypriniform Fishes

Species are introduced to new environments on a daily basis, but only about 10% do well enough to become an invasive species. Invasive species have successfully navigated the four main steps of invasion: introduction, spread, establishment, and population growth to a detrimental density. These four steps require a unique suite of life history traits to succeed and nowhere is this more apparent than in behavior. When applied across environmental contexts, species-typical behaviors can form a species-wide behavioral syndrome, or suites of correlated behaviors reflecting between-individual behavioral consistency. A "bold" behavioral syndrome has been linked with a higher dispersal potential, a key component of both the spread and establishment steps of the invasion process. Using both a shelter latency and a maze task, we tested species-wide boldness and exploratory drive in a known invasive fish, the goldfish, with comparisons to a noninvasive fish, the giant danio. Within species analysis showed behavioral consistency across environmental contexts for shelter latency, but between species analysis did not show a significant difference due to high individual variation. Total distance traveled in the open field was similar between species, but was significantly different in the maze task ($p<0.05$). Goldfish also spent significantly more time investigating the novel areas of a complex chambered maze task prior to entering a darkened shelter "reward" area. These data are consistent with the hypothesis that invasive species have a higher degree of boldness and exploratory drive than species that are not invasive.

P2-115 LEFAUVE, MK*; HERNANDEZ, LP; George Washington University; *mlefauve@gwu.edu*

Early Ontogeny of Sensory Processing Regions in the Brain of the Grass Carp

The grass carp (Ctenopharyngodon idella) is a cyprinid fish native to Eastern Asia. Originally cultivated for food, the grass carp was introduced to North America as a biological control for aquatic weeds. As one of the infamous Asian carp species, the grass carp is an invasive species in North America and has been found in most of the freshwater systems linking the Great Lakes and the Mississippi River basin. During development the establishment and maintenance of nervous tissue is energetically costly and senses that are of critical importance for early survival are typically ready to function earlier in development. As cyprinids, it is likely that grass carp are heavily reliant on vision and hearing as primary senses and will therefore develop the processing capacity for these senses relatively rapidly during early development. This is demonstrated with grass carp larvae exhibiting a mildly positive phototactic response as early as 4 days post fertilization. This project examined the development of vision and lateral line processing regions in the grass carp brain at critical life history points such as phototactic response initiation, pre and post yolk absorption, and larval to juvenile transition. Behavior-based hypotheses suggest that the retinorecipient areas of the optic tectum are developing after phototactic response initiation. This indicates that a simple phototactic response may be encoded initially by other brain regions, such as through the dorsal thalamus pathway, so multiple brain regions were assessed for each sense across development.

112-8 LEIGH, SC*; PAIG-TRAIN, M; California State University Fullerton; *sleigh@fullerton.edu*

The catch of the day is…plastic? The ingestion of microplastics by zooplankton in southern California

Plastic pollution is pervasive in marine environments. While much attention has been given to the effects of macroplastics on a variety of marine organisms (i.e. ingestion and entanglement of large plastic debris by charismatic megafauna), the effects of microplastics in the marine environment are also of major concern and less thoroughly investigated. Given that organisms have been shown to consume microplastics across trophic levels, there is the potential for bioaccumulation of these particles. Zooplankton is a critically important food source for many secondary consumers. Currently, there is limited information regarding the ingestion of microplastics by zooplankton in southern California; a densely populated area with the potential for high quantities of microplastic pollution, as well as an important supplier of commercial fisheries. As such, we categorized the types and quantities of plastic ingested by important zooplankton foundation species through field surveys in four environments within the southern California Bight: 1) LA harbor, 2) a nearshore urban environment, 3) a channel, and 4) open ocean. We have shown that marine zooplankton are ingesting microplastic particles, indicating that species at lower trophic levels of the marine food web are mistaking plastic for food. In a laboratory setting, we have also shown that microplastics can be transferred from brine shrimp (*Artemia salina*) to a predatory moon jelly (*Aurelia aurita*), which raises fundamental questions about potential risks to higher trophic level species within different habitats of the southern California Bight. This represents a path whereby microplastics could enter the food web and transfer up trophic levels, potentially effecting commercially important species that humans rely on for food.

74-2 Lenard, A*; Diamond, S; Case Western Reserve University; *axl710@case.edu*

Butterfly Traits Resolve Variation in Range Shift Responses to Recent Climate Change

Variation in species geographic ranges is astounding – why some species exist on only a small part of one island while others occupy nearly the entire globe has been a key pursuit in biological research for centuries. Over millions of years, ecological and evolutionary forces shaped and continue to shape species ranges. But contemporary species are under novel pressures that could shape their ranges in unprecedented ways. Under recent climate change, many species are rapidly shifting their geographic ranges. Although there is a general trend toward poleward and upslope geographic range shifts, there is still considerable variation in the magnitude and even direction of contemporary range shifts. Comparative species trait-based approaches have been used widely to develop generalizable relationships between species-level traits and variation in the range shift response. Here I quantify the range shift responses of butterflies in the midwestern United States to recent climate change over the last several decades. I then explore the potential for butterfly traits including range and distribution attributes, dispersal ability, and thermal niche to explain variation in the magnitude and direction of the range shift response. Finally, I explore how evolutionary history and the evolutionary rate of change in the thermal niche also shape the range shift response. In general, while traits typically examined in this context such as range area were broadly predictive of the range shift response to recent climate change, I also found support for an important role of the evolution of the thermal niche trait. These results suggest that a deeper understanding of the mechanisms that underlie species responses to climate change can aid in predicting where species might be found in the future as the environment continues to change.

P2-137 LENT, DD*; MENDOZA, A; CSU Fresno; *dlent@csufresno.edu*

Navigating in the face of change: Modeling how changes in the visual environment of ants disrupts navigation.

Visual navigation in ants has been studied extensively in a variety of species. Landmark features that ants relay on to define their routes have been identified as well as how they fixate on learned cues during their return approaches. We created a computational model to study ant navigation in a procedurally generated environment. The model of foraging is based on behaviors of live ants and aims to examine a random foraging event that results in the simulated ant finding a goal and the subsequent walks to that learned goal. Using this model, we explored how memory is modified with experience, if navigation is robust regardless of the direction of the initial path, and how disruptions in the environment are predicted to affect visual navigation in live ants. Our model provides insight into processing and learning of visual information, supports that ants prioritize relevant features and do not need to constantly process information from their environment, and that routes converge on the same goal while being idiosyncratic. To study the response to changes in the environment, we tested the model in two ways: (1) remove specific portions of objects from the rendered environment after training and determine how it affects subsequent foraging; (2) add uneven terrains with random hills and valleys to the simulated environment and examine how that disrupts the model. The model predicts that features that are enroute minimally disrupt navigation when removed whereas features that are far away cause greater disruption. Finally, the model predicts the necessity of head stabilization and terrain-angle specific visual sampling to improve foraging success.

S5-11 LENTINK, D*; CHIN, D.D. ; HIGHTOWER, B.J.; INGERSOLL, R.; Stanford; *dlentink@stanford.edu*

Design principles of Fluid Force and Moment Platforms for biological locomotion studies

One of the key challenges in studying the biomechanics of organisms moving in fluids is measuring the instantaneous fluid force and moment exerted by the organism on its environment. During the past three decades particle image velocimetry revolutionized our ability to measure the associated flow fields in vivo. These flow field snapshots could then be used to approximate the forces by simplifying the governing control volume equations for fluids in various ways, but this approach is not only cumbersome, it also has limited numerical accuracy. During the past decade we invented and dramatically improved a new method to directly measure fluid forces and moments by using force plates that mechanically integrate the pressure and shear stress distributions on the control surfaces of the fluid volume in which the organism moves. Summing the reaction forces and moments acting on these surfaces precisely matches the resulting instantaneous forces and moments exerted by the organism. During the past decade we refined this method for air, enabling us to record the aerodynamic force generated by freely flying birds directly in vivo. The economic recording method gives instantaneous wingbeat-resolved results, which provided new insights in how birds generate and use lift and drag to fly. Here we summarize the design, manufacturing and testing principles of Fluid Force and Moment Platforms in a simple and ready to use format for anyone studying ‘life in moving fluids' in the spirit of Steven Vogel. Applications include swimming, running over water, and flight of a wide range of organisms.

96-3 LENZ, AS; School of Biological Sciences, University of Bristol, UK; *anne-kristin.lenz@bristol.ac.uk*

Structural Adaptations of Nepenthes gracilis Pitcher Lids to Capture Insects Using Drop Impacts

Pitcher plants are a group of carnivorous plants that trap and digest prey in their cup-shaped leaves. The traps are passive and have several adaptations to attract and capture prey. In particular the temporarily-slippery peristome and a wax crystal-layer on the inside as well as the viscous fluid in the bottom of the pitcher facilitate the capturing and prevent an escape. In addition to those structures the species *Nepenthes gracilis* has a unique mechanism to capture prey, exploiting the impact energy of rain drops. It produces an increased amount of nectar on the underside of the lid directing prey there. Impacting raindrops accelerate the lid so that insects can't grip to the wax-coated surface and fall into the pitcher. In comparison to those of other, non-specialised species the lid of *N. gracilis* does not bend and reaches a higher speed when accelerated by a raindrop. Previous studies showed that the high stiffness of the lid and a specialized friction-reducing wax-coating on its underside are both essential for its trapping function. Here we report further structural adaptations of the 'neck' region connecting the lid and the pitcher. We used micro-CT imaging to characterize the three-dimensional deformation during impact and investigate the role of structural reinforcement in the 'neck' region and pitcher rim, and estimate the reaction forces of the system. A comparison with the non-specialized pitcher plant *Nepenthes rafflesiana* confirmed the crucial role of the 'neck' region for the function of this exceptional trapping mechanism.

119-6 LENZ, PH*; RONCALLI, V; CIESLAK, MC; CASTELFRANCO, AM; HARTLINE, DK; University of Hawaii at Manoa, University of Hawaii at Manoa and University of Barcelona; *petra@hawaii.edu*

Organism-Environment Interactions in Marine Zooplankton: Transcriptomic Characterization of a Copepod Phenome

The subarctic Pacific is home to the lipid-rich copepod *Neocalanus flemingeri*. With a one-year life cycle, this copepod depends on a short annual spring phytoplankton bloom for growth and accumulation of capital to fuel both diapause and reproduction. This species is highly resilient: its distribution spans the northern Gulf of Alaska, a region where spring food resources vary by one to two orders of magnitude. RNA-Seq was used to profile global gene expression of pre-adult *N. flemingeri* collected across the shelf and in Prince William Sound. t-Distributed Stochastic Neighbor Embedding (t-SNE) analysis of gene expression profiles followed by group identification using the DBSCAN algorithm identified three phenomic clusters. With one exception, these corresponded to three distinct collection regions. Functional analysis of differentially expressed genes identified lipid metabolism as a key biological process contributing to regional differences in transcription. Genes involved in lipid synthesis were up regulated in individuals from Prince William Sound, while genes involved in lipid catabolism were up-regulated in individuals collected in high-nutrient low-chlorophyll (HNLC) gulf waters. Gene expression divergence in *N. flemingeri* indicated acclimatization to local conditions, and a capacity to persist in a habitat with steep resource gradients. We hypothesize that the observed resilience of these copepods stems from a combination of acclimatizion to low food conditions and the ability to exploit pulses of high food to build lipids to fuel diapause and reproduction.

S6-5 LEPIANE, K/L*; CLARK, C/J; University of California, Riverside; *krista.lepiane@email.ucr.edu*

The dorsal velvet surface of owl feathers decreases sounds of rubbing during flapping flight

One wing feature that owls have evolved to silence their flight is the velvet, made up of elongated filamentous projections, or pennula, that stick up on the dorsal surface of feathers. There are two hypotheses as to how the velvet silences flight: aerodynamic noise and structural noise. The aerodynamic noise hypothesis predicts silencing features reduce low frequency sound produced by turbulence development over the surface of the wing. This hypothesis predicts that impairing the velvet will increase low frequency sounds produced during the downstroke, when airspeed over the wing is greatest. Alternatively, the structural noise hypothesis predicts velvet reduces frictional noise, or broadband sound produced when two feathers rub together. Rubbing is likeliest during flapping flight. This hypothesis predicts that impairing the velvet will increase broadband sound produced during the upstroke, when wing deformation causes feathers to rub together. Further, this hypothesis predicts impairing the velvet on regions of feather overlap (trailing vane) will increase sound produced during flight and impairing an adjacent portion of the feather, where there is no feather overlap, will not. To test these hypotheses, we applied hairspray to the dorsal surface of five flight feathers (P1 - S4) on live Barn Owls (*Tyto alba*). We flew owls over a stationary microphone and recorded flight sounds at three experimental conditions: control, manipulation, and manipulation removed. Applying hairspray to flight feathers increased the broadband sound Barn Owls produce during the upstroke, supporting the structural noise hypothesis.

131-1 LESSIG, EK*; NONACS, PN; University of California, Los Angeles ; *elessig@utexas.edu*

Foraging choices, learning, and behavior across paths that vary in risk

Cooperatively foraging species often adjust their search strategies in complex environments to efficiently find and exploit food sources. These strategies become more complicated when food and risk can be simultaneously present and when they differ in predictability. This study examines how colonies of Argentine ants *(Linepithema humile)* learn and respond to negative features of their environments, when potential paths to food differ in the cues that indicate the presence of risk. These cues are either a live competitor (velvety tree ants, *Liometopum occidentale* (LO)) or formic acid (FA), a defensive chemical commonly associated with formicine ant species. The two types of stimuli elicited significantly different behavioral responses, both in path use and time to find food across days. Specifically, *L. humile* were attracted to paths with LO but avoided FA. The intensity of these responses changed over time. The response to FA was constant while the response to LO declined. Further, *L. humile* colonies that were exposed to LO cues were faster at finding food across days compared to colonies exposed to FA. Thus, it appears that *L. humile* foragers assess and respond to features of their environment in order to adopt a successful foraging strategy .

P2-55.5 LESSNER, E/J*; HOLLIDAY, C/M; University of Missouri; *ejlessner@mail.missouri.edu*

Diversity and evolution of trigeminal branching patterns in sauropsids

Vertebrates evolved numerous types of integumentary sensory systems, many of which enhance facial somatosensation. Species with sensitive faces exhibit high densities of trigeminal nerve-innervated receptors at the ends of nerve branches that course through bony canals and foramina in the face and mandibles. These bony features of the trigeminal system are often used to infer facial sensation in extinct vertebrates. However, the form and function of the trigeminal system are diverse in extant reptiles, and its physiological significance and phylogenetic patterns are unclear. Extant reptiles display morphological diversity in proximal (i.e., trigeminal fossa contents and trigeminal division pathways), intermediate (i.e., inferior alveolar canal [IAC] neurovasculature and its relation to teeth and integument), and distal structures (i.e., symphyseal neurovasculature and bill-tip-organs). These structural differences are reflected in the behavioral diversity (e.g., lingual vs. jaw prehension in squamates, tactile-feeding in birds) across Reptilia. Using histological and CT data, we performed morphometric analyses of the maxillomandibular foramen, IAC, and distal mandibular foramina of several extant sauropsids. Comparing IAC branching patterns, we find a more dendritic arrangement in crocodylian IACs in comparison to squamates in which accessory canals transmit mostly vascular tissue to squamate integument, suggesting reduced ability for mandibular sensation. Additionally, crocodylians distribute more neurovasculature branches across smaller areas of the mandible than the squamate taxa sampled, suggesting smaller receptive fields and increased sensory ability. Overall, these findings assist in reconstruction of soft tissues from osteological correlates in fossil taxa and will help uncover patterns of reptilian somatosensory ecology and evolution.

95-2 LEVELL, ST*; REZNICK, DN; University of California, Riverside; *sleve004@ucr.edu*

Can Mothers Diferentially Allocate Resources to Offspring Sired by Different Males?

The Viviparity-Driven Conflict Hypothesis (VDCH) predicts that the mammalian placenta provides a novel arena for parent-offspring conflict over resources. Parent-offspring conflict is a predicted to result from inequalities in the optimal quantity of resources transferred from the parent to the offspring. This conflict is exaggerated if females' mate with multiple males because of lower coefficients of relatedness that result from being a half- rather than a full-sibling. 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. The principles of the VDCH can be extended to matrotrophic (embryonic mother-feeding) livebearing fishes (family: Poeciliidae) such as Heterandria formosa, which 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 (with the volume of sperm held constant) to determine whether mating with multiple males affects offspring number or size within and among broods. Preliminary results suggest that the paternal genome dictates offspring size when males from a single population are used. However, when sperm is mixed from multiple populations of males, the size of the resulting offspring is biased in one population.

133-1 LEVENDOSKY, MW*; LANIER, M; BEDORE, CN; Georgia Southern University; *ml06458@georgiasouthern.edu*

Effect of Anesthesia Immersion on the Coral Catshark, Atelomycterus marmoratus

Sensory experiments require anesthesia so the animal is immobilized. Traditional fish anesthetics (e.g. tricaine) depress the sensory system, although the degree to which results are affected is unclear. Newer anesthetics, such as propofol, may offer the same anesthetic relief, but the action of propofol differs from tricaine, so sensory responses may not be affected. Propofol has been used intravenously on small elasmobranchs but may provide prolonged effects if used as an immersion anesthetic. Due to its potential to maintain a surgical plane of anesthesia during sensory physiology experiments, investigation of propofol as an alternative anesthetic warrants investigation. The objectives of this study were 1. Determine the appropriate dose of anesthesia to minimize induction and recovery time for animals anesthetized at a surgical plane of anesthesia and 2. Measure physiological response of the pupil to light stimuli during anesthetic immersion. To address our objectives, we used the coral catshark *Atelomycterus marmoratus*. Respiration rate and response to mechanical stimuli were recorded to measure induction and recovery times in 8 tricaine and 7 propofol doses and generate dose response curves. Appropriate doses of anesthesia are approximately 175 mg L^{-1} tricaine and 1.25 mg L^{-1} propofol. After 1.5 hours of dark adaptation in an anesthetic bath (50, 100, or 150 mg L^{-1} tricaine or 0.5, 1, or 1.5 mg L^{-1} propofol) or no anesthesia (control), tricaine 100 mg L^{-1} trials show reduction in percent pupil constriction ($p<0.5$; ANOVA). While these results suggest propofol may be appropriate for use in sensory experiments, anesthetics are often species specific so the effect of propofol immersion in other elasmobranch species will be investigated.

P3-252 LEVY, MG; University of California, Berkeley; *mglevy@berkeley.edu*

Modeling the Developmental Shape Transition in the Morphogenesis of Cowrie Shells

Seashells are a proving ground for ideas about mechanical development of geometrical form (shell shape), biological pattern-formation programs (shell pattern), and evolutionary morphospaces. This work touches on modeling efforts in all of these directions. Cowries, snails of the family *Cypraeidae*, are among the most popular finds of shell collectors, prized for their pattern, their shape, and their shiny luster. Despite all this attention for the shells (from collectors) and of shells (from modelers) there is no model for their peculiar form in the literature. Here we rectify this by coupling growth, form, and a developmental/behavioral shift in the soft body of the mollusc to recapitulate a possible mechanical developmental program for the mature cowrie shell. We present morphological phenomenology, finite-element solutions to elasticity equations coupled to shell geometry, numerical continuation models of growth, and novel formalisms for coupling elasticity to growth. Our model explains both the shape of the central line spiral and the formation of teeth at the shell opening, exploiting only local geometry, known programs of shell deposition, and material properties of the snail and its shell. We show that cowries exploit only a portion of morphospace and compare cowrie shell shapes with those of a phenotypically similar family, the *Olividae*. This work gives insight into the evolution of shell ornamentation and how biological systems can build beautiful sophisticated structures without the benefit of global information or an explicit blueprint. If time permits, results on the morphospace of shell pattern will be reported along with an explanation for how the sensory-neural loop underlying pigmentary deposition constrains the shell patterns found in nature.

P3-206 LEWIS, JA*; SECOR, SM; University of Alabama; *jalewis5@crimson.ua.edu*

Postprandial Remodeling of Organs and Intestinal Tissues by the Boa Constrictor

Boa constrictors (*Boa constrictor*), native to Central and South America, are sit-and-wait foragers that feed relatively infrequently. Characteristic of infrequently feeding pythons and rattlesnakes is the rapid upregulation of digestive performance and remodeling of tissues with feeding, followed by downregulation of organ performance and tissue atrophy once digestion has completed. In this project, we examined the capacity for changes in organ mass and the remodeling of the intestine with feeding and fasting for the boa constrictor. Organs were removed and weighed from snakes fasted (30 days since last meal) and at 12 hours, 1 day, 3 days, and 6 days after feeding. Sections of proximal small intestine were also prepared for light microscopy. Boas experience significant increases in the mass of the esophagus, liver, and kidney within 1 day and of the stomach, pancreas and small intestine within 3 days after eating. Most noted are the respected increases of 74%, 87%, and 112% for the pancreas, liver, and small intestine. In contrast, the gall bladder lost mass due to the secretion of bile used for digestion. Feeding also induced a remodeling of the small intestine, highlighted by a near doubling in the thickness of the mucosa layer, a 30% increase in enterocyte width, and a 75% increase in enterocyte volume. Similar to infrequently feeding pythons and rattlesnakes, boa constrictors experience the characteristic rapid remodeling of their organs and tissues with feeding that ensure the efficient digestion and assimilate of their large meals.

P2-63 LEWIS, AK; University of Florida; *lewis23a@ufl.edu*

Understanding Sex and Gender as a Scientist: Why It Matters Now More Than Ever

As scientists, we aim to be objective in all aspects of our research. We expect the scientific method and scientific practice to make our work objective, but this expectation has led to a cis-heteronormative and binary sex focused paradigm. Historically and currently, science has provided resources for continued oppression of women, reinforced sex behavioral differences, and reinforced gender roles. Scientific research is influenced by the context of its production, and this provides a concrete reason why biologists studying sex need an informed understanding of sex and gender. With regard to sex, there have been challenges to the traditional definitions of male and female for more than a millennium. People with a mosaic of sex characteristics or with nonbinary sex characteristics, those who are intersex, have been known across cultures and throughout history. Unfortunately, these historical data have been largely contained within the humanities and social sciences. The social and societal expectation of binary sex has led to institutional and medical regulation of people's bodies, which has been the subject of increasing spotlight recently. In 2019, the first bill that proposed to outlaw cosmetic, medically unnecessary surgeries on intersex minors unable to give consent in the United States was introduced in California (SB201). This year has also seen notable regulation of intersex bodies by athletic associations. Regulation in the athletic community is neither new nor finished. This spotlight on nonbinary sex demonstrates the timeliness for examining the biases within the way we research and discuss sex. We know this paradigm is present within scientific research. It is reinforced by how we communicate science to various audiences, as well as how we introduce ourselves in the classroom, in meetings, and at conferences. This presentation provides actionable ways to address the paradigm at individual and institutional levels.

140-7 LEWIS, ZR*; DUNN, CW; Yale University, Department of Ecology and Evolutionary Biology; *zrlewis@gmail.com*

UV Tolerance in the Portuguese Man of War (Physalia physalis)

The Portuguese Man of War (*Physalia physalis*) is a cnidarian that lives at the surface of the ocean and travels by catching wind in a sail filled with carbon monoxide. A number of aspects of its physiology remain enigmatic, including how it is able to tolerate high levels of UV-radiation (UVR) to minimize cellular and genomic damage. To better understand the mechanism by which *Physalia* survives under regimes of high UVR, we used UV photography to determine the differential UV-absorbing capabilities of *Physalia* tissue types. We extracted and characterized *Physalia's* UV-absorbing molecules using HPLC-tandem mass spectrometry. One class of UV-absorbing molecules are the mycosporine amino acids. Mycosporine amino acids are derived from the same biochemical pathway used to synthesize aromatic amino acids. Enzymes necessary for the synthesis of both aromatic and mycosporine amino acids are thought to be absent in metazoans. Therefore, metazoans must obtain these amino acids from their diet or symbionts. By sequencing *Physalia's* genome, we provide evidence that some of the enzymes for mycosporine amino acid synthesis are present and expressed across most tissues. Additionally, analysis of new cnidarian genome sequence data provides evidence that several other cnidarians endogenously possess enzymes employed in mycosporine amino acid synthesis. Endogenous production of mycosporine amino acids may be one way that *Physalia* manages to thrive under high UVR conditions.

S7-4 LI, J*; LEVITAN, B B; KÜLTZ, D; University of California, Davis; *joli@ucdavis.edu*

Quantitation and comprehension of context-dependent changes of dynamic proteomes

Understanding the complex biochemical mechanisms behind the evolution of salinity tolerance in euryhaline fish is best achieved using systems biology approaches. The proteome provides a wealth of information regarding the molecular phenotype of an organism. The abundance and state of certain proteins indicates life history and environmental exposures. Recent advances in mass spectrometry have allowed for the development of data-independent acquisition (DIA) assays to simultaneously monitor thousands of proteins in virtually any context. Since protein abundance information for only select proteins in response to salinity or temperature challenges provides a limited scope for determining the overall molecular phenotype of an animal, we are continuing to develop comprehensive DIA assay libraries for organisms of interest. These assay libraries permit highly accurate and consistent quantitation of exactly the same sets of proteins in all samples. The consistent proteome coverage enables systematic network and topological data analysis (TDA) approaches that yield detailed mechanistic insight into environmental and developmental effects on organisms. These approaches will be illustrated by discussing salinity and temperature effects on the three-spine stickleback *(Gasterosteus aculeatus)* gill proteome. Our results indicate that differences in habitat salinity and temperature are accurately reflected in the dynamic changes of the gill proteome. Therefore, DIA quantitative proteomics assays and corresponding bioinformatics analyses enable deduction of molecular mechanisms associated with environmental changes in aquatic organisms. This work was supported by NSF grant 1656371.

4-5 LI, DH*; KATIJA, K; GILLY, WF; Stanford University, Monterey Bay Aquarium Research Institute; *dhli816@gmail.com*

Hydrodynamic constraints on jet propulsion in squid paralarvae at intermediate Reynolds numbers

Squid are known for their use of jet propulsion, and paralarvae rely on this locomotor strategy immediately after hatching. Unlike their adult counterparts operating at high Reynolds number (Re) where inertia dominates, paralarvae must contend with both inertial and viscous forces in intermediary Re regimes. Observations of jet wake structure in squid paralarvae reveal that vortex rings, a key feature in potential thrust and efficiency enhancement, appear distorted when compared to observations in adults at high Re. It is possible that viscosity plays a role in changing jet wake structure, with consequences for the effectiveness of jet propulsion as Re decreases. Numerical simulations on how Re affects jet propulsion have proposed a theorized limit at Re = 10, below which swimming speeds quickly decay and jetting is no longer effective. By using micro particle tracking velocimetry to visualize jet hydrodynamics of tethered and free-swimming squid paralarvae in seawater and in fluids with twice and four times the viscosity of seawater, we find experimental evidence supporting the idea of a critical limit for jet propulsion. When Re < 10, significantly less thrust is produced and vorticity in the wake is disorganized with no evidence of coherent ring structures. Moreover, paralarvae are unable to swim under such conditions even though the magnitude of mantle contractions increases. For a dynamically similar scenario in seawater, a paralarva would have to be smaller than that for any known species of squid, suggesting that viscous forces at low Re may play a role in hydrodynamically constraining size at hatch for these small, jet-propelled organisms.

P1-219 LI, EY*; KACZMAREK, EB; OLSEN, AM; WELLER, HI; CAMP, AL; BRAINERD, EL; Brown University, University of Liverpool; *ellen_li@brown.edu*

The Relationship Between Movement Coordination and Suction Power During Feeding in Royal Knifefish (Chitala blanci)

Many species of fish use suction, generated by the rapid expansion of the mouth cavity, to capture prey. The force and speed of such suction events require considerable power, but the amount of power produced varies between strikes. Over a dozen cranial skeletal elements move during the expansion of the mouth cavity, but the motion of no single element can act as a proxy for power production. Instead, looking collectively at skeletal movements may indicate that motion coordination acts as a proxy for power production. While it is known that patterns of coordination vary across different behaviors, such as suction feeding and prey processing, we predict that patterns of coordination will also vary within the same behavior, specifically suction feeding strikes that differ in the power production. We tested whether coordination was correlated to strike power by using X-Ray Reconstruction of Moving Morphology (XROMM) to create 3D animations of the cranial skeleton of a royal knifefish (*Chitala blanci*) during suction feeding strikes. Knifefish are a fitting species to examine this question because of their highly kinetic skulls and dramatic suction feeding strikes. We estimated instantaneous power by using a dynamic endocast of the mouth cavity to measure the rate of volume change and combining this with intraoral pressure measurements. We calculated patterns of motion coordination by cross-correlating the relative motion of different skeletal elements and compared them among strikes of different power outputs. Examining the relationship between skeletal coordination and suction expansion power will allow us to better understand how the musculoskeletal system controls feeding kinematics.

96-2 LIAO, JC*; AKANYETI, O; Whitney Lab for Marine Bioscience, University of Florida, Aberystwyth University, Ceredigion UK; *jliao@whitney.ufl.edu*

How fishes use body wave interference to accelerate

The ability for fishes to move fast is critical for successful prey capture and predator evasion. Here, we uncover the physiological and hydrodynamic mechanisms of a previously undescribed method of propulsion which allows undulating fishes to double their maximal swimming speeds; they do this by superimposing a low-amplitude impulse wave onto their main undulatory wave. Analogous to constructive interference in physics, the impulse wave enhances the transfer of the body momentum to the wake by snapping the tail like a whip, propelling the fish forward in ways that would not be possible with classical undulatory movements. The superimposed impulse wave increases tail tip velocity independently without increasing the body wave speed. Our preliminary data (n=3 rainbow trout, L=22.4±2.0 cm) show that during whipping, an impulse wave is initiated in the region of the dorsal fin. Trout regulate timing and speed of the impulse wave in a way that increases the lateral amplitude of the tail tip excursion up to 20% compared to fish swimming steadily. This allows fish to increase tail tip velocity and angle of attack by 40% and 15°, respectively. Our results also show that a whipping fish generates optimal vortex rings with much higher circulation than those observed during undulation at a comparable speed. We hypothesize that during whipping fish separate muscle functions by coordinating undulatory and impulse waves independently. We predict that red muscles continue powering body undulations as in steady swimming, whereas a transient burst of local white muscle is responsible for the initiation and transmission of the impulse wave.

7-4 LIDGARD, AD*; FRENCH, SS; HUDSON, SB; Utah State University; *audrey_lidgard@yahoo.com*

Stress Sensitivity to Temperature in Plateau Side-blotched Lizards (Uta stansburiana uniformis): Implications for Immune Function

Ectothermic organisms, such as reptiles, rely on the external environment for regulating internal temperatures necessary for vital physiological processes. When faced with environmental challenges, temperature may differentially affect how allostatic mediators (e.g., glucocorticoid hormones) are released to mediate energy allocation for handling stressors. Subsequent differences in energy mobilization and circulating metabolites during a stress response may ultimately influence self-maintenance processes such as immunity. The aims of this research were to determine how stress sensitivity varies with diurnal temperatures in the Plateau Side-blotched Lizard (*Uta stansburiana uniformis*) and to assess the potential implications for immune function. Both baseline and stress-induced levels of glucocorticoids (corticosterone) and energy metabolites (glucose) were compared to body temperature and the thermal environment. Variation in innate immune function (bactericidal ability) was then compared to both temperature and physiological parameters at baseline and stress-induced levels. Stress reactivity via glucocorticoid release positively corresponded with body and environmental temperatures, although glucose release did not. Bactericidal ability subsequent to a stressor negatively corresponded with body temperature and glucocorticoid release. Such findings provide further insight on how stress sensitivity and self-maintenance can vary across the thermal environment, posing potential fitness consequences for an ectothermic organism.

116-4 LIEBL, AL*; DUPREY, ER; RUSSELL, AF; University of South Dakota, University of Exeter; *andrea.liebl@usd.edu*

What is the relationship between developmental stress hormones and adult helping behavior in a cooperatively breeding bird?

Cooperative breeding behavior is a paradoxical behavior wherein some individuals forego breeding to help raise the offspring of other individuals. In many cooperatively breeding species, individuals tend to help raise related offspring, thus increasing their own fitness indirectly; however, even within these systems, considerable variation exists in helping behavior among individuals that cannot be explained by relatedness. Here, we predicted developmental experience may help explain some of this variation. In particular, we focused on developmental stress hormones which have been shown to be predictive of adult morphology, physiology, and behavior in other species. Using the obligate cooperative breeding chestnut-crowned babbler (*Pomatostomus ruficeps*), we measured feather corticosterone in chicks just before fledging. We predicted feather corticosterone would be related both to developmental environment (specifically, number of helpers) and to adult cooperative behavior. Helpers in this species help by provisioning nestlings and, unsurprisingly, the number of helpers is positively related to the amount of food provisioned to each brood. Surprisingly, we found a positive relationship between feather corticosterone and helper number. Analyses between feather corticosterone and adult provisioning behavior are still ongoing. However, identifying the proximate mechanisms that drive variation in cooperative behavior may also begin to explain the ultimate mechanisms by which cooperative breeding has evolved.

48-3 LIGUORI, AL; Stony Brook University; *alyssa.liguori@stonybrook.edu*

Exploring local adaptation to salinity and temperature variability in the copepod Tigriopus californicus

Local adaptation has been studied in a broad range of taxa for decades. However, we have limited understanding of how often local adaptation occurs in variable environments. Whether phenotypic plasticity can evolve in distinct ways among populations experiencing different patterns of abiotic variability is unclear. Abiotic conditions in coastal marine habitats can be highly heterogeneous, which might promote local adaptation. *Tigriopus californicus* (tidepool copepod) populations on San Juan Island, WA have distinct morphology and life history. The goal here was to test whether these differences are a result of local adaptation, and to quantify responses to different magnitudes of temperature variation. To identify potential selective pressures in the field, temperature and salinity were measured in high shore pools for 6 months. A common garden experiment with factorial combinations of 7 temperature and 2 salinity (32, 55 ppt) treatments was conducted on 3 populations. Two temperature treatments varied daily, both with an average of 20°C, but different ranges (low amplitude: 15-25°C, high amplitude: 10-30°C, 12:12 hour exposure). The other 5 treatments were the average, maximum, and minimum temperatures held stable. Fecundity, survivorship, and development were characterized across two generations. Preliminary results show differences in abiotic variability among sites, despite their geographic proximity. The experiment revealed strong effects of temperature on fecundity and survival, but these effects were not the same among populations. Abiotic patterns in the field did not seem to explain the observed population differences, thus limited evidence for local adaptation was found. For these populations, differences in selective pressures among sites might not be strong enough to overcome the influence of genetic drift.

P2-157 LIMA, AS; FERREIRA, LF; GOMES, FR; TITON, SCM*; University of São Paulo, São Paulo, SP, Brazil, University Center Fundação Santo Andre, São Paulo, SP, Brazil; *stefannychristie@gmail.com*

Thermal Sensitivity of Bullfrog's Immune Response Kept at Two Different Temperatures

Amphibian populations are declining worldwide. Thermal regimes alterations and emerging infectious diseases are often described as the most important factors associated with this pattern. Temperature change alters both pathogen physiology and host immune response performance against infection. The aim of this study was to characterize the thermal sensitivity of the Bullfrog's (*Lithobates catesbeianus*) immune response and the effect of acclimation at different temperatures (28°C and 34°C) on it. Male bullfrogs (n = 12) were kept on a climatic chamber at 28°C for seven days, then a blood sample was collected. After 30 days at 28°C, the animals were divided in two groups: maintenance at 28°C (n = 6) or 34°C (n = 6). New blood samples were taken 20 and 40 days after the group's settlement. Phagocytosis assays were conducted with the blood leukocytes, and bacterial killing ability (BKA) assays with the plasma. The assays were conducted at different incubation temperatures (5-40°C, 5°C range intervals). The incubation temperature affected BKA either on animals kept at 28°C and 34°C, with maximum values at lower temperatures (5-20°C), but did not affect the cellular response (phagocytosis). Although phagocytosis and BKA decreased over time for both animals kept at 28°C and 34°C, there was no shift on thermal sensitivity curves in function of maintenance temperature. Moreover, immune parameters were generally characterized by sustained high values in large range of incubation temperature, indicating an eurythermal feature of the Bullfrog´s immune response.

P2-212 LIN, K*; FEILER, A; CHU, W; GARCIA, N; ILTON, M; Harvey Mudd College, Claremont, CA; *klin@g.hmc.edu*

Understanding the Elastic Efficiency of Biological Springs

Organisms such as mantis shrimp and trap-jaw ants achieve amazing kinematic output using elastically-driven rather than purely muscle-driven power. In these latch mediated spring actuated (LaMSA) systems, an actuator (muscle) deforms a spring to store energy, with the loaded spring held in place using a latch. When the latch is removed, the stored elastic energy is rapidly released. During this unloading phase, the elastic material undergoes a large deformation at an extremely high rate. Examples of LaMSA systems in nature utilize a variety of biological spring materials and can differ in size by many orders of magnitude. Open questions remain about how materials and size-scale affect the limits of kinematic performance in LaMSA systems. Previous work has focused on the effects of size-scale and the degree of loading on elastic unloading. At constant degree of loading, velocity was independent of size-scale, while acceleration became larger for small systems. At high rates of unloading, materials became less efficient at releasing elastic energy. Our current work continues to explore the effects of and coupling between parameters such as size-scale, degree of loading, materials, and geometries. We focus on connecting the ideas of energy efficiency of elastic materials to more traditional materials testing approaches that can be applied to elastic biomaterials. Using a series of synthetic elastomers, we find a relationship between the resilience measured in a tensile test and the phase angle measured with dynamic mechanical analysis. By probing the fundamental materials physics of composite elastic structures, the biomechanics of latch-mediated spring actuated organisms can be better understood.

S2-8 LINDNER, M; VIITANIEMI, H; VAN OERS, K; VISSER, M; LAINE, V; VERHAGEN, I; HUSBY, A*; Netherlands Institute of Ecology, University of Helsinki, Uppsala University; *arild.husby@ebc.uu.se*

Epigenetic regulation of seasonal timing of reproduction

Seasonal timing of reproduction in plants and animals is an important trait closely associated with fitness but the molecular genetic mechanism behind seasonal timing is not well understood. I will review some recent attempts at understanding the molecular genetic mechanism behind timing of reproduction where we have used within indivdual (longitudinal) sampling to examine changes in DNA methylation across the breeding season using great tits (Parus major) as a model organism. Our recent work demonstrate both temporal genome wide change in methylation over the breeding season and also rapid changes in methylaiton in the regulatory region of some previously identified reproductive genes around the date of first egg laying in this species. These findings demonstrate and further establish that epigenetic mechanisms such as DNA methylation can be an important mechanism in regulating seasonal timing of reproduction.

AMS-1 LINDSAY, SM; University of Maine, Orono; *slindsay@maine.edu*

The Art of Seeing: Using Microscopy to Power STEAM Learning in Biology

Close observation is central to both art and science, as practitioners in both disciplines describe, compare, and seek to understand or interpret the natural world. Indeed, as the artist and writer Guy Davenport noted, "The vision by which we discover the hidden in nature is sometimes called science, sometimes called art". In the last decade, the movement to integrate Science, Technology, Engineering and Mathematics with Arts and Humanities (i.e., STEAM learning) has gained traction in K-12 education. A recent National Academies report (2018) examines the case for integrating humanities and the arts in undergraduate STEM education. Microscopy provides an excellent vehicle for engaging all kinds of students in integrative (STEAM) learning about Biology and for encouraging them to observe the world closely. In this address, I will highlight activities and approaches that use microscopy to engage learners of all kinds, examine how using microscopes changes students' attitudes about science and biology, and explore the intersection of microscopy and visual art.

S4-6 LIPSHUTZ, SE*; ROSVALL, KA; INDIANA UNIVERSITY; *slipshut@iu.edu*

Neuroendocrinology of sex-role reversal

Across the animal kingdom, females of some species are "sex-role reversed," suggesting they face stronger competition for mates than males do. Sex-role reversal is often associated with additional life history traits, such as male-only parental care and female-biased dimorphism in ornamentation, weaponry, and body size. While much attention has been paid to behavioral and morphological sex differences, less is known about the physiological mechanisms underlying sex-role reversal. We review the hormonal, neural, and genomic evidence that females are physiologically 'reversed' from systems with 'conventional' sex roles. We evaluate largely untested hypotheses on the interplay between sex-roles, physiology, and the resolution of trade-offs between mating and parental effort.

P2-161 LISONDRO AROSEMENA, AK*; MENDEZ NARVAEZ, J; Universidad Autonoma de Chiriqui, Smithsonian Tropical Research Institute; *astridlizondro23@gmail.com*

Thermal Ecology in Two Neotropical Frogs with Different Degrees of Terrestriality

Thermal adaptations and thermoregulatory strategies are used as predictors of physiological performance in ectotherms and may help to understand diversity and distribution patterns. In frogs, aquatic to terrestrial breeding transitions have evolved independently many times, leading to new physiological challenges as they face new, warmer, and more variable thermal environments on land. We hypothesized that species that have evolved terrestrial breeding differ in their thermal parameters (critical thermal maxima and preferred temperature) and thermoregulatory strategies compared to aquatic-breeding species, and higher thermal tolerance may facilitate terrestrial breeding. We studied two sympatric and closely related Neotropical foam-nesting frogs during their reproductive season: *Engystomops pustulosus* (*Ep*) that breed in temporary ponds and *Leptodactylus fragilis* (*Lf*) that build terrestrial subterranean chambers in areas that will flood. We found that females of *Lf* preferred higher temperatures in a thermal gradient than females of *Ep*. Data on environmental temperatures in the reproductive sites of each species will be used to test for a match with their preferred temperatures. Females of *Lf* also had higher CTMax than either females or males of *Ep*. Within both species, females tended to have a higher CTMax than males, but in *Ep* females after oviposition had a significantly lower CTMax than either females with eggs or males. Weight, but not snout-vent length, was correlated with CTMax and females in both species were heavier than males, except for *Ep* females after oviposition. Altogether, our results suggest that biological aspects such as reproductive status, sex and body condition may affect thermal parameters that are correlated with transitions to terrestrial breeding.

102-2 LITTLER, A*; GARCIA, M; TEETS, N; University of Kentucky; *asli226@uky.edu*

Does a Well-Balanced Diet Keep You Going When the Going Gets Cold?

Cold stress is detrimental to insect fitness and has driven the evolution of coping mechanisms for low temperature stressors. Ecological factors including seasonal shifts in day length and temperature influence an insect's cold tolerance, and recent studies have suggested that diet may also impact insect cold tolerance. However, the components of an insect's diet that are most important for cold tolerance, and how their effects differ among genetically distinct individuals, remain unclear. In this study we determine which dietary component are crucial to insect cold tolerances using the fruit fly, *Drosophila melanogaster*. Specifically, we examine the impact of four commonly used fly foods on: 1) insect cold tolerance, 2) reproduction, and 3) the ability to maintain reproduction after cold stress. We selected six, distinct isogenic fly lines which vary in basal cold tolerance and reared them on four standard diets that vary in their nutritional content. We then measured cold shock survival, total reproductive output, and reproductive output following cold exposure. Current results show that nutrition significantly influences cold tolerance, and that these dietary effects vary by genotype. In ongoing experiments, we are identifying whether diet affects reproduction and the protective effects of diet on reproduction following cold stress. Ultimately, we seek to understand the extent to which diet influences fitness-relevant traits like cold tolerance and the importance of diet for the evolution of these fitness-related traits. Practically, our results indicate that diet selection is an important consideration when designing a cold tolerance experiment.

S6-4 LIU, H*; RAO, C; NAKATA, T; Chiba University; *hliu@faculty.chiba-u.jp*

Robust strategies in owl silent flight: aerodynamic force production and noise suppression

Owls are widely known for silent flight, achieving remarkably low noise gliding and flapping flights owing to their unique wing morphologies, which are normally characterized by leading-edge serrations, trailing-edge fringes and velvet-like surfaces. Recently we discovered that leading-edge serrations can passively control the laminar-turbulent transition over the upper wing surface, i.e. the suction surface at all angles of attack ($0° < AoA < 20°$), and hence play a crucial role in aerodynamic force and sound production; and there exists a tradeoff between force production and sound suppression [Rao et al 2017]. The leading-edge serrations were further confirmed to be of potential gust fluctuation rejection or robustness in aerodynamic performance while the tradeoff between turbulent flow control (i.e. aero-acoustic suppression) and force production in the serrated model holds independently to the wind-gust environments [Rao et al 2018]. Moreover, three-dimensional effects of morphological features and location of the leading-edge serrations on aeroacoustics have been newly evaluated to be of great importance through three-dimensional modeling and Large Eddy Simulations (LES). Inspired by the unique owl's wing structures, we thereby developed a prototype biomimetic rotor for drones, successfully achieving a remarked noise-reduction [Noda et al 2018]. Our results demonstrate that the owl-inspired leading-edge serrations could hold the key as a robust micro-device to noiseless multi-rotor drones and aircrafts as well as wing turbines and other fluid machineries.

S11-8 LIU, Y; University of Texas Southwestern Medical Center, Dallas; *yuxiang.liu@utsouthwestern.edu*

The Era of Single-Cell Sequencing: Lessons from Comparative Cognition of Model Organism

Comparing with non-human primates, we evolved unique cognitive abilities which have been attributed to high volume of human brain especially the expansion of prefrontal cortex (PFC). To understand gene regulatory mechanism underlying human brain specialization, a comparison of cortical transcriptomes between human and closely related primates revealed that human CLOCK (huCLK) is up-regulated in human PFC. However, how huCLK results in human brain specializations? To address the question, we firstly generated humanized (HU) mice which overexpress huCLK in CLK-knockout mice to mimic relative expression of CLK in human versus other primates. Through a battery of cognitive tests, we found that HU mice showed similar activity, anxiety, and general learning abilities as wildtype (WT) mice, while HU mice outperformed WT mice in social learning and cognitive flexibility both of which are PFC dependent cognitive abilities. We then leveraged immunohistochemistry to compared neuroanatomical characteristics of PFC between genotypes. Results show that HU mice did not alter cortical thickness and lamination while they possessed higher density of neuron and oligodendrocyte than WT mice. To understand gene regulatory mechanism behind the alternations of HU mice, we did single-nuclei RNA-Seq in PFC of young adult mice (8 weeks). Preliminary analysis shows that nuclei of HU mice are enriched in an interneuron cluster and an oligodendrocyte cluster. More results, such as differential expression and pathway analysis are in progress. In summary, we found that overexpression of huCLK resulted in improved cognitive flexibility, higher neuron and oligodendrocyte density, and alternation of cell composition in PFC. These results suggest that huCLK might play an important role in proliferation and differentiation of cortical cells under the evolution of human brain.

P3-17 LLEWELLYN, HJ*; HARE- HARRIS, A; HRANITZ, JM; SURMACZ, CA; SURMACZ, Cyn; Bloomsburg University; *csurmacz@bloomu.edu*

Sublethal Doses of the Neonicotinoid Imidacloprid Alters mRNA Expression in Cellular Stress Pathways in Honey Bees

Global declines in honey bees have been linked to the widespread use of pesticides. Sublethal doses of the neonicotinoid imidacloprid have been shown to cause physiological and behavioral changes that negatively impact hive health. Work in our laboratory has shown that bees fed sublethal doses of the neonicotinoid pesticide imidacloprid displayed impaired motor responses and elevated levels of the cellular stress protein HSC70 and superoxide dismutase (SOD), an indicator of oxidative stress. The goal of this research was to determine how sub-lethal doses of the neonicotinoid imidacloprid alter gene expression and cellular pathways. We investigated the effects of the $1/20^{th}$ of the LD_{50} dose of imidacloprid (18 ng/bee) on the transcriptome. Bees were assigned to a control group (1.5 M sucrose) or an imidacloprid treatment group (0.9 ng/bee) and heads were excised at Time 0 h or Time 4 h. Bee brains were dissected over dry ice and RNA was isolated. Genome-wide RNA sequencing analysis was conducted to identify altered gene expression patterns in the treatment group. Of the 11,000 genes sequenced, 30% were differentially expressed. Altered cellular functions were determined using functional clustering analysis in DAVID and KEGG pathway analysis. The expression of genes in the peroxisome pathway were altered, supporting our previous work showing elevated SOD and cellular stress responses following imidacloprid treatment. Additionally, the FOXO Signaling Pathway differed between the treatment and the control groups. Our results also indicate that imidacloprid has a potential broader impact on other cellular processes, including signal transduction and metabolism.

46-7 LOCHAB, AK*; EXTAVOUR, CG; Harvard University; *alochab@g.harvard.edu*

Traveling Without a Destination: Primordial Germ Cell Migration in a Hemipteran Insect

In many animal species, the first line of restricted germ cells (Primordial Germ Cells) are formed in a location independent from the site of gonad development. In these species, the germ cells must migrate to the future gonad location before they are incorporated into the developing gonads. In some animals, such as *Drosophila melanogaster*, the tissue where PGCs will end up has already been specified when the PGCs begin migrating. However, in other animals, including the hemipteran insect, *Oncopeltus fasciatus*, PGCs begin migrating before the cells of their final resting place have been formed or been given an identity. In this insect, the mechanisms used by PGCs to find their location while the abdominal segments are growing and being specified around them remain unknown. Similarly, during this process, whether PGCs exhibit active cell migration and/or passive movement driven by the surrounding tissue that is growing is an open question. As a first step towards elucidating these mechanisms, we aim to characterize the cellular dynamics of PGCs moving through the surrounding embryonic tissue. We also aim to determine the molecular identity of the directional cues that eventually guide PGCs to the correct abdominal segments. Here we present progress on (1) a quantitative description of PGC migration, and (2) a candidate gene approach to determine the molecular basis of this process.

113-7 LOCPORT, JK*; DANIEL, TL; WILLIS, MA; University of Washington, Case Western Reserve University, University of Washington, Case Western Reserve University; *jkl60@case.edu*

Agent-based Models of Insect Odor Tracking Based on Behavior Experiments

Previous behavioral studies in American cockroaches, *Periplaneta americana*, show they can track an odor plume even when all but a small portion of one antenna is lost. Their tracking performance improves with increasing amounts of antenna present whether bilateral symmetry is preserved or not. These observations lead us to propose an agent based model featuring spatial and temporal integration across an antenno-topic map to describe how *P. americana* tracks an odor plume. We focus on three models of how brains use the odor information detected by antennae. One model integrates across the antennae spatially and temporally, one compares between the two antennae bilaterally, and one compares concentration over time. We tested these models with nine different antennal configurations consisting of three arrangements (two bilaterally symmetric antennae, one antenna on the left, or one on the right) and with three different antennal lengths (10 mm, 20 mm, and 40mm). We modeled the plume using a computational fluid dynamic model coupled to diffusive mass transport. Additionally, electroantennogram and photo-ionization detector recordings provided validation of the plume structure. The integrative model is relatively inefficient (search paths are long), but robust against any type of missing antenna segments. Whereas, the bilateral comparison modelis more successful (higher fraction finding the source) but fails with a loss of one of the two antennae. Meanwhile, the purely temporal comparison model is remarkably robust, showing high levels of success in all but the highest noise trials.

P3-129 LOGSDON, M; University of Washington; *mnwilson003@gmail.com*

LiEFi (Light-Energy Fish): Using Simple Bio-Mechanical Models to Simulate Climatic Changes in Fish Communities

There are many different ways to model climatic changes: through computer modeling, idealized simulations, or real-life mechanical models. This project uses a simple fish-like ROV model with an idealized "fish-eye" ,a rear thruster, and a three dimensional accelerometer to simulate the sight ability, energy use, and stability in flow of a pelagic fish in an estuarine environment. The robotic build, LiEFi, or Light-Energy Fish, measures the ideal speed and orientation for stability at different flow speeds, as well as direct measurements of spectral reflectance in the red, blue, and green wavelengths at different depths, and ideal fin shape. Information gathered during the design / build / and testing procedure addressed key ocean science and technology questions using biomechanical modeling techniques; what worked, what did not, and how to design a process that allows for practical approaches to modeling solutions. The data collected shows the effectiveness of the biomimetic research vessel in measuring stability, power, and light levels. This data is informative of the energy requirement and efficiency of organisms in any given habitat and how the effects of climate change in estuarine environments may impact movement and behavior. The project exists as a way to show that even simple, innovative modeling techniques based on straightforward means are capable of producing compelling results and providing information on possible future behavioral changes that can be used to manage these environments.

103-5 LOHMANN, KJ*; BROTHERS, JR; LOHMANN, CMF; University of North Carolina at Chapel Hill; *klohmann@email.unc.edu*

No Place Like Home: Sea Turtles and Geomagnetic Imprinting

Various marine animals migrate across vast expanses of ocean before returning as adults to reproduce in the areas where they originated. How animals accomplish such feats of natal homing has remained an enduring mystery. Studies with sea turtles, however, have provided evidence that turtles imprint on the magnetic field of their home area when young and use this information to return as adults. Behavioral experiments indicate that turtles have the sensory abilities needed to detect the unique ‘magnetic signature' of a coastal area. In addition, analyses have revealed that subtle changes in the geomagnetic field of the home region are correlated with changes in the distribution of nests along beaches. A relationship between population genetic structure and the magnetic fields that exist at nesting beaches has also been detected, consistent with the hypothesis that turtles recognize their natal areas on the basis of magnetic cues. Taken together, the results imply that geomagnetic cues play a central role in the natal homing of sea turtles and, in many cases, can fully account for a turtle's ability to return to a specific home beach. Similar mechanisms may underlie long-distance natal homing in diverse marine migrants such as fish and marine mammals.

82-3 LOLAVAR, A*; WYNEKEN, J; Florida Atlantic University; *alolavar@fau.edu*

The impact of sand moisture on the temperature-sex ratio responses of developing loggerhead (Caretta caretta) sea turtles

All species of sea turtles exhibit a cooler male/warmer female temperature-sex ratio response. Field and experimental studies on loggerhead sea turtle sex ratios suggest that increased sand moisture impacts sea turtle sex ratios with, and perhaps beyond, a cooling effect. This study examines how varying sand moisture impacts the embryo's response to temperature. In 2016-2018, we collected loggerhead sea turtle (*Caretta caretta*) eggs and transferred them into boxes. Across three years, eggs were incubated at temperatures ranging from 28.0°C to 33.0°C. Groups of eggs were incubated in one of three volumetric moisture contents: low, medium, or high. Temperatures inside the group of eggs were recorded throughout incubation. Hatchlings were transported to the Florida Atlantic University Marine Laboratory where they were raised for 2–3 months and sex was identified laparoscopically. We calculated temperature response curves for groups of eggs incubated at each moisture level. Pivotal temperatures did not different among eggs incubated in different sand moistures. The transitional range of temperatures (TRT) for eggs incubated in high moisture and low moisture was narrower than the TRT for eggs incubated in medium moisture. The results of this study are crucial for understanding how sea turtle embryos respond to temperature under different moisture conditions. Current sex ratio predictions rely on the embryos response to temperature only and may inaccurately estimate sex ratios especially during periods of heavy rainfall or drought.

85-2 LOMAX, JJ*; BRAINERD, EL; Brown University, Brown University ; *jeremy_lomax@brown.edu*

Comparative Skeletal Kinematics of Overbite-Shearing and Compressive Chewing Cycles in a Pacu Fish, Piaractus brachypomus

Pacus are a group of herbivorous fishes known to extensively process a variety of plant materials with their oral jaws by means of their robust incisiform teeth. This method of mechanical breakdown, while common in mammalian species, is less frequently observed in fishes, leaving the biomechanics of this processing behavior largely unknown. Using X-ray Reconstruction of Moving Morphology (XROMM), this study found similarities between the processing behavior of one species of pacu, *Piaractus brachypomus*, and a chondrichthyian species, *Potamotrygon motoro*,. Much like the freshwater stingray, *P. brachypomus*, alternates between periods of short compressive chews, where the amplitude of mandible rotation is small but food is still actively engaged between the teeth, and periods of extreme rotation of the lower jaw which result in the shearing of food between the mobile dentary and the stationary premaxillary teeth. In the pacu species, the exaggerated overbite motions of the lower jaw are facilitated in part by the morphology and motions of the hyomandibula. In most ray-finned fishes, the hyomandibula-neurocranial joint is a straight and flat hinge joint, effectively permitting only abduction and adduction of the suspensorium. However, the articular surface of the hyomandibula in *P. brachypomus*, is rounded at its joint with the neurocranium, contrary to the typical actinopterygian condition, and contrary to the largely carnivorous relatives of the pacu, piranhas. The rounded surface appears to permit rostro-caudal rotation of the suspensorium which in turn facilitates periods of overbite shearing during the pacu processing cycle.

58-6 LONG, JH*; AARON, E; LIVINGSTON, K; HAWTHORNE-MADELL, J; Vassar College, Poughkeepsie, NY, Colby College, Waterville, ME; *jolong@vassar.edu*

Evo-Devo Biorobotics: Masquerading Genomes and the Mapping of Genotype to Phenotype in Embodied Agent Models

By Barbara Webb's codification, biorobots test hypotheses about biological systems. While those systems may be particular organisms, they may also be processes. Evolution, for one, has been modeled in embodied robots to test hypotheses about the origin of early vertebrates. But explicit models of development, the mapping of genotype to phenotype, have been wanting. Thus our work extends evolutionary biorobotics to include development, allowing the two processes to be studied as they interact. Specifically, we test the hypothesis that random errors in transcription feed back to the genotype over generational time to increase genetic variance of the population and alter the evolution of morphological complexity. Key to this process is that random errors in development create *masquerading genomes*, individuals with indeterminate mapping of genotype to fitness. We digitally simulate populations of autonomous mobile 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. We simulated 11 levels of genetic mutation rate and transcription error rate in 10 populations of 60 robots over 100 generations, with fitness determined by a simple locomotion task. In the presence of directional selection, genetic variation was proportional to the rate of transcription error. Moreover, transcription error and mutation acted independently and in different ways on the evolutionary dynamics of the population. This work was funded by the U.S. National Science Foundation (grant no. 1344227, INSPIRE, Special Projects).

P1-96 LONG, HE*; FOLTZ, SL; DAVIS, JE; SAMUELS, T; Radford University; *hlong14@radford.edu*

ScaryFeeder: Gauging Behavioral Responses When Introduced to Potentially Threatening Stimuli in Wild Songbirds

Accurate recognition of and appropriate response to predators can be a matter of life and death to free-living animals. Response to predator-related stimuli comes with trade-offs; foraging animals must give up feeding and expend energy to escape. This study aims to understand how different songbird species perceive and react to an array of visual stimuli, specifically images of various potential threats. Using a computerized bird feeder, we displayed different types of visual stimuli to the birds during their feeding visits, including eyespots, various predators, and human faces. We compared the responses of songbird species to these stimuli and found there is a significant difference in reactions that is species-dependent, as well as a difference depending on the type of stimuli. For example, our initial analyses comparing images of predator and competitor species showed that house sparrows (Passer domesticus) were less likely to respond to any of the stimuli, while more timid species like American goldfinch (Spinus tristis) reacted more aversively. Eastern gray squirrels (Sciurus carolinensis) and mourning doves (Zenaida macroura) totally disregarded all stimuli. All songbird species appeared more attentive to predator images than to non-predators. Analyses of the eyespots and human faces data are on-going, but we expect to see similar species-dependent and stimuli-dependent patterns within these sets of data as well. Such a pattern would suggest that recognition of the predators tested here is common across various songbird species, but that species may assess the immediate risk of remaining to feed vs. costs of fleeing differently.

P3-173 LONGMIRE, AE*; CLARK, AE; EARLEY, RL; GRESHAM, JD; University of Alabama; *aelongmire@crimson.ua.edu*

Self-Compatibility in a Self-Fertilizing Fish

The mangrove rivulus fish (*Kryptolebias marmoratus*) is one of two self-fertilizing vertebrates; populations consist of hermaphrodites and males. Males result from sex change, and the likelihood to change sex is genotype-dependent. Wild populations vary considerably in rates of outcrossing between hermaphrodites and males, but selfing is the primary mode of reproduction in most populations. In an ongoing attempt to understand when and why outcrossing occurs and why it varies among populations, we questioned whether the ability to successfully self (i.e., self-compatibility) varies among hermaphrodites. We hypothesized that some hermaphrodites would lay more unfertilized eggs and/or have reduced hatching success. We also hypothesized that self-compatibility would vary as a function of age or the lineage's propensity to change sex to male. We raised 227 individuals from hatching, derived from genetically distinct lineages that vary in their propensities to change sex. Beginning at 67d post-hatch, eggs were collected weekly from each fish, examined to determine if they were fertilized, unfertilized, or dead, and kept until they hatched as a measure of hatch success. Preliminary data suggests that 95% of eggs laid are fertilized while the other 5% are dead and/or unfertilized. The lineages' propensities to change sex did not predict the proportion of fertilized, unfertilized, or dead eggs. However, older fish laid more dead eggs, which likely were deposited in an unfertilized state. These results suggest that increased rates of outcrossing in some populations might be due to its age structure, with populations having either longer-lived fish or a smaller proportion of younger fish also exhibiting more outcrossing. As a result, male reproductive success might be contingent upon finding older hermaphrodites that deposit unfertilized eggs.

29-2 LONGO, SJ*; COX, SM; AZIZI, E; ILTON, M; OLBERDING, JP; ST. PIERRE, R; PATEK, SN; Duke University, Pennsylvania State University, UC Irvine, Harvey Mudd College, UC Irvine, Carnegie Mellon University; *sjlongo@ucdavis.edu*

Beyond power amplification: new insights from latch-mediated spring actuation (LaMSA)

Organisms across the tree of life have evolved mechanisms to perform extremely rapid movements by temporarily storing energy in elastic structures (springs) and then mediating the release of that energy using latches. These types of mechanisms were first described in jumping insects, where it was shown that the power output of a spring-actuated mechanism mediated by latches resulted in mechanical power outputs exceeding muscle power outputs. The phenomenon, called power amplification, became an important diagnostic tool for biologists to discover elastically-driven animal movements. With the introduction of accessible high-speed high-resolution video equipment, spring-actuated movements have been described in a wide diversity of organisms and for a surprising array of uses. Examples now include many organisms that do not possess muscle, and are therefore not limited by muscle power limits, such as plants and fungi that use elastic mechanisms for ballistic seed or spore dispersal. In addition, while the presence of latches in elastic mechanisms has long been appreciated, recent work highlights the central role that latch characteristics play in mediating energy transformations. We will highlight how focusing on the shared underlying components in these systems (springs, latches, and actuated masses) has given new insights into the trade-offs and considerations for diversity and tuning. Some examples utilizing the latch-mediated spring actuation (LaMSA) framework in snapping crustaceans and rapid feeding mechanisms in fish will illustrate how LaMSA can stimulate new avenues for studying evolution, control, and performance.

58-4 LOPEZ JUAREZ, J*; VENTURA, D; ZHANG, L; DAVIDSON, B J; Swarthmore College; *jlopezj1@swarthmore.edu*

Developmental systems drift in tunicate neural gene regulatory elements

Developmental mechanisms often remain stable despite changes in the architecture of underlying gene regulatory networks (GRNs). This evolutionary process is termed developmental systems drift. We explore developmental drift through comparisons of tunicate GRNs, including the recently assembled genomes of Corella inflata and Boltenia Villosa along with that of the well-characterized model organism, Ciona robusta. We have begun to deploy this comparative analysis to examine changes in the regulatory elements for three different neural genes (Otx, DMRT, and Foxc). Despite any discernable sequence conservation, regulatory elements for the Corella Inflata orthologs to these genes are capable of driving neural expression in Ciona embryos. These Corella elements contain binding motifs for upstream trans-factors (Ets and GATA) characterized in Ciona. This preliminary data suggests that drift has occurred in the arrangement of binding sites while upstream trans-factor inputs have remained constrained. However further testing is required to determine whether these candidate sites are required for regulation of neural gene expression in Corella. We have also identified regulatory elements for Boltenia orthologs of two of these neural genes (DMRT and Otx) along with three cardiac progenitor lineage genes (Mesp, FoxF and Hand-like). Corella and Ciona are much more closely related to each other then they are to Boltenia villosa. Thus, comparisons between all three species will help to address questions about the rate and nature of developmental drift across different levels of divergence.

12-1 LORD, NP*; WELLER, HI; SHARKEY, CR; Louisiana State University, Brown University, University of Minnesota; *nlord@lsu.edu*

The Color of Jewels: Evolution of Color Patterns Across a Speciose Lineage of Jewel Beetles

Animal coloration is a fundamental aspect of visual communication (*e.g.*, sexual selection, aposematism) and crypsis (*e.g.*, camouflage, mimicry). Insect coloration is largely determined by either pigmentation, local nanostructures, or a combination of both. A number of structural optical mechanisms are employed, producing striking visual effects including iridescence and polarization. While the totality of visual signal produced is incredibly complex to tease apart in a biological context, an important initial step is to determine what aspects of visual signal(s) are present and how they are produced. Recently, a number of new image analysis packages and toolboxes (*e.g.*, colordistance, micaToolbox, NaturePatternMatch, pavo2, patternize) have been released. Here we used these tools to analyze digital image data across a speciose lineage of jewel beetles (Buprestidae: *Chrysochroa*), a group that displays a dazzling array of both structural iridescence and pigmented colors, alongside a visual system that exhibits diverse wavelength sensitivity. We used these data to investigate phylogenetic, taxonomic, biogeographic, and natural history components of a beautiful, yet classification-challenged group of economically important beetles. While visual signals will always remain an inherently complex system to study both qualitatively and quantitatively, repeatable measurements and statistical analyses of these data are advancing rapidly, paving the way for foundational exploration necessary to inform more rigorous spectrophotometric measurements and to precede formative behavioral studies.

41-6 LOVE, AC*; GRISHAM, K; DURANT, SE; University of Arkansas, Oklahoma State University; *ashley.c.love@okstate.edu*

Perception of Infection: Public Information about Disease Influences Immunity in Songbirds

Sick animals often provide visible cues that they are infected through behaviors such as lethargy, and physical signs, such as inflammation and lesions. The detection and avoidance of sick conspecifics is common among animals, but less is known about how viewing diseased conspecifics influences an organism's physiological state. Work in humans suggests that visual cues of infection are capable of stimulating the immune system, presumably to help the body prepare for an impending immune threat. Whether visual cues of disease can also induce changes in immunity in non-human organisms is not well understood, however if organisms can adjust investment in immune defenses to match the probability of pathogen exposure this could have important implications for disease transmission dynamics. The avian pathogen *Mycoplasma gallisepticum* (MG) is an ideal tool for investigating how the perception of social cues of disease shape immunity in healthy individuals, as infection with this bacterium causes obvious visual signs of infection, including lethargy and conjunctivitis. We tested whether social information transmitted by MG-infected individuals can stimulate innate immune responses in domestic canaries housed in visual contact with either healthy or MG-infected conspecifics. We found that immune profiles differed between birds viewing sick and healthy conspecifics. Specifically, we observed immune activation in healthy birds viewing MG-infected individuals around 6-12 days post-inoculation, which is when infected stimulus birds exhibited the greatest degree of disease pathology and lethargy. These data indicate that social cues of infection are capable of altering immune responses in healthy individuals and suggest that public information about disease could play a role in shaping individual variation in disease susceptibility.

41-3 LOVE, AC; DURANT, SE*; WILDER, SM; YOUSEFF, NH; U Arkansas, Ok State; *sedurant@uark.edu*

Macronutrients, the microbiome, and illness-induced feeding behavior: Are birds shaping immune responses through selective feeding?

The importance of specific macronutrients to immune processes is partly due to their ability to provide the building blocks of immunoproteins and fuel expensive immune responses. More recently we have begun to appreciate that macronutrient content of the diet also can affect immune processes through the gut microbiome. In this study, we conducted two experiments. The first explored whether birds exhibit shifts in the gut microbiome community and immune responses when fed isocaloric diets differing in macronutrient ratios, specifically lipids and proteins. We then designed an experiment to determine whether birds alter macronutrient intake when presented with an immune challenge. We found that macronutrient content of the diet changed the relative abundance of microbes, but not the diversity of microbes present in the gut. Despite changes in the gut microbiome, we did not find effects of diet on the physiological endpoints we measured, complement activity and corticosterone concentrations. However, birds given the choice of isocaloric diets high in either protein or lipids, then injected with an immune antigen (lipopolysaccharide; LPS), exhibited illness-induced anorexia that was macronutrient specific. Birds decreased intake of the protein rich diet, but maintained intake of the lipid rich diet. These results indicate that birds exhibit selective feeding when immune challenged, presumably because lipids provide a larger caloric gain than proteins, and proteins can benefit pathogen growth. Although we did not detect macronutrient-specific effects on complement activity, immune effects may still occur and could be more apparent with a more severe immune challenge.

P2-5 LOWNDS, BI*; TOPPING, NE; JOST, JA; Bradley University, Peoria, IL; *blownds@mail.bradley.edu*

The Effect of Clumping Behavior on the Survival, Growth, and Cellular Physiology of the Zebra Mussel (Dreissena polymorpha) in a Central Illinois Population

The invasive zebra mussel (*Dreissena polymorpha*) has caused significant ecological and economical damage since its introduction to the United States. While zebra mussel physiology has been examined for a variety of environmental conditions, less is known about the cellular processes during stressful fluctuations. Also, given the variability in reported values for both optimal and lethal temperatures, it is challenging to develop biologically relevant laboratory experiments for a specific population. Therefore, our objectives were to (1) determine the optimal conditions for a zebra mussel population at Banner Marsh by measuring survival, growth, and cellular physiology (via cellular stress markers) to environmental parameters (water quality, food quantity, and temperature), and (2) investigate whether clumping behavior altered mussel performance. Field enclosures were deployed for four weeks in May and mid-June 2018. Mussels were either allowed to clump freely as they do in nature or divided into individual chambers. While water quality and food quantity varied over time, conditions remained within the optimal ranges. Mussel survival was consistently high for both treatments and months. On average, mussels experienced greater shell growth and lower tissue loss when they were housed individually, suggesting that clumping negatively affects growth. Yet, clumping behavior did not produce significant differences in the levels of cellular markers. Mussels experienced greater shell growth and lower tissue loss in May than in June, which may be attributed to the fact that water temperature regularly exceeded 31°C in June/July. These results were corroborated by significantly higher heat-shock protein 70 levels in June/July.

P2-112 LOZIER, NR*; SISNEROS , JA; University of Washington; *nlozier@uw.edu*

Changes in Saccular Hair Cell Density During Ontogeny of the Plainfin Midshipman Fish

Plainfin midshipman fish (*Porichthys notatus*) are a marine teleost species that relies on the production and reception of acoustic communication signals for mating, and therefore development of the auditory system is important for survival and reproduction. Previously, free swimming juvenile and nest attached larval midshipman were found to behaviorally startle in response to acoustic pure tones, indicating functional auditory and/or lateral line systems at these stages. Also, inner ear physiology studies show that juveniles and sexually mature adult midshipman have similar peripheral auditory sensitivity to frequencies contained in midshipman acoustic signals, with adult hair cells being more sensitive at higher frequencies than juveniles. However, it is unclear whether inner ear hair cell density changes during ontogeny from larvae to sexually mature adults and whether changes in inner ear hair cell density play a role in ontogenetic changes in midshipman hearing sensitivity. We quantified hair cell density by staining hair cell stereocilia bundles with fluorescently labeled phalloidin in larval, juvenile, and adult midshipman saccules, the primary auditory end organ in most fishes. We found that saccular hair cell density decreases from larvae to adults but the estimated total number of hair cells increase as a function of fish size and saccule macula area. The adaptive significance of early development of the auditory system is discussed.

P1-13 LUC, HM*; BERNING, DJ; ADAMS, H; GROSS, JB; University of Cincinnati, University of Cincinnati ; *luchm@ucmail.uc.edu*

Expression Analysis of In-Frame Indel Mutations in Astyanax Cave- and Surface-Dwelling Fish

Troglobites exhibit extreme phenotypic changes such as eye loss, albinism, and expanded non-visual senses. The Mexican tetra, *Astyanax mexicanus*, includes a cave-dwelling morph which harbors a number of regressive phenotypes that can be compared to closely-related surface-dwelling morphs. Despite clear phenotypic differences between these morphs, less is known of the genetic underpinnings of these traits. To identify putative genetic differences, we screened the *Astyanax* genome for indel mutations using RNA-sequencing reads derived from three independent populations. We confirmed the presence of seven indel mutations in genes associated with blood physiology, growth factor signaling, and collagen structure. Six mutations differed in the surface-dwelling population, with one varying in the Tinaja cave population. Here, we present *in situ* hybridization (ISH) analyses at three embryonic stages, designed to visualize expression differences of these genes between populations. Two genes, *mki67* and *ghrb*, were expressed at substantially higher levels in cavefish, while expression of *plg* appeared to mark the developing liver, which grows at a much faster rate in cavefish compared to surface morphs. Three genes showed rather diffuse staining with similar expression patterns in all three populations. The gene *mlf1*, associated with blood progenitor specification, was expressed at similar levels in cave and surface fish, however the mutation is predicted to be deleterious in cave morphs. Overall, this work demonstrates the value of deep-sequencing as a means of identifying genomic mutations in an evolutionary system. The integration of whole-mount expression analysis deepens our understanding of how indel mutations may impact, or arise as a consequence of, life in total darkness.

132-4 LUCAS, KN*; LAUDER, GV; TYTELL, ED; University of Michigan, Harvard University, Tufts University; *kelsey.n.lucas@gmail.com*

Revisiting Dubois: the roles of positive and negative pressure in force production during fish swimming

In biomechanics classes, many of us have been shown the classic figure of pressure along a fish's body during swimming: high pressure on the head, negative pressure along much of the body, and positive pressure on the caudal fin. This figure was the result of a series of seminal works by Dubois and colleagues, who implanted pressure sensors into the skin of fish to measure the pressure gradients generated by their carangiform swimming movements. Using our new techniques for quantifying pressure and force distributions at high temporal and spatial resolutions, we revisit these findings. On average, the profile matches the classic figure. But instantaneously, the pressure gradients oscillate substantially around this average. Negative pressure contributes on average 42% of total thrust, and the anterior body produces 36% of total thrust. Further, temporal patterns of positive and negative pressure around the caudal fin suggest that negative pressure may play a key role in the timing of thrust delivery. These relatively subtle shifts can substantially change thrust production during swimming, and since swimming is an essential component of many fish behaviors, it is tied to the evolution of fish body forms and ecological roles. By leveraging these new methods to understand force production mechanisms, future work will reveal evolutionary pressures leading to the diversity of body forms we see in fishes today and inspire designs for fast, efficient underwater vehicles.

P1-237 LUCAS, KN*; KEEP, S; MOREY, S; University of Michigan, BiteScis, BiteScis and Abbott Lawrence Academy; *kelsey.n.lucas@gmail.com*

BiteScis: Teacher-Researcher Partnerships to Develop Engaging Research-Based Lessons

In recent years, it has become clear that we need for new approaches to STEM education to increase scientific literacy, engagement, and student retention. While several interventions have been made at the university level, interventions are also paramount in high school (grades 9–12). Nearly 20% of students in the ninth grade, an important year that marks the transition to high school, are not enrolled in a single science course. For those do take a science class, it's important to show students that what they are learning is both applicable to their lives today and the entry point to exciting future careers. BiteScis (bitescis.org) is dedicated to engaging students by exposing them to current science research that provides context to the content they are expected to master. BiteScis lesson plans are developed in collaborative partnerships between high school teachers and early career STEM researchers. The development process provides relevant, useful, and unique professional development for both "BiteScientist" partners. For the researchers, the proves offers an opportunity to practice effective communication and to achieve broader impact goals. Educators get to develop and share high-quality, standards-aligned and easy-to-implement. Both learn from each other. This poster will describe our model and present some of the biology resources currently available, free and fully-editable, on our webpage. Like all of our lessons, they affirm for students that the knowledge they are gaining in the biology classroom is the foundation for emerging research, from looking at ancient skeletons in search of an answer to osteoarthritis to growing bacteria on a giant Petri dish to understand antibiotic resistance.

P1-100 LUCIA, RL*; KINGSTON, ACN; SPEISER, DI; University of South Carolina; *rlucia@email.sc.edu*

The Impact of the Orbital Hood on Spatial Vision in the Snapping Shrimp Alpheus heterochaelis

Snapping shrimp (Decapoda: Alpheidae) produce shock waves with their snapping claws and they use these shock waves to stun or kill predators, prey, and competitors. Snapping shrimp also have an extension of their carapace—termed the orbital hood—that may protect their heads against these shock waves. The presence of armor over their eyes has led to the hypothesis that snapping shrimp have impaired visual abilities. We tested this hypothesis and found that the snapping shrimp *Alpheus heterochaelis* can see through their highly transparent orbital hood. To do so, we conducted behavioral experiments employing the optomotor responses of *A. heterochaelis* and showed that these snapping shrimp have an angular resolution of ~ 8 degrees. After demonstrating that *A. heterochaelis* has a functional visual system, we next asked if the presence of the orbital hood affects its visual abilities. The transparency of the orbital hood suggests it does not help or hinder vision in *A. heterochaelis*, but its high refractive index ($n = 1.525$) suggests it may influence vision in this species. To assess the impact of the orbital hood on vision in *A. heterochaelis*, we performed optomotor trials on a group of shrimp with intact orbital hoods and a second group of shrimp from which we removed the orbital hoods. Our stimuli consisted of alternating black and white vertical bars with angular widths of 2, 4, 10, and 20 degrees, as well as a control stimulus that was a uniform grey. From these trials, we found that snapping shrimp demonstrate spatial vision whether their hoods are present or absent. Further, preliminary results indicate shrimp with intact hoods may have more acute vision than those without hoods, and that orbital hoods may contribute to vision in snapping shrimp.

P1-152 LUDINGTON, SC*; MCKINNEY, JE; O'CONNELL, LA; Stanford University, Stanford, CA; *sarahl21@stanford.edu*
Role of Transcription Factor FOXP2 in Tadpole Social Communication
Communication of hunger during infancy is our first social interaction, laying the foundation for a healthy life by acquiring nutrition and establishing strong social bonds with caregivers. However, the neural basis of neonate social communication is not well understood. The Forkhead Box P2 (FOXP2) protein has been implicated in several human communication disorders, including deficits in language through abnormal development of motor neural circuits. This protein has also been linked to communication in songbirds, honeybees, and rodents. We studied the neural basis of neonate communication of nutritional need in Mimetic poison frog (*Ranitomeya imitator*) tadpoles. In this species, mothers feed tadpoles unfertilized eggs after the tadpole performs a begging display characterized by vigorously dancing back and forth. Preliminary data from our lab suggested that FOXP2-positive neurons are active during these tadpole begging displays. In this study, tadpoles were placed individually in an arena for 30 minutes with either an adult female, a conspecific tadpole, or a novel object as a non-social control. After quantifying the begging behavior displayed by the tadpoles, the tadpole brains were isolated and immunohistochemistry was used to visualize a marker of neural activation (pS6) and FOXP2. FOXP2 was widely distributed in the brain, with FOXP2-positive cells in the striatum, hypothalamus, and spinal cord, among other brain regions. In particular, FOXP2 colocalized with a marker of neural activation predominantly in the cerebellum and the thalamus. Current work involves generating brain-specific knockdowns of FOXP2 to functionally test the role of this protein in amphibian communication. Overall, this work points to a conserved role for FOXP2 in social communication and thus provide important insights into how infants convey their nutritional needs.

P3-72 LUEBBERT, KM*; MARTIN, AL; Saginaw Valley State University; *kmluebbe@svsu.edu*
How Predators and Conspecifics Influence Crayfish Shelter Preference?
In the natural environment, there are varying levels of complexity of resources such as food, shelter, and mates. Previous studies have shown that crayfish exhibit preferences for shelters, and these preferences have typically been examined in the context of aggressive interactions. However, it is unknown how external stimuli such as the presence of predators, naïve conspecifics, and status specific crayfish influence the focal animal's preference in the absence of physical interactions. Shelter-seeking behavior of male rusty crayfish, *Faxionus rusticus*, was examined in relation to stimuli from a crayfish counterpart as well as a largemouth bass predator, *Micropterus salmoides*. Five different experiments were performed with a naïve focal crayfish: 1) a control, 2) exposure to a naïve conspecific, 3) a dominant crayfish, 4) a subordinate, and 5) a largemouth bass. Individual crayfish were presented with four variable PVC shelters, consisting of one, two, three, or four openings inside a transparent chamber physically isolated from the external stimulus. The first two experiments consisted of 16 trials, while the last three each had five trials, all of which were recorded for 24 hours under a 12:12 hour light-dark cycle. Each trial was analyzed by observing shelter type and the duration of time spent in that shelter. Focal animals exhibited preference in the presence of naïve conspecifics, but they did not exhibit preference in the control experiment. External stimuli altered crayfish shelter use and preference, but further trials are necessary to understand the broader influence of varying stimulus types.

P1-63 LUNDEEN, IK*; BERTRAND, OC; SILCOX, MT; University of Texas at Austin, University of Edinburgh, University of Toronto Scarborough; *ilundeen@utexas.edu*
Ecogeographic variation and phylogenetic signature in rodent respiratory turbinates
Among mammals, harsh environments, such as deserts or tundra, pose physiological challenges for their inhabitants. In particular, relatively arid or cold environments present unique challenges for the respiratory system. Therefore, mammals living in these regions often have adaptations for enhanced air conditioning such as relatively large respiratory turbinates, sinuses, or nasal fossae. However, these adaptations have been noted primarily in relatively large bodied mammals (e.g. carnivorans, hominins). Here, we test whether the same patterns in environmental adaptations may be applied to smaller bodied mammals by testing for their presence in Rodentia, an order of mammals that includes those at small body sizes. We used computed tomography scans from 66 rodent species, including representatives from Anomaluromorpha, Castorimorpha, Hystricomorpha, Myomorpha, and Sciuromorpha, to quantify the respiratory turbinate surface area, a proxy for respiratory epithelial surface area, scaled relative to skull length. We found a strong linear relationship between skull length and respiratory turbinate surface area but also noted substantial differences in respiratory turbinate morphology when comparing sciuromorphs with other rodent suborders included in this analysis. Despite these morphological differences, when controlling for phylogenetic relatedness, there are no statistically significant differences between biome groups. These results suggest that alternative behavioral strategies (e.g. burrowing or hibernating) may be used to cope with these environmental challenges, creating microclimates thus ameliorating the survival of the animals inhabiting those regions.

42-7 LUNGMUS, JK*; ANGIELCZYK, KD; LUO, ZX; University of Chicago, Field Museum of Natural History; *jlungmus@uchicago.edu*
Limb Ecometrics Show Limited Applicability for Quantifying Ecological Novelty in the Deep Evolution of Synapsida
Mammalia are the only living members of the larger clade known as Synapsida, which has a fossil record spanning from 320mya to today. Despite the fact that much of the ecological diversity of mammals has been considered in light of limb morphology, the origin of broader synapsid limb diversity and its influence on ecological diversity has received less attention. Here we present shape analyses of the forelimbs of the multiple fossil synapsid radiations in comparison to a broad sample of extant Mammalia. Previous work by the authors has shown that shape broadly is not informative of specific locomotor ecomorphologies in earliest fossil Synapsida. Considering the broader scientific use of limb morphology in testing for fossil ecomorphologies, we sought to better understand at what juncture in synapsid evolutionary history do limb metrics begin to show utility in ecomorphological analyses. Shape data on humeri and ulnae elements from an extant sample representing known ecomorphologies provided the framework for a comparative study of extinct ecomorphologies, associated specifically with locomotion. We conducted linear and geometric morphometric comparisons between the extant sample and five taxonomic subsampled radiations moving crown-ward along the synapsid lineage. Taxonomic designations were the PermoCarboniferous "pelycosaurs”, both Permian and Triassic therapsids, "Non-mammaliaforme cynodonts”, and "Mammaliaformes”. Results show that many limb ecomorphological metrics commonly used are not effective designators until close to the origin of crown Mammalia, as late as the Jurassic. This brings into question the overall utility of using extant analogues to test for ecological signal in a given tetrapod group's deepest fossil ancestors.

6-6 LUNSFORD, ET*; LIAO, JC; Whitney Laboratories for Marine Bioscience, St. Augustine, FL; *elunsford@ufl.edu*
Lateral line activity is attenuated during the glide phase of intermittent swimming behavior
Accurate sensory processing during movement requires the animal to distinguish between external and self-generated stimuli to maintain sensitivity to biologically relevant cues. Descending modulatory inputs from the brain have long been hypothesized to be a principle mechanism for filtering sensory reafference in the periphery via corollary discharge during muscle activation. The lateral line system in fishes is a mechanosensory organ that experiences sensory feedback via detection of self-generated fluid motion during swimming. We simultaneously monitored motor neuron commands and spontaneous lateral line afferent activity during and after swimming. Lateral line afferent activity was reduced during swimming, but was not fully inhibited in all cases. The attenuated spike frequency was sustained even after the offset of motor activity indicating the inhibitory control was not confined to the duration of the swim. This reduction in spike rate was substantial and only returned to intrinsic spontaneous spike rates after a well-defined refractory period. We quantified the anticipated influence the refractory period would have during the glide phase of intermittent burst-and-glide swimming behaviors. The relationship between the proportion of time the refractory period overlaps with the glide duration to tail-beat frequency and swim duration reveals that employing fast, short swimming strategies minimizes lateral line desensitization during the glide period. Our results detail a neuromodulatory mechanism in larval zebrafish that adaptively filters self-generated flow stimuli during both active and passive phases of locomotion.

P1-18 LUO, YJ*; RICCI, L; HULETT, RE; SRIVASTAVA, M; Harvard University, Cambridge, MA; *yjluo@fas.harvard.edu*
Single-cell profiling of acoel stem cell dynamics during development and regeneration
Animals capable of whole-body regeneration carry a large population of pluripotent stem cells that are able to differentiate into any missing cell type. However, the molecular control of this cell type is poorly understood. Here we apply single-cell RNA sequencing to profile the cell transcriptional states of the acoel worm *Hofstenia miamia* during development and regeneration. We identify cell types shared across juvenile and adult stages, including neural, epidermal, muscle, digestive, and multipotent/pluripotent stem cells, reflecting major bilaterian cell types. Reconstruction of developmental single-cell trajectories reveals that juvenile and adult pluripotent stem cells have distinct cell states and population size. Single-cell profiling of regenerating worms shows that wound-induced genes are specifically expressed in muscle cells, suggesting a role for muscle in early regenerative responses. Furthermore, we find that germline stem cells are reduced around one-week post amputation, indicating a dichotomy for balancing soma and germline stem populations during regeneration. Together, our study uncovers juvenile and adult cell state dynamics and provides insights into the evolution of pluripotent stem cells.

P1-112 LUSCAVAGE, E*; GOLDINA, A; Elizabethtown College; *goldinaa@etown.edu*
Invasive crayfish Orconectes rusticus exhibit sexually dimorphic responses to conspecific pheromones
The invasive crayfish *Orconectes rusticus* has invaded most watersheds in Pennsylvania and has spread throughout the Northeastern United States. Existing methods to regulate *O. rusticus* populations have been ineffective. Because crayfish communicate chemically by secreting pheromones, understanding the information these pheromones carry can help improve trapping methods. The aim of this study was to determine how *Orconectes rusticus* respond to chemical signals produced by conspecifics of the same and opposite sex. Previous studies in our lab have shown that when presented with a choice of either a pheromone or a water control, female *O. rusticus* are attracted to pheromones produced by males, but don't exhibit avoidance or attraction to female pheromones. Males, on the other hand, avoid signals produced by conspecific males, but do not exhibit a differential response towards female signals. In this study, we utilized a Y-maze to present *O. rusticus* with a choice of male or female conspecific pheromone simultaneously and recorded their preference. The behavior of the crayfish was videotaped and individuals were believed to make a choice when they moved towards or away from one of the arms containing the pheromone. Preliminary findings suggest that males prefer female pheromones, while females do not exhibit a preference towards male or female preference.

P3-35 LUSK, EP*; WITEK, TAR; CASTO, JM; Illinois State University; *elusk@ilstu.edu*
Effects of in ovo treatment with etiocholanolone on nestling development
When transferred to egg yolks during oogenesis, maternally derived testosterone can alter offspring phenotypes. However, avian embryos readily metabolize testosterone to etiocholanolone early in incubation. Thus, it remains unclear whether testosterone or etiocholanolone mediates the phenotypic effects of maternal yolk testosterone, or whether this metabolism serves to inactivate the maternal steroid signal. Previously, injection of artificially incubated European starling (*Sturnus vulgaris*) eggs with etiocholanolone resulted in no detectable changes in embryonic phenotype after five days of incubation; however, few phenotypic traits were readily assessed at that embryonic age. Here, we examine the effects of in ovo etiocholanolone treatment on starling nestling phenotypes throughout nestling development. On the day they were laid, eggs were marked, injected with 5 ng of etiocholanolone in sesame oil, oil alone, or left uninjected, and returned to nests to complete incubation. The fates of eggs and their resulting nestlings were followed through fledging. At five, ten, and fifteen days of age, structural growth was assessed, and blood was collected to assess hematological development, blood glucose, and corticosterone titers. Pre- and post-hatching nesting success was similar among treatments. Structural growth and hematological development were also largely unaffected by experimental treatment. While it remains to be determined whether plasma concentrations of the metabolic hormone corticosterone were affected by treatment, preliminary analyses support the idea that embryonic metabolism of testosterone to eticholanolone serves to inactivate a maternal signal that influences offspring development rather than mediate the maternal effects of that signal.

S7-3 LYKO, F; German Cancer Research Center (DKFZ); *f.lyko@dkfz.de*

Epigenetic adaptation in a clonal invasive crayfish

The parthenogenetic marbled crayfish (Procambarus virginalis) is a novel species that has rapidly invaded and colonized various different habitats. Remarkably, adaptation to different environments appears to be independent of the selection of genetic variants, as marbled crayfish represent an evolutionary young and genetically homogeneous clone. It therefore seems likely that marbled crayfish adaptation depends on epigenetic mechanisms. We have recently established the complete genome sequence of the marbled crayfish and identified an active DNA methylation system, thus establishing the capacity for epigentic regulation of this genome. We are now using integrated analysis of DNA methylation, chromatin and gene expression datasets to characterize the regulatory mechanism(s) used for epigenetic adaptation in marbled crayfish. In addition, we are analyzing epigenetic modification patterns of animals from ecologically distinct habitats at the population scale. Our results provide novel insights into invertebrate DNA methylation and its function in adaptive gene regulation.

S4-10 LYNCH, KS*; RYAN, MJ; Hofstra University, University of Texas at Austin; *kathleen.lynch@hofstra.edu*

Social Regulation of Hormones and the Implications for Female Mate Choice

Classic studies by Lehrman and others have repeatedly demonstrated that hormonal condition can be regulated by social context and social cues. This social regulation of hormones or other neuromodulators allows males and females to coordinate the timing of reproductive behaviors. By attending to the sexual signals of their partners, males and females also orchestrate the timing of reproductive physiology. In a separate but related line of study, it is also well described that females choose mates based on what Darwin described as the females' sexual aesthetic. In this case, the female selects males with spectacular songs, colors, or odors because these traits match perceptual biases in her sensory system. However, female perceptual biases can by modified by her physiological state. So, if physiological state can be modified by social context or reception of social cues, is it possible that simply sitting at a dawn or evening chorus and listening to singing males can modify the females' physiology in such a way that ultimately influences who she will select among her male suitors? If so, this indicates that social regulation of hormonal state (or other physiological conditions) becomes a component of how female mate choice decisions occur. Here, we will describe a type of positive feedback loop in which courting males may enhance their chances of attaining a female response just by continuing to display. We describe how social regulation of the female hormones or other neuromodulators may be an additional component of mate choice via sensory exploitation. Overall, such a positive feedback system would indicate that timing is everything with respect to mate choice decisions. Therefore, in mating competitions, if at first a courting male does not succeed, he should try, try again.

37-4 LYNCH, LM*; MCKENNA, ME; DUDGEON, JV; Washington University in St. Louis School of Medicine, Idaho State University, Center for Archaeology, Materials, and Applied Spectroscopy Center; *leigha.marie.lynch@gmail.com*

Living on the edge: ecology of the extinct Noble marten as determined by morphological and isotopic evidence

The end of the Pleistocene saw the extinction of many megafaunal taxa in North America as climate changed and habitats shifted. North American *Martes*, comprised of three species, was one of the few small-bodied clades to decline in taxonomic diversity entering the Holocene, with the extinction of the Noble marten, *?M. nobilis*. Using morphological and isotopic evidence, we sought to determine the ecology of the Noble marten in order to better understand the cause of its extinction. We quantified limb bone shape in *?M. nobilis* using 3D geometric morphometrics and compared this shape to that of the extant *M. americana* and *M. caurina*. To determine diet, we measured δ13C values from the enamel and dentin of *?M. nobilis* collected from the same locality as the limb elements. We found that the Noble marten significantly differs in limb shape from both of the extant species and possesses a more robust morphology. This suggests that the taxon was less arboreal than the extant species. δ13C values, adjusted with a 13‰ fractionation for diet, ranged between -24.19‰ and -20.37‰, indicating that the Noble marten was eating a mix of C3 and C4 plants and/or prey with this diet. The results of this study suggest that *?M. nobilis* lived within an ecotone between Pleistocene forests and grasslands. This is supported by the mix of woodland and plains taxa found at fossils sites with *?M. nobilis*. Ecotones are highly dynamic environments and often act as buffers for the adjacent communities. Within an ecotone, the Noble marten likely encountered more drastic habitat changes at the end of the Pleistocene than extant *Martes*, which are found entirely in forested habitats. Such habitat instability could then have resulted in the extinction of *?M. nobilis*.

5-2 LYNCH, J*; GAU, JF; SPONBERG, S; GRAVISH, N; University of California, San Diego, Georgia Institute of Technology; *jelynch@ucsd.edu*

Resonance Properties of Insect-Inspired Series-Elastic Flapping Wings

Flying insects are thought to achieve energy-efficient flapping flight by storing and releasing elastic energy in their muscles, tendons, and thorax. The dynamics and energy efficiency of this process depend on the insect anatomy and the aerodynamic forces experienced by the wing. However, despite significant investigation into the aerodynamics of flapping wings, the influence of elasticity and wing inertia on the dynamics and control of wing movements is relatively unexplored. We developed a dynamically-scaled robophysical experiment to study the resonance properties of flapping wing aerodynamics in the regime of insect flight (Reynolds number between 10^2 – 10^4). We observed the steady-state behavior of an acrylic wing actuated in series with a cast silicone torsion spring, varying the elastic element stiffness over a 4-fold range, system inertia over a 3-fold range, flapping amplitude (10 – 64 deg), and frequency (0.5 – 4.1 Hz). Comparing our results to a simplified analytical model of the system with quasi-steady drag forces, we found that the model fits the observed resonance behavior within ± 10% at steady state, suggesting that unsteady aerodynamic phenomena have a weak influence on the steady state dynamics of flapping wings with elastic elements. These experiments indicate the importance of wing inertia, body elasticity, and muscle actuation dynamics towards minimizing energy expenditure in flapping wing flight and aerodynamic force control in insects.

121-5 LYONS, K*; WYNNE-EDWARDS, KE; Georgia Aquarium, University of Calgary; *klyons@georgiaaquarium.org*
Legacy PCB Contamination Negatively Impacts Osmoregulatory Biomarkers in Pregnant Stingrays and their Embryos
Elasmobranchs utilize a unique osmoregulatory strategy based on urea as the main osmolyte. Because this strategy is energetically expensive, perturbations to homeostasis, such as that presented by legacy polychlorinated biphenyl (PCB) exposure, may be detectable in osmoregulatory biomarkers. Multiple tissues were obtained from pregnant Round Stingrays (*Urobatis halleri*) and associated embryos over the course of a gestational cycle from two locations where both environmental concentrations and physiological response to PCB exposure differs between sites. Solutes (urea, TMAO, proteins) were quantified in matched pairs of maternal plasma and histotroph and activities of enzymes indirectly and directly related to urea synthesis were measured in maternal and embryonic liver tissue. Pregnant females from the reference site maintained stable plasma urea concentrations, whereas plasma urea declined over the course of pregnancy in females from the contaminated site. In addition, muscle protein content significantly declined in contaminant-exposed, but not reference, females, indicating a potential loss of substrate for urea formation. Embryonic enzymes involved in the urea cycle and protein processing were functional, in contrast to the hypothesis that internal gestation (matrotrophic histotrophy), would delay the developmental onset of embryonic osmoregulation. While embryos were able to maintain urea and TMAO concentrations comparable to reference embryos, their liver protein content also significantly decreased over development, suggesting that osmoregulatory costs were higher. Increased costs for osmoregulation join other physiological measures adversely affected by legacy PCB contamination in these stingrays.

86-5 LYONS, MP*; VON HOLLE, B; WEISHAMPEL, JF; University of Central Florida, Orlando, University of Central Florida, Orlando and National Science Foundation, Washington, DC; *marta.lyons@gmail.com*
Impacts of Climate and Flooding on Current and Future Sea Turtle Nest Survival in the Eastern United States
Beaches along the southeastern coast of the United States provide important nesting habitat for three species of sea turtle, *Chelonia mydas*, *Caretta caretta*, and *Dermochelys coriacea*. These nesting areas are increasingly threatened due to sea level rise, human shoreline development, and changing climate. Female sea turtles come on land to nest under a wide range of conditions with non-obvious, context-dependent environmental and historical cues dictating nest site preference. Though nesting occurs under a range of environmental conditions across latitudes, developing embryos are extremely sensitive to local climate and disturbance. We are modeling how climate during incubation as well as the location of a nest in relation to the high tide line, other nests, and human development impacts overall nest success. We are accomplishing this through using multiple decades of nest success and locality data from six National Parks that span the current latitudinal extent of United States Atlantic sea turtle nesting. Our results support that the number of eggs that successfully hatch and emerge from the nest is dependent on the temperature and precipitation during incubation as well as the presence of disturbances like nest flooding and depredation, with species level differences relating to physiological temperature tolerances and phenology. This work allows us to quantify the effectiveness of current management practices, like nest relocation and predator exclusion, while creating spatial forecasts for future nest success that take into account changes in sea level, climate, and storm surge flooding over the next century.

48-7 MACK, JM*; DE CARLE, D; KVIST, S; University of Toronto, Royal Ontario Museum, University of Maryland, College Park, University of Toronto, Royal Ontario Museum; *joemack@umd.edu*
Prey, Populations, and the Pleistocene: Evidence for Low COI Variation in a Widespread North American Leech
Geographically widespread and morphologically diverse species typically exhibit limited gene flow, poor dispersal abilities, and cryptic diversity. The leech *Placobdella rugosa*, long a challenging organism to classify, represents an exception. Recent molecular analyses revealed a surprising lack of genetic variation among morphologically disparate, geographically widespread specimens of *P. rugosa*. Given the lack of any obvious mechanism by which this species could disperse between distant habitats, it was expected that widespread populations would be genetically isolated from each other. In the present study, we investigate the relationship between geographic distance and genetic diversity in *P. rugosa* using COI sequences from specimens collected across Canada and the United States. Although we find preliminary evidence for a barrier to gene flow between eastern and western collecting localities, our vastly expanded dataset largely corroborates prior studies, showing minimal phylogeographic signal among the sequences and negligible levels of genetic isolation by distance. A recent range expansion following the last ice age and/or host-mediated dispersal are discussed as potential explanations for this unexpected phylogeographic pattern.

109-5 MACKESSY, SP; University of Northern Colorado; *stephen.mackessy@unco.edu*
A little variety goes a long way: Diversification of three-finger toxins in rear-fanged snake venoms
Rear-fanged snakes ("colubrids") include a remarkable diversity of species that are found more broadly distributed than any other group of snakes, in part because of venom systems that are proving to be very diverse variants of a familiar theme. Among snake venoms, the three-finger toxins (3FTxs) are one of the better known families, with highly conserved structural scaffolds that supports a myriad of pharmacologies. For example, α-neurotoxins are potent blockers of motor endplate acetylcholine receptors, but structurally similar molecules are used by plethodontid salamanders in courtship and in limb regeneration. Snakes in the Asian genus *Boiga* produce numerous 3FTxs, and some of them, such as irditoxin, are dominant venom components with taxon-specific and potent neurotoxic effects directed toward lizard prey. This motif is turning out to be common among the rear-fanged Colubridae – New World *Oxybelis* also shows this pattern, and we have recently characterized a lizard-specific dimeric 3FTx, with high homology with irditoxin, in the venom of *Spilotes sulfureus*,. Like *Boiga*, the venom gland transcriptome of *S. sulfureus*, formerly considered to lack a Duvernoy's venom gland, is dominated by 3FTxs, and the expressed venom consists of >92% 3FTxs, higher even than the vast majority of elapid venoms. However, in addition to a lizard-specific 3FTx, *S. sulfureus* venom also contains a mammal-specific monomeric neurotoxin, sulmotoxin, which is non-toxic to lizards. This is a unique toxin among 3FTxs and snake venoms generally, and it illustrates further the extent to which selection has favored diversification of a single toxin scaffold among snake venoms. Our results clearly demonstrate that a diversity of novel structural and functional variants of familiar toxins exist among rear-fanged colubrids.

24-7 MACKNIGHT, NJ*; DIMOS, BA; BRANDT, M; MULLER, E; MYDLARZ, L; The University of Texas at Arlington, The University of Virgin Islands, Mote Marine Laboratory; *nicholas.macknight@uta.edu*

The species-specific and shared immune competence of seven Caribbean coral when exposed to white plague disease

Intraspecies and interspecies immune competence was captured in seven Caribbean coral after laboratory-controlled exposure to white plague disease. A spectrum of phenotypic disease susceptibility differentiated the species and provided the backbone for identifying unique or shared gene expression profiles across species. Gene expression profiles were correlated to disease phenotypes, including lesion growth rate using WGCNA networks. 100% of *Orbicella faveolata* contracted the disease, showing significant expression of calmodulin binding and metalloendopeptidase regulation. 0% of *Montastrea cavernosa* contracted white plague disease and has significant changes in the expression of G-protein coupled receptors and developmental processes. The remaining species, which did not have all of their fragments contract the disease, offer species-specific insight on the gene expression that is unique in fragments that contracted the disease versus fragments of the same species that were exposed but did not contract the disease. The intermediately susceptible *Siderastrea siderea* had 60% disease prevalence by the end of the study and presented significant enrichment of caspases and inhibition of transforming growth factor-beta in fragments that were exposed but did not contract the disease. By identifying the gene regulation that drives the immune competence of these species, better predictions on future species composition and abundance can be made for Caribbean reefs.

S11-2 MACLEAN, E*; GNANADESIKAN, G; BRAY, E; SNYDER-MACKLER, N; University of Arizona, Arizona State University; *evanmaclean@email.arizona.edu*

Dog Diversity as a Natural Experiment in Cognitive Evolution

Dogs were once written off as a highly artificial species with little to contribute to the scientific study of behavior, cognition, or evolution. However, across the last two decades there has been a resurgence of scientific interest in dogs, in fields ranging from cognitive science to genetics. I will present a series of studies probing diversity in cognitive processes in dogs, considering patterns of variation at both the breed and individual level. Using a combination of pedigree-based and molecular genetics approaches, we find that a large proportion of variance in diverse cognitive measures is attributable to genetic factors. I will present ongoing work aimed at identifying specific genetic variants associated with variance in these cognitive phenotypes and discuss the implications of this work for understanding the processes of cognitive evolution.

P2-59 MACLEOD, PF*; RENN, SCP; RENN, Sus; Reed College; *renns@reed.edu*

The operational sex ratio and reproductive state influence female aggression and competition in a conventional 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 studied dominance hierarchies are those observed among males under conventional sex-role mating systems in which reproductive success is highly variable for males, and dominance is most often correlated with reproductive success. In such situations, females are generally considered to play a passive role, selecting from available dominant males. However, females do interact with each other social and potential exists for the formation of dominance hierarchies among females as well. It is therefore important to ask whether female dominance influences reproductive success either through female-female competition or male choice for female dominance. The maternal mouth-brooding lekking cichlid fish *Astatotilapia butroni* provides an interesting opportunity to study female dominance hierarchies. We show that female biased operational sex ratios increase intra-sexual aggression within females, yet despite the heightened aggression, the dominance hierarchy remains relatively stable. The aggressive behavior of the females correlates with reproductive stage and suggests that females may in fact be competing for opportunities to mate.

140-6 MACRANDER, J*; SACHKOVA, M; SURM, J; LEACH, W; KETCHUM, R; REITZEL, A; MORAN, Y; Florida Southern College, University of Bergen, Hebrew University of Jerusalem, University of North Carolina at Charlotte, Hebrew University of Jerusalem; *jmacrander@flsouthern.edu*

A Multi-omic Approach to Evaluate Environmental Influence and Population Dynamics of Venom Production in Nematostella vectensis

The estuarine sea anemone *Nematostella vectensis* has emerged as a model organism to study the dynamic interactions between cell specific venom composition, development specific venom composition, and the impact of varied toxins on their biological targets. Within nearshore dynamic estuarine mud flats and temporary pools *N. vectensis* are apex predators feeding on a variety of invertebrate and potentially vertebrate prey as adults, however, their position as apex predators is a drastic shift from when they had to use their venom to defend themselves against predators as mobile planulae larvae. The complexity of these interactions may be further influenced by abiotic factors the predators encounter in these different environments as it relates to their geographical location. Here we report the differential gene expression patterns of *N. vectensis* when subjected to stressful environmental conditions and evaluate the potential role regional adaptations have on changes in venom gene expression. Additionally, we evaluate venom composition with a fine scale analysis using targeted MiSeq analysis of their key toxin protein and contrast this diversity with potential prey abundance using COI DNA barcoding. These approaches are further complemented by the use of comparative transcriptomics to identify strong overall population structure which correlates with toxin gene diversity. Our combined multi-omic analyses further highlights the usefulness of *N. vectensis* to address evolutionary and ecological questions as it relates to dynamic interactions between this complex venomous animal and its varied environment.

43-7 MADELAIRE, CB*; BARSOTTI, AMG; WAGENER, C; SUGANO, Y; BAXTER-GILBERT, J; GOMES, FR; MEASEY, J; Northern Arizona University, University of São Paulo, Stellenbosch University , Stellenbosch University; *cmadelaire@yahoo.com.br*

Invasive toads shift behavioral traits to find water

The adaptive nature of invasive species is becoming recognized as facilitating their survival in conditions that differ from their native range. Behavioral changes in invasive populations have been poorly explored but offer a wide potential when combined with physiological traits. For anurans invading xeric habitats, the importance of finding water is relevant for reproduction, to maintain hydration to function optimally and not experience dehydration stress. The water-finding hypothesis (WFH) states that survival can be enhanced through the behavioral ability to find water. We tested the WFH in *Sclerophrys gutturalis* from their native population in Durban and an invasive population in Cape Town Additionally, we tested if artificially elevated levels of corticosterone (CORT), which is known to increase during dehydration stress, affect water-finding behaviors. In a labyrinth experiment, we observed the toads' ability to find water in different hydration states (100%, 90% and 80%). We found that individuals from the invasive population took longer to engage in water-searching behavior and spent more time near to the water source after finding it. Also, toads from the invasive population were more active and at 90% dehydration they show higher number of attempts to find water. Moreover, elevation of CORT in fully hydrated toads increased the success of finding water. Our experiment suggests that rapid adaptative water-finding behavior might facilitates survival of an invasive anuran in a xeric habitat. Additionally, we suggest a link between elevated CORT levels and water finding success. Our results lend support to the importance of adaptive behavior in successful invasions and the modulation of water-finding behavior by CORT.

P2-225 MADRID GALICIA, VS*; ARIAS, AA; VEGA, K; ELSEY, RM; AZIZI, E; OWERKOWICZ, T; Univ of California Irvine, CSU San Bernardino, Rockefeller Wildlife Refuge, CSU San Bernardino; *vmadridg@uci.edu*

Effects of caudofemoralis longus tenotomy on 3D kinetics and kinematics in juvenile alligators

The caudofemoralis longus (CFL) muscle is known as an integral locomotor muscle in the hindlimb of all non-erect terrestrial vertebrates and has been particularly well-studied in archosaurs (crocodilians, birds, and their relatives). CFL's designation as the primary driver of propulsive force generation in alligators is based on relatively qualitative anatomical and electromyographical data, but lacks direct quantitative support. Here we compare hindlimb joint mechanics before and after bilateral CFL tenotomy in juvenile alligators using high-speed videography (dorsal and lateral views) and force plate ergometry. Data were collected for n=12 alligators (CONTROL) and subsequently split into two post-operative groups of n=6 each: CFL-tenotomized (SURG) and sham-operated (SHAM). Only trials where animals walked at a moderate speed (0.16 + 0.03 m/s) were analyzed. Preliminary data analyses show significant differences (RM-ANOVA $p<0.05$) between CONTROL and SURG groups in average peak propulsive force, time to reach peak propulsive force and stance phase duration, but no discernible differences in total propulsive impulse. Hip joint kinematics remain largely conserved, but distal hindlimb joints in SURG begin stance phase significantly more flexed, flex more during stance phase, and on average extend less during stance phase. These results suggest that specific features of hindlimb mechanics are affected by CFL tenotomy, but broader patterns remain relatively conserved with the loss of a major hindlimb muscle in walking alligators. This work directly tests the effects of complete deactivation of a major hindlimb muscle on limb mechanics, and highlights the redundancy and complex interrelationship between muscle and locomotor performance in vertebrates.

64-1 MAEDA, M*; WALKER, SM; FABIAN, JM; LIN, HT; BOMPHREY, RJ; Royal Veterinary College, University of Leeds, Imperial College London, Imperial College London; *mmaeda@rvc.ac.uk*

Aerodynamic and Structural Modelling and Simulation of Dragonfly Wing: Towards the Understanding of "Fly-by-Feel"

During flight, insect wings undergo large, periodic deformations on each cycle due to the inertial and aerodynamic loads they experience. Various studies over the last decade have shown that such deformations can have a significant impact on increasing aerodynamic force and/or reducing aerodynamic power, enhancing flight performance. It is therefore beneficial for a flying insect not only to detect and control its body attitude but its wing aeroelastic state as well. Strains that result from aeroelastic loads are detected by campaniform sensilla near the wing base, and a variety of flow sensors capture aerodynamic features on the wing. While the degree of sensory innervation varies drastically across the insects, this form of mechanosensory feedback has been shown to provide important information for the flight controller in some species. In this study, we aim to generate predictions of the strain field across dragonfly wings using fluid-structure interaction (FSI) numerical simulation, where computational fluid dynamics (CFD) and computational structural dynamics (CSD) are coupled. Towards that goal, we constructed dragonfly forewing and hindwing morphology models based on X-ray microtomography (micro-CT) scans. Dynamically deforming flapping wing models are reconstructed based on multiple-camera, high-speed recording of dragonfly flights. Preliminary findings from the CFD and CSD simulations are presented.

S1-6 MAHON, AR*; HALANYCH, KM; Central Michigan University, Auburn University; *mahon2a@cmich.edu*

Revisiting phylogeographic patterns in Antarctica in the age of '-omics.'

Antarctic fauna, particularly marine benthic invertebrates living on the continental shelf, are far more diverse than previously realized. Thanks to recent increases in sampling efforts, our understanding of Southern Ocean biodiversity has improved dramatically. In addition to increased sampling efforts around the continent, the application of molecular genetic and genomic tools to understand patterns of biodiversity is allowing us to understand and investigate entirely new patterns and processes from organisms in the Southern Ocean. Historically, studies employing mitochondrial genes or gene fragments (e.g., cytochrome c oxidase subunits I and II, 16S rDNA, cytochrome b) have found numerous unknown yet distinct genetic lineages in several invertebrate taxa isopods, sea spiders, echinoderms, and others. Despite this increased appreciation of diversity from the region, we are still trying to explain the bigger picture phylogeographic patterns around the Antarctic and the factors that produced such patterns. The development and application of new molecular methods on organisms from the region are allowing us to address questions relating to scenarios that may have impacted the current distributions of Antarctic shelf marine fauna using the resultant evolutionary patterns reconstructed from molecular data. These scenarios include a transantarctic seaway, Antarctic circumpolar current admixture, localized refugia, isolation by distance models, and other hypotheses. In this presentation, we will discuss our ongoing work that challenges major hypotheses related to the understanding of diversity in the Antarctic. As found in our previous studies, we expect that knowledge of organismal diversity through the implementation of additional 'omic studies will have tangential impacts throughout Antarctic biological research efforts.

P2-129 MAIER, MA*; MARUSKA, KP; Louisiana State University, Baton Rouge; *mmaier3@lsu.edu*

GnRH as a Neuromodulator in Midbrain Sensory Regions during the Female Cichlid Reproductive Cycle

Gonadotropin-releasing hormone (GnRH) 1 neurons in the hypothalamus regulate the reproductive axis, whereas GnRH2 and GnRH3 have widespread projections throughout the brain in most vertebrates. These extra-hypothalamic GnRH neurons are neuromodulators that integrate sensory information important for mediating behaviors. However, little is known about whether this modulatory potential in specific sensory processing regions of the brain might be influenced by an animal's reproductive condition. The cichlid fish *Astatotilapia burtoni* is an ideal model to examine GnRH modulation of sensory function because courting males produce visual-acoustic courtship displays towards gravid receptive females, but non-receptive mouthbrooding females are typically uninterested in male signals. Immunostaining demonstrates dense innervation of GnRH2/3 to visual-acoustic processing centers in the midbrain; tectum and torus semicircularis. To test for reproductive state-dependent changes in GnRH modulatory potential, we analyzed mRNA levels of GnRH receptors in microdissections of these midbrain regions in gravid, recovering, and mouthbrooding females. In the tectum, GnRH-R2 levels were higher in mouthbrooding compared to gravid and recovering females. In the torus semicicularis, however, GnRH-R2 levels were higher in gravid compared to mouthbrooding females. We are currently analyzing GnRH 2/3 innervation to these nuclei by quantifying varicosity densities across reproductive states. These results demonstrate reproductive-state changes in the neural substrates associated with GnRH 2/3 modulation and contribute to better understanding the mechanisms responsible for sensory plasticity that leads to adaptive behaviors.

13-5 MAINWARING, MC*; MARTIN, TE; WOLF, BO; TOBALSKE, BW; University of Montana, University of New Mexico; *mark.mainwaring@mso.umt.edu*

Nests reduce the energetic costs of brooding offspring for passerine birds in the tropics

Reproduction is an energetically expensive activity for parents and keeping endothermic offspring at their thermal optima represents a significant energy cost. Avian offspring develop optimally at ~39˚C. The tropics are generally thought to provide warm ambient conditions that require less effort to keep offspring warm. Yet, the synergistic effects of high rainfall and winds that characterize the mid-montane tropics may exacerbate heat loss and mean that the energetic costs of keeping altricial offspring at optimal temperatures are substantially higher than previously imagined for the tropics. However, the building of enclosed and thus sheltered nests may enable birds to buffer the effects of adverse weather conditions. Here we provide experimental and observational evidence that ambient temperatures in the tropics are ~20°C below the thermal optima of 39˚C and that rainfall and wind synergistically combine to increase the energetic costs of keeping offspring at thermal optima. Meanwhile, those costs varied between nest types, with species building enclosed nests saving significantly more energy than species building open nests. Our measurements and experiments demonstrated that rainfall, wind and their synergistic effect induces convective cooling that dramatically increases the costs of keeping endothermic offspring at their thermal optima in tropical regions. However, nest design can mitigate those costs and provide an important way of enabling animals to adapt to adverse environmental conditions in biodiversity-rich, but anthropogenically-threatened, tropical regions. (NSF: IOS: 1656120).

P2-223 MAISONNEUVE, MC*; SCHIEBEL, PE; GOLDMAN, DI; Georgia Institute of Technology ; *mmaisonneuve3@gatech.edu*

A robophysical snake with bio-inspired actuation to explore the role of passive mechanics in limbless locomotors.

Animals like snakes use traveling body bends to move in multi-component terrestrial terrain. Previously we studied [Schiebel et al., PNAS, 2019] a desert specialist (*Chionactis occipitalis*) traversing sparse rigid obstacles and discovered that passive body buckling, facilitated by unilateral muscle activation, allowed obstacle negotiation without additional control input. In this poster, we explore the benefits and limitations of this obstacle negotiation strategy using a novel robophysical model designed to capture muscle morphology and activation patterns in snakes. Most snake robots have one motor per joint whose positions are precisely controlled. In contrast, the actuation in our robot is modeled after biological snakes; pairs of muscles, one on each side of the spine, create body bends by unilaterally contracting. The robot snake has 8 joints and 16 motors, one motor with a pulley on each side. Each pulley is connected to a wire that, when shortened, bends the robot toward that side. Inspired by snake muscle activation patterns [Jayne, J. Morph., 1988], we programed the motors to be unilaterally active and propagate a sine wave down the body. Opposite an active motor, the pulley is completely unspooled so that the joint can be bent toward the active pulley without tension force from this passive wire. These pairs of motors can thus resist forces which attempt to lengthen active wires but not those pushing them shorter, resulting in mechanical passivity. Preliminary tests demonstrate that the robot can move on hard ground when drag anisotropy is large, achieved via wheels attached to each segment on the robot's belly.

115-2 MAJORIS, JE*; FORETICH, MA; HU, Y; NICKLES, KR; DI PERSIA, CL; CHAPUT, R; SCHLATTER, E; WEBB, JF; PARIS, CB; BUSTON, PM; Boston University, Boston, MA and King Abdullah University of Science and Technology, Thuwal, Saudi Arabia, University of Miami, Miami, FL , University of Rhode Island, Kingston, RI and Boston College, Chestnut Hill, MA , University of Rhode Island, Kingston, RI , Boston University, Boston, MA; *j.e.majoris@gmail.com*

Neon Goby Larvae have Sufficiently Developed Sensory Systems and Swimming Abilities to Orient Directionally Beginning Shortly After Hatching

Though once considered passive particles, it is now widely recognized that late-stage reef fish larvae can detect and orient their movements in relation to olfactory, visual, and auditory cues. These behaviors have the potential to influence the emergent pattern of larval dispersal, with important consequences for marine population dynamics and conservation. Yet, little is known about when larvae develop the ability to orient their movement. In this study, we raised a coral reef fish, the neon goby *Elacatinus lori* , from hatch through settlement to investigate the development of their: i) sensory systems, ii) swimming abilities, and iii) orientation behaviors. Using a variety of anatomical techniques, we show that all of the major sensory organs are present and likely functional at hatch and their sensory organs increase in size, number, and/or structural complexity throughout the larval phase. Using a drifting behavioral arena (DISC), we show that larvae actively swim upon hatching and that swimming speeds increase throughout the larval phase. We also demonstrate that individual larvae orient directionally at all ages (2-30 days post hatch), providing compelling evidence that *E. lori* have the potential to influence their dispersal trajectory throughout the entire larval phase. Taken together, our results suggest that neon goby larvae may behave in ways that help to explain the relatively restricted pattern of dispersal for the species.

93-2 MALISCH, J/L*; HAHN, T/P; BREUNER, C/W; MALISCH, Jes; St Mary's College of Maryland, University of California, Davis, University of Montana ; *jlmalisch@smcm.edu*
Should I Stay Or Should I Go Now? Predictors of Facultative Altitudinal Migration in Mountain White-crowned Sparrows (Zonotrichia leucophrys oriantha)
Organisms that inhabit regions with high environmental variability must cope with sudden shifts in climatic conditions to survive and reproduce. In areas with steep elevation gradients, temporary movement from an area of high elevation to low elevation, facultative altitudinal migration (FAM), is a useful adaptation that promotes survival but may come at a cost to reproduction through the loss of territory or abandonment of a nest. White-crowned sparrows (*Zonotrichia leucophrys oriantha*) that reside in Tioga Pass Meadow, CA (elevation 3,030 m) are migratory and typically arrive in early May from their wintering grounds in Mexico. Snow cover is usually 100% and late spring snow storms are not uncommon. Furthermore, lower elevation refugia in the Mono Basin (~2,000 m elevation) are readily available. As such, this is a model population to investigate environmental and physiological variables that influence FAM behavior. Furthermore, this population has a relatively high rate of return allowing for an estimation of year to year survival. Here we review research on this single population spanning several decades and synthesize recent findings in a framework that includes environmental variables, physiological variables, and return rate in regard to FAM behavior. The physiological variables include glucose mobilization, glucocorticoid physiology and body condition. For FAM events that include corticosterone binding globulin measurements we will also discuss the difference between free corticosterone (CORT), total CORT, and bound CORT in reference to the Free Hormone Hypothesis, the Total Hormone Hypothesis and the Reservoir Hypothesis.

P1-238 MALTBY, R*; WILLIS, KL; MARKHAM, MR; University of Oklahoma, Norman; *rmaltby@ou.edu*
Weakly Electric Fish as Charismatic Midi-fauna: Lessons in Neuroscience Broader Impacts.
Science communication is linked to basic research in ways that are increasingly appreciated by the scientific community, funding agencies, and the public at large. Our lab has harnessed the remarkable phenotype of weakly electric fish for informal public science education, with the main goals being to increase participants' understanding of ecological biodiversity and bioelectric signaling, and positively broaden their ideas of science inclusion and accessibility. Here, we report on seven years of outreach and engagement activities. We have designed a modular traveling program, "The Electric Fish Roadshow" which can be adjusted to target several different groups and settings including elementary individual classrooms, K-12 school wide science fairs, senior citizen groups, and public lectures. We use representatives from several Gymnotiform and Mormyrid species to lead participants through interactive demonstrations and inquiry-based experiences that show the biodiversity of electric fish species, adaptations and animal life history, and demonstrate the electrogenic properties of participants' own bodies. The laboratory has visited 15 sites, engaging with over 850 people. Assessments show significant increases in participants' understanding of biological diversity, increased positive attitude towards science, and increased traffic to our outreach webpage. Future improvements will include updates to our demonstration materials, expanding the demographic and geographical reach of the demonstrations, continuing to build classroom curricula at the state level, and development of stronger quantitative assessment methods.

14-1 MANAFZADEH, AR*; KAMBIC, RE; GATESY, SM; Brown Univ., Johns Hopkins Univ.; *armita@brown.edu*
How informative is joint mobility? A 3-D analysis of potential versus realized joint poses in archosaurs
Paleontologists have traditionally reconstructed the locomotion of dinosaurs and other extinct animals by manipulating their fossil bones and inferring the mobilities of their limb joints. But even if we could estimate the ranges of motion (ROMs) of joints perfectly, are we justified in assuming that all of an animal's potential joint poses are exploited in life, let alone in locomotion? Here we evaluate the predictive power of joint mobility by determining what portion of a joint's full passive ROM is actually used during various behaviors. We measured the passive joint ROMs of the hip, knee, and ankle of the helmeted guineafowl (*Numida meleagris*) and the American alligator (*Alligator mississippiensis*) based on manipulations of fully intact cadavers. We then measured thousands of poses used at each of these joints during locomotor and non-locomotor behaviors using XROMM, and plotted the mobilities and poses on a common ROM map in 3-D joint pose space. We found that in all the joints studied, steady forward locomotor poses form a small and uncentered subset of all possible joint poses. The centroid of each joint's mobility -- sometimes termed the joint's "neutral pose" and thought to reflect habitual stance -- has no relationship to posture or locomotion. Rather, locomotor poses often fall along the edges of cadaveric ROM envelopes in 3-D joint pose space. These results suggest that even well-estimated joint ROM, though critical for the elimination of impossible joint poses, is a poor predictor of the locomotor poses actually used by extinct ornithodirans such as non-avian dinosaurs and pterosaurs. Future analyses of hindlimb joint surface interactions during life are necessary to further constrain paleontological reconstructions of locomotion.

57-2 MANEY, DL; Emory University; *dmaney@emory.edu*
Evolution of alternative behavioral phenotypes: A story of genes and bird brains
Disruptive natural selection can drive the evolution of alternative phenotypes, or "morphs", within one or both sexes. The morphs, so named because they differ with respect to a morphological trait such as coloration, often differ also with respect to behaviors such as courtship, territoriality, and parenting. In white-throated sparrows (*Zonotrichia albicollis*), birds of the white stripe (WS) morph engage in a more territorial, competitive strategy, whereas birds of the tan stripe (TS) morph assume a more parental strategy. These alternative phenotypes are genetically fixed in that they segregate with a chromosomal rearrangement present only in the WS birds. The rearrangement, or "supergene", contains differentiated genes known to contribute to territoriality and parenting, making this species an excellent model for studying how changes in gene sequence can ultimately cause changes in behavior. In this talk I will present highlights from our research in which we combine the fields of genomics, molecular biology, neuroscience, and field endocrinology to understand the evolution of behavioral phenotypes.

P3-131 MANN, SD*; REED, SA; BERGMANN, PJ; Clark University; *smann@clarku.edu*
Running on Land and Water: Three-dimensional Limb Kinematics and Locomotor Performance of Anolis sagrei
Anolis lizards have radiated into many ecological niches, with different ecomorphs using different types of perches. *A. sagrei* is a trunk-ground ecomorph that has adhesive toe pads, is quadrupedal, and mostly arboreal. However, we show that *A. sagrei*can also run on water, yet it is unknown to what extent the species relies on this behavior in nature. Water running has been studied extensively in *Basiliscus*, but has never been compared to running on land. Here, we compare the locomotor performance and three-dimensional limb kinematics of *Anolis sagrei* running on land and on water. Our objective is to address whether *A. sagrei* does the same movements when running on water as when it runs on land, and if not, to understand what kinematic adjustments it makes when running on water. We used two synchronized high-speed cameras recording at 480 Hz to film *A. sagrei* running on a horizontal race track lined with cork board, and on water in an aquarium. We quantified locomotion by comparing kinematic and performance variables such as acceleration, velocity, duty factor, stride length, stride frequency, joint angles, and angles of the body. We found that *A. sagrei* had higher average and maximum velocities on land but higher maximum accelerations on water. Animals also had a lower duty factor on water than on land, so their hind limbs were lifted for more time when running on water than on land. However, stride length was consistently longer on land than on water. *A. sagrei* individuals also had a higher stride frequency on water than land. Our results suggest that *A. sagrei* lizards achieve different levels of performance and adjust their limb kinematics when running on water compared to land.

P2-218 MANNAVA, A*; SCHAPKER, N; LEWIS, C; GERMAN, R; YOUNG, JW; NEOMED; *alekhya.mannava@gmail.com*
Effects of preterm birth on locomotor performance in infant pigs
One of the most significant milestones in a human child's locomotor development is the ability to walk. However, the time at which infants begin to walk varies greatly with gestation length. Specifically, motor development in preterm human infants is known to be delayed relative to term infants. Here, we test the predictions that 1) motor development will progress more slowly in preterm infants and 2) that preterm infants will require specific adjustments to gait kinematics to promote stability. We collected high-speed video of 8 term and 4 preterm infant pigs walking/running in an enclosed runway using food motivation. Because preterm pigs were born 6 days premature (comparable to 30-32 weeks of human gestation) we subtracted 6 days from their chronological age for comparison to the term pigs. Locomotor performance of infant pigs was assessed by quantifying speed - made dimensionless to compensate for size growth - as well as duty factor and the mean number of supporting limbs during the stride. Preterm pigs significantly increased speed with increasing age ($p<0.001$), whereas term pigs did not ($p>0.05$). Controlling for speed, both preterm and term pigs maintained constant duty factors throughout growth ($p>0.05$), but significantly decreased the mean number of supporting limbs using at older ages ($p<0.01$). Controlling for speed, preterm pigs always moved with significantly greater duty factors and mean numbers of supporting limbs than term pigs (all $p<0.01$). As predicted, preterm infants showed protracted motor development and adjusted their gait in ways consistent with the need to maintain greater stability. Our work suggests that infant pigs may be a promising animal model for the study of preterm birth on locomotor development. Supported by NIH RO1-HD-088561 and NEOMED

139-3 MANTILLA, DC*; TUCKER, EL; HSIEH, ST; Temple University, Philadelphia, PA; *dcmantilla@temple.edu*
Sand specialists and Non-specialists use Similar Kinematic Strategies for Running on Incline Granular Media
In the wild, animals encounter substrates varying in material properties and orientation. Feet have been shown to be more sensitive to changes in substrate properties by displaying posture and resilience adjustments on level granular and solid substrates. However, little is known about legged locomotion on inclined granular substrates, such as sand dunes, which fluidize with every step. It would therefore be reasonable to expect sand specialists to have kinematic adaptations for running on granular substrates, and fluid specialists to run well on sand due to its fluidizing properties. Previous results show that although running speeds are similar on the level granular substrate, sand specialist lizards consistently run faster than both generalist and fluid specialist lizards on the incline, with fluid specialists performing the most poorly. Here, we quantify how the kinematics differ among species and between surface angles. We ran a sand specialist (*Callisaurus draconoides*), a fluid specialist (*Basiliscus vittatus*), and a generalist (*Crotaphytus collaris*) along a level and incline (31°) fluidizable bed trackway. Lizards were filmed at 500 fps (Photron SA-3), and videos were analyzed in MATLAB. All three species similarly decreased impact speed on the incline compared to the level (P

P3-236 MANZI, S*; MACRANDER, J; FRIAS, A; KRANTZ, J; Florida Southern College; *serenamariemanzi16@gmail.com*
A Comparative Analysis of Differentially Expressed genes from a stress response to increased water temperatures between sea anemones Exaiptasia pallida, Diadumene lineata
Climate change has become the biggest issue humans have had to face yet. Above all the other impacts that climate change has had on the natural world, most notably its decimation of coral reef ecosystems. With heat waves at new intensities, corals are bleaching at alarming rates causing whole ecosystems to collapse and a loss of most reefs around the world. In order to combat this, scientists have been studying the effects of climate change, and how to possibly combat it, using sea anemone models that have similar relationships with zooxanthellae. The sea anemone species *Exaiptasia pallida* has emerged as a laboratory model for studying corals associations with the zooxanthellae endosymbionts and its associated stress response with the host organism in elevated water temperatures. The focus of the study was to highlight comparisons of differential gene expression between *E.pallida* and *Diadumene lineata*, another species of sea anemone that does not have zooxanthellae. Both species of sea anemone were tested in the same heat conditions of 25 °C (control), 30 °C (elevated sea surface temperatures) and 35 °C (heat wave). The inclusion of *D. lineata* was to identify if the differentially expressed stress genes of *E.pallida*, that may be restricted to stress response in sea anemones, and not mimic those observed in corals. Individuals representing both species had total RNA extracted and sequenced using a TAGseq approach to identify any differentially expressed genes related to stress response as it relates to elevated water temperatures. Our analysis also evaluated how the overall genomic heat response in these sea anemones compared to to different species of corals as it related to future resilience to climate change.

112-2 MARBACH, S*; XU, W; Texas A&M University Corpus Christi, Corpus Christi, TX; *smarbach211@gmail.com*

The Toxic Effects of Nanoplastic Particles on Fish Embryonic Development

Plastic pollution is a globally recognized environmental threat that poses potential toxic effects on human- and aquatic organisms. Micro- and nanoplastic particles, which originate from various sources, such as clothing fibers, plastic production, and degraded plastic pollutants, have been of scientific interest in the past decades due to their characteristics of bioaccumulation in a wide variety of marine animals and their ever-increasing global distribution in aquatic environments. In this study, we investigate accumulation of nanoplastics (NPs) in fish embryo and the toxic effects on fish embryonic development using zebrafish *(Danio rerio)* as a model. Within 6 hours post fertilization (hpf), the zebrafish embryos were cultured in water solutions of fluorescent amine-modified polystyrene latex beads with concentrations of of 1µg/mL, 10µg/mL, and 100µg/mL. The development of embryos and the accumulation of the NPs in the embryos were monitored under a fluorescent microscope at 16, 32, and 48 hpf. Mortalities were recorded to obtain and analyze the toxicity and possible LD50 values of NPs. Additionally, genetic responses of the zebrafish embryos to the NP toxic effects were analyzed using quantitative PCR (qPCR). The bioaccumulating rates of NPs in zebrafish embryos at different concentrations were also calculated by monitoring the NP concentrations at 16, 32, and 48 hpf. The result of the present study will help to address the concern of NP contamination in water and the potential impacts to the aquatic animal health. It also contribute to the mechanistic study in the host immune response to NP toxicities.

123-3 MARCE-NOGUE, J*; LIU, J; University at Buffalo; *liujuan@buffalo.edu*

Testing an Isometric Ontogenetic Model for Vibrations of Weberian Ossicles in Zebrafish

Weberian apparatus (WA), known to enhance hearing in otophysan fishes, conduct sound vibrations through coupling of the gas bladder and inner ear. WA of the zebrafish are well developed with four pair of ossicles, and present diverse morphotypes in laboratory settings, and thus provide a great platform to understand the conductive hearing system of vertebrates. A key question is whether an isometric growth model (IM) can explain observed hearing capability of zebrafish through ontogeny. Here we present the first study to model isometric WA growth in zebrafish. We scanned an adult zebrafish using uCT (4.67 um/voxel) and reconstructed the WA digitally at its original size (OM, length of the ossicular chain (Lwoc) 2.6 mm). We then generated an IM series allowing size to vary from 1 to 10 mm in Lwoc. To evaluate their biomechanical performance, we performed harmonic analyses using Finite Element Analysis. The results show that the OM of WA predicts the expected amplitude and phase of the vibration. Second, analyses of the IM series result in proportional increase of bone displacement in each ossicle and a constant amplitude factor (ratio of amplitude of the first and last ossicles) with increasing size. Results from the OM suggest that the WA acts as a spring-transmitter at audible frequencies, permitting a coupling of gas bladder motion to the saccule. Furthermore, the IM could explain observed audiogram in actual zebrafish ontogenetic sequences. These findings suggest that the functionality of WA could be weakly influenced by allometric changes in ossicles chain morphology through zebrafish ontogeny. This model has potential to further elucidate whether the WA in different otophysan species of varied WA morphologies and sizes are comparable in terms of biomechanical performance.

P3-98 MARK, D*; NASARI, A; TRIANO, N; BAUER, C; Adelphi University, Garden City, NY, USA, Hicksville High School, Hicksville, NY, USA; *cbauer@adelphi.edu*

Early identification of pregnancy in a precocial rodent (Octodon degus)

The Common degu (*Octodon degus*) has a gestation period of approximately 90 days, which is unusually long for a rodent. This is likely due to their precociality, as pups are born fully furred with well-developed sensory and thermoregulatory abilities. This long gestation period, however, makes scheduling and designing laboratory experiments difficult. Therefore, we aimed to better identify and characterize early pregnancy in *O. degus* females. Before being housed with males, we examined the estrus cycles of eight female degus by determining duration of vaginal patency and vaginal discharge cell types. Additionally, we took biweekly blood samples to measure progesterone levels and weekly body weight measurements. After allowing females to breed, we continued monitoring vaginal patency, vaginal smears, progesterone levels, and body weight. We also used canine/feline pregnancy tests every 3 weeks after mating to test for the presence of high relaxin levels. Unexpectedly, we found that all pregnant females were vaginally patent and had bloody vaginal discharge 1.5–2 months before parturition. This low-cost, accurate assessment will make future early pregnancy identification much easier in degus and possibly other caviomorph rodents.

55-6 MARKS, JR*; SORLIN, MV; LAILVAUX, SP; SCHWARTZ, TS; BEATTY, AE; University of New Orleans; *jrmarks@uno.edu*

Effect of Diet Restriction on Insulin-like Growth Factor 1 and 2 Expression in Female Green Anoles (Anolis carolinensis)

The insulin and insulin-like signaling (IIS) network is an important mediator of growth and metabolism in response to environmental conditions and is conserved across all animal taxa. Although the two main ILS hormones, insulin-like growth factor 1 (IGF-1) and insulin-like growth factor 2 (IGF-2), appear to mediate the trade-off between growth and reproduction, they have been studied primarily in mammals and their individual roles in other taxa, such as reptiles, are only vaguely characterized. Indeed, most studies on IGF have been performed in rodents, which do not express IGF-2 postnatally; and while fluctuations of IGF-1 in response to nutrient availability have received most attention, the responsiveness of IGF-2 to different environmental conditions has never been explicitly tested. We imposed a dietary restriction regime on green anole (*Anolis carolinensis*) females to test the hypothesis that IGF-1 and IGF-2 expression respond differently to dietary restriction. Specifically, we predicted that IGF-1 expression would be downregulated in diet restricted animals relative to controls, as is the case in other reptiles, whereas IGF-2 expression would be unaffected by dietary restriction. We discuss our results within the greater context of the IIS network as a lynchpin pathway for life-histories, and the potential for differential IGF expression to facilitate adaptive plasticity and maternal effects.

P2-176 MARROQUIN, CM*; MUNOZ-GARCIA, A; The Ohio State University, Columbus, OH, The Ohio State University at Mansfield, Mansfield, OH; *marroquin.11@osu.edu*

Energy Expenditure Among Different Roost Types and Colony Sizes Observed in Chiroptera

Bats spend a significant portion of their lifetimes in roosts. The variety of roost types that different species use is associated with microclimatic conditions that bats experience, which might have an impact on their energy budgets. We collected data from the literature on metabolic rates at different ambient temperatures, colony size, and roost type for 52 species of bats. We hypothesized that metabolic rate (MR) would be dependent on roost microclimate. To test our hypothesis, we used colony size and roost type as our independent variables. We predicted that less exposed roosts and larger colony sizes were associated with lower energy expenditure. We used ANCOVA, with diet as a covariate, in our analyses. We found that bats living in more exposed roosts had a significantly higher MR than bats in more protected roosts. Larger colony sizes were associated with a reduction in MR at low ambient temperatures. We found a significant interaction between roost category and diet, and colony size and diet; thus, we ran analyses separately for frugivorous and insectivorous species, and found the same patterns as with the whole data set. Patterns of torpor differed according to roost type: species roosting in more exposed roost types entered torpor at higher ambient temperatures than those species living in protected roosts. Overall, we found evidence that roost microclimates might have a significant impact on the bats' energy budgets. We expect that individuals would select those roosts with conditions that maximize fitness. We also expect that bats would compete for the best roosts, both at the intra- and interspecific levels. Knowledge on the influence of microhabitat on energy expenditure in bat species can be used to make efficient and impactful conservation policies and help identify particularly important roosts for bats.

P2-155 MARROQUIN-FLORES , RA*; MORTIMER, NT; PAITZ, RT; BOWDEN, RM; Illinois St U; *ramarro@ilstu.edu*

Thermal fluctuations produce ecologically relevant expression profiles for temperature-responsive genes

The red-eared slider turtle (*Trachemys scripta elegans*), exhibits temperature-dependent sex determination, where sex-specific genes are produced in response to incubation temperature. Cold-inducible RNA-binding protein (*Cirp*) is a candidate gene in the sex-determining pathway as previous research has demonstrated sex-specific *Cirp* expression in several species of turtles. However, prior studies have used constant incubation temperatures, which fail to capture the thermal variability that developing embryos would naturally experience. We compared patterns of *Cirp* expression in the gonads of *T. s. elegans* embryos exposed to a simulated heatwave during a period when developing gonads are sensitive to thermal cues. Eggs were incubated for 24 days at male-producing temperatures (25.0 ± 3 °C) before a subset were shifted to female-producing temperatures (29.5 ± 3 °C). Embryos were then sampled from both the male-producing and female-producing conditions for six consecutive days. In contrast to results from constant temperature studies, we found that *Cirp* expression did not differ between the fluctuating male-producing and female-producing temperatures. These findings highlight the importance of using ecologically relevant conditions when evaluating gene expression. Although *Cirp* did not vary under thermal fluctuations, we have submitted a subset of our samples for RNAseq to identify other genes that are responsive to fluctuating thermal regimes. A *de novo* assembly will be used to determine differential expression of male- and female-producing genes, allowing us to identify temperature-responsive candidates that are expressed during gonadal differentiation.

P3-201 MARSHALL, AS*; MULLINS, H; URISTA, CY; DAVIS, JE; Radford University, Radford, Virginia; *amarshall39@radford.edu*

Neutrophil/Lymphocyte Ratio as a Measure of Immune Response in Humans Exposed to Novel Microbiomes

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 occurred in a group of 16 North Americans in 2017 and 15 individuals in 2018 in the Peruvian Amazon for three weeks, 9 individuals in Patagonia, Chile in 2019, and 4 individuals in London, England. Specifically, we examined weight, body temperature, and neutrophil/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.

73-6 MARSHALL, CD*; RALEY, LN; PEREDO, CM; PYENSON, ND; Texas A&M University, Portland State University, University of Michigan, Smithsonian Institution; *marshalc@tamug.edu*

Implications for The Antiquity of Raptorial Biting in Pinnipedimorphs: Exploring Mandible Morphology in the Callorhinus Lineage

The integration of morphology and feeding performance studies can address questions relevant to feeding ecology and evolution. Pinnipeds are a major mammalian lineage with functional innovations for aquatic feeding. Recent functional data show that northern fur seals (*Callorhinus ursinus*) exclusively use a raptorial biting mode with the greatest gape angle opening velocity reported to date. It appears they are not capable of suction feeding, which is an unusual behavioral trait among extant pinnipeds. Furthermore, northern fur seals are considered to be the most basal living otariid pinniped. The *Callorhinus* lineage includes several extinct species and due to the craniodental morphological continuum of this lineage, they appear to retain their ancestral otariid feeding mode. We ask, is the feeding mode of *Callorhinus* indicative of deeper, ancestral feeding behavior among stem pinnipeds? Using 2D geometric morphometrics, we compared the shape of twenty-two fossil stem and crown pinniped mandibles. Sixteen homologous landmarks were digitized using the package Stereomorph in R. Function was then inferred from extant otariid performance studies to stem pinnipeds. Principle Components and Canonical Variates Analyses support the hypothesis that stem pinniped mandible shape does not differ significantly from extant *Callorhinus*. Therefore, stem pinnipeds likely employed the same raptorial feeding mode used by *Callorhinus* today, suggesting that *Callorhinus* retains the ancestral feeding mode through 25 million years of pinniped evolution.

36-3 MARSHALL, TL*; DAVIS, DR; HILLIS, DM; University of Texas at Austin, University of Texas Rio Grande Rio Grande Valley; *thomm80@utexas.edu*

Mitonuclear Discordance in the North American corn snakes (Pantherophis guttatus complex)

Mitochondrial markers have been widely used over the past 30 years to study phylogeography and infer species boundaries. The utility of these markers for such studies is based on the premise that variation within mitochondrial genes is largely neutral. However, evidence that different mitochondrial haplotypes within species confer differential fitness, and thus undergo selection, challenges this assumption. This, along with other factors, such as sex-biased dispersal and mitochondrial introgression across species, can lead to discordant genetic structure between mitochondrial and nuclear genomes. Mitonuclear discordance has been increasingly observed in a wide range of organisms, calling into question mitochondrial-based inferences of species boundaries. Here, we use a cytochrome-b sequence fragment and nuclear SNPs to investigate the presence of mitonuclear discordance in the North American corn snakes (Pantherophis guttatus), a complex that has been taxonomically defined by mitochondrial genetic structure. We identified five geographically partitioned mitochondrial haplotypes, indicating greater mitochondrial diversity than was previously recognized. However, only two of these haplotypes were monophyletic in our nuclear SNP phylogeny, which differed in topology from the mitochondrial tree. Further, population structure analyses using nuclear SNPs showed little evidence of reproductive barriers across haplotype boundaries.

106-6 MARSHALL, CA*; ZELLER, KR; GHALAMBOR, CK; Colorado State University; *Craig.Marshall@colostate.edu*

The Effects of Long- and Short-Term Salinity Acclimation on the Aerobic Scope of Trinidadian Guppies: Implications for Dispersal

Euryhaline fish species are able to tolerate a wide range of salinities. However, the extent to which fish populations cope with the energetic costs associated with fluctuating salinity levels through plasticity remains understudied. Moving from freshwater to brackish water should increase the minimum amount of energy required for basic physiological processes, or routine metabolic rate (RMR), and could decrease the maximum metabolic rate (MMR) if fish decrease gill permeability. An increase in RMR along with a decrease in MMR can result in an insufficient scope of activity, or aerobic scope (AS) to promote osmotic homeostasis. In Trinidad, the guppy (*Poecilia reticulata*) is confined to freshwater and behaviorally avoids brackish water, despite being considered euryhaline. To test if reduced AS contributes to the avoidance of brackish water, we conducted a common garden experiment that examined how long- and short-term acclimation to salinity altered AS. Wild-caught guppies were bred out to the second generation, and upon birth were split into either fresh- (0ppt) or saltwater (30ppt). RMR and MMR were measured, and AS was calculated in their rearing salinity to test long-term acclimation. We also used a gradual, step-wise acclimation to 5, 15, and 30ppt to test the effects of short-term acclimation. We predict AS should be maintained after long-term acclimation to saltwater, but should decline in response short-acclimation. Although the mechanisms of salinity acclimation are known in euryhaline fish, less is known about the potential trade-off between acclimation ability to salinity changes and other performance traits associated with fitness.

116-1 MARTIN, RJ*; KRUGER, MC; MACDOUGALL-SHACKLETON, SA; SHERRY, DF; Western University; *rmarti88@uwo.ca*

Temperature as a supplementary cue in the reproductive timing of the Black-capped chickadees (Poecile atricapillus)

Reliable environmental cues, such as photoperiod, allow birds to time their reproduction to match peak food abundance for their offspring. It is possible, however, that more variable local cues, like temperature, can provide more temporally precise information about the timing of these food events. Resident birds especially should be sensitive to temperature cues and use them to modulate their reproductive timing on a fine scale. We conducted two experiments to examine the effect of temperature on reproductive condition in a resident songbird, the black-capped chickadee, *Poecile atricapillus*. In the first experiment, we exposed birds to three over-winter temperature treatments under semi-natural conditions and assessed gonadal development in the spring. In the second experiment, we used a 2x2 factorial design to assess changes in gonadal development and circulating testosterone levels of birds experiencing different temperatures under photostimulatory and non-photostimulatory photoperiodic conditions. Temperature had no independent effect on gonadal development or testosterone levels, but when photostimulated, birds exposed to warmer conditions became reproductively ready earlier than birds experiencing cooler conditions. We conclude that temperature acts as a supplementary cue that aids birds in the timing of reproduction.

P3-43 MARTIN, MN*; ZIMMERMAN, LM; Millikin University; *mnmartin@millikin.edu*

In vitro synergistic activity of antibiotics and red-eared slider plasma on bacterial growth

From the use, overuse, and misuse of antibiotics, microorganisms in our environment are constantly altered, making bacterial illnesses tougher to overcome. Microbes have genetic capacities that allow them to evolve and mutate at unpredictable rates, employing advantages such as biofilm to resist antibiotics. Thus, new methods of attack against microorganisms are needed. We hypothesized that plasma from the red-eared slider turtle (*Trachemys scripta*) would act in a synergistic way with antibiotics to improve bacterial killing. T. scripta plasma contains proteins that have immunogenic capacities, such as the complement cascade, that could be helpful in allowing antibiotics to kill bacteria more effectively. Slider plasma was added to sub-inhibitory concentrations of streptomycin for use against *Escherichia coli* and *Staphylococcus aureus* bacteria. A bacterial killing assay was observed over 4 hours, and data was collected in colonies from contrasting plates of bacteria, bacteria & plasma, bacteria & antibiotic, as well as bacteria, plasma, & antibiotic. There was a significant effect of time for fresh and frozen plasma in killing *E. coli* and *S. aureus*. The effect of treatment was significant in fresh and frozen plasma in killing E. coli. However, there was not a significant time by treatment interaction in any trials. It was established that plasma and lower amounts of antibiotic could be used to increase the rate of bacterial elimination. Specifically, further analysis and experimentation could be used in support of employing slider plasma for decreasing antibiotic use in the treatment of bacterial infections.

12-4 MARTIN, CM; University of California, Berkeley; *chmartin@berkeley.edu*

How to investigate the origins of novelty: insights gained from ecology, genomics, function, and fitness landscapes

Biologists are drawn to the most extraordinary adaptations in the natural world, i.e. evolutionary novelties, yet rarely do we understand the microevolutionary processes underlying the origins of novel traits, behaviors, or ecological niches. Here I discuss insights gained into the origins of novelty from my research program over the past decade on Caribbean pupfishes, spanning biological levels of organization from genotype to fitness landscape. I focus on a case study of the origins of novel trophic specialists on San Salvador Island, a sympatric radiation including the endemic scale-eating and mollusk-eating specialist pupfishes. I highlight questions that can be addressed about the origins of novelty at different biological levels, including the contributions of ecological opportunity, the isolation of novel phenotypes on the fitness landscape, the spatiotemporal origins of adaptive variation contributing to novelty, gene misregulation due to adaptive divergence, and form-function relationships for novel traits. Evolutionary novelties are rare, almost by definition, yet integrative case studies can provide insights into this rarity relative to more common adaptations, such as the relative isolation of novel phenotypes on fitness landscapes and the transient availability of ecological, genetic, and behavioral opportunities for novelty.

77-4 MARTIN, LM*; ESBAUGH, AJ; The University of Texas at Austin, Marine Science Institute; *leighann.martin@utexas.edu*

Recovery from catch-and-release angling in Gulf of Mexico fishes

The Gulf of Mexico's recreational fisheries has been estimated to provide in excess of $7 billion annually, and sportfish species like Atlantic tarpon (Megalops atlanticus) and red drum (Sciaenops ocellatus) are major contributors. Catch-and-Release (CAR) angling was implemented to help protect sportfish species, and the associated economic interests of stakeholders, yet the effectiveness of CAR can vary between species and ecosystems. Tarpon are unique among marine fishes because they can breathe air; however, their reliance on air breathing remains uncertain, which has important implications for CAR. As such, this study has two goals: 1) to determine if air-breathing behavior is facultative or obligate in tarpon, and 2) to assess the importance of air-breathing to recovery from exhaustive exercise. Juvenile tarpon were first observed via video for 1 h period in normoxia and hypoxia (20% oxygen saturation) to categorize air-breathing behavior. Consistent with facultative air-breathing, tarpon significantly elevated air-breathing rate when exposed to hypoxia. To simulate CAR events, individuals were chased to exhaustion and sampled, or allowed to recover for 1 or 4 h with or without access to the surface. A similar protocol was undertaken for red drum to provide a comparison to a non-air-breathing sportfish. Each individual was sampled for blood, white muscle, gills, and heart and assessed for a panel of common indices of exercise stress. Preliminary results suggest that tarpon begin to recover from exercise by 4 h post-exercise, with no clear benefits of having access to the surface. This was similar to the recovery profile exhibited by red drum. As such, no special considerations are needed in CAR procedures to accommodate the air-breathing physiology of tarpon.

16-6 MARTINE, C.T*; KELL, A. ; Bucknell University, Lewisburg, PA; *ctm015@bucknell.edu*

Cross-pollination: Art & Sex through the Lens of Botany

Offered as a sophomore-level Integrated Perspectives course at Bucknell University, Art & Sex Through the Lens Botany integrates the professional perspectives of a visual artist and a botanist into one course that seeks to impart the importance of making connections across disciplines and the value of visual literacy across academic lines. The course introduces foundational concepts in each field and encourages students to integrate these different systems of knowledge and to explore their intersections. We hope that our interdisciplinary approach to botany and to creating art will not only give students a new appreciation and understanding for each field, but also an awareness of the ways they can contribute meaningfully to cultural dialogue (including on topics in human sexuality) through the integration of science and art.

118-7 MARTINEZ, CM*; FRIEDMAN, ST; CORN, KA; LAROUCHE, O; PRICE, SA; WAINWRIGHT, PC; University of California, Davis, Clemson University; *cmimartinez@ucdavis.edu*

Large Mouths and Tapered Tails: Morphological Disparity Increases with Ocean Depth

Morphological traits comprising fish body plans can tell us a lot about how species interact with their surroundings. However, much of our understanding of the distribution of morphological disparity across habitats and environments is geographically constrained and taxonomically limited. In this study, we investigate body shape evolution and disparity at a global scale, as it occurs with increasing ocean depth, an environmental dimension along which many biologically important factors vary, including light, temperature, pressure, and nutrients. We make use of a large morphological dataset of ray-finned fishes, evaluating body shape disparity for over 3,000 marine species. Fishes were categorized into four traditional depth zones, epipelagic (0-200m), mesopelagic (200-1,000m), bathypelagic (1,000-4,000m), and abyssopelagic (4,000-6,000m). Using eight size-corrected linear traits, we show that morphological disparity increases more than two-fold across ocean depth zones. Body length and caudle peduncle traits had the greatest variance and elevated rates of evolution at depth. We observe that deep-sea fishes readily diversify along a body elongation axis, accessing the full range found at shallow depths in addition to novel elongate morphotypes. We also find greater jaw size (but lower variance and rate of evolution) with depth, a pattern that is frequently offered anecdotally, but has never been shown in a comparative study of this magnitude. The relative constraint on jaw size in aphotic, deeper waters is consistent with opportunistic trophic strategies. In contrast, the large variance in body elongation in the deep-sea may reflect a release from selective pressures on locomotion compared to light-dominated surface waters.

P1-254 MARTINEZ, V*; GRACE, JK; Texas A&M University; *vm_983277@tamu.edu*

Interactions between stress hormones and blood parasites along elevation gradients

Vertebrate animals respond to changes in the environment with hormonal responses, such as glucocorticoids, to maintain homeostasis. Glucocorticoids are steroid hormones that influence metabolism and the immune system. Corticosterone (i.e., the primary avian glucocorticoid) is elevated in birds infected with parasites, although why this relationship exists is unclear. Little is still known about the interactions between parasite prevalence and the hormonal stress response in the wild, or the differing roles of glucocorticoid concentrations in mediating parasite colonization. Elevational zones are excellent models for investigating these interactions in nature because there are known parasite trends across differing elevations. This study investigates the interactions between avian glucocorticoids, parasite prevalence, and environmental elevation to improve our understanding of the mechanisms underpinning elevational refugia from disease, with implications for disease transmission and species survival under climate change scenarios. We present preliminary results from two field seasons and discuss them within the context of the ongoing project.

P3-213 MARTINEZ, J; KOPLYAY, C; MISAMORE, M*; Texas Christian University; *m.misamore@tcu.edu*

Environmental factors effecting the survival and reproductive success of the invasive zebra mussel Dreissena polymorpha

The zebra mussel (*Dreissena polymorpha*) is an invasive freshwater mussel infesting many waterways of the eastern, central, and southern United States. Recently, they arrived in north Texas and are currently spreading southward into multiple water basins in Texas. Key to their continued invasion into Texas waters is their reproductive ability through broadcast spawning and direct larval development in the water column. Downstream transport of veliger larvae and anthropogenic transport of adult mussels are the two main mechanisms of spread. As indicated by zebra mussel spread into Texas, zebra mussels have demonstrated the ability to survive and reproduce in environmental conditions beyond predicted values for this cold-water species. The focus of this study was looking at various environmental factors which might affect mussel survival, growth, and reproduction. Factors addressed include temperature and calcium concentration as well as the effects of copper as a potential mechanism of control. Impacts on mussel growth, survival, and reproductive success including fertilization and larval survival were studied. Zebra mussels showed high levels of survival under varying calcium concentrations, were susceptible to high water temperatures, and were negatively impacted by exposure to copper.

P1-94 MARTINS, L*; LOWER, S; Bucknell University; *lmm037@bucknell.edu*

Dark Firefly Seduction: Identifying the Mate Attracting Mechanism of Ellychnia corrusca via Bioinformatics

The mechanisms by which insects attract mates can be divided into three categories: visual, chemical, and auditory. Fireflies (Lampyridae) are an excellent example of the first category, as males travel throughout the night displaying their species-specific flash in search of a female during the summer months. However, not all fireflies light up. In fact, a number of species have evolutionarily lost the ability to produce light as adults and are thus considered "dark". Therefore, if these "dark" fireflies are unable to light up, what other mechanism are they using to find mates? While the majority of firefly research has been conducted on lighted species, there is much to be discovered regarding their "dark" counterparts. In this project we investigated chemoreception, specifically olfaction, as an attraction method since many insects rely on pheromones in their search of potential mates. Odorants receptors (ORs) are the primary mechanism by which insects detect pheromones and other volatile chemicals. Using computational methods, we identified 33 putative odorants receptors (ORs), in the *Ellychnia corrusca* genome, a "dark" species of firefly, and compared their phylogeny to known ORs of other beetles (Coleoptera). By identifying and comparing these ORs we are able to understand their importance in mate attraction for *Ellychnia corrusca*. In addition, we are able to gain evolutionary insight into an instance of closely related species employing diverging sensory modalities for the same behavior.

P2-50 MASON, JN*; STEVENS II, DR; GRAHAM, MA; FOSTER, SA; BAKER, JA; Clark University; *JiMason@clarku.edu*

Predation Effects on the Evolutionary Trajectory of Brain Morphology in the Threespine Stickleback Fish

Novel pressures introduced to an environment due to human interaction disrupts the native biodiversity. Thus, it is important to understand the evolutionary trajectory resulting from novel selective pressures introduced by anthropogenic activities in making informative conservation efforts. Rainbow trout (*Oncorhynchus mykiss*) is a species routinely stocked in Alaskan lakes previously devoid of the species, altering the predation regime to which native threespine stickleback (*Gasterosteus aculeatus*) are exposed. Here we examine effects of trout introduction on brain structure and overall brain size. This study evaluated two Alaskan lake populations, Whale Lake (not stocked) and Bear Paw Lake (stocked), that were sampled from the years 1993 until 2019. The telencephalon, optic tecta, and cerebellum will be quantified using the ellipsoid model between these populations and across time. The ellipsoid model assumes the lobes of the brain maintain an ellipsoid shape, by taking the length, height, and width of these lobes volumetric quantities can be calculated through the formula $0.167\pi lwh$. Previous studies are in conflict, suggesting that predators select for either an increase or decrease in brain size related to specific predator-prey interactions. Due to the high metabolic cost of brain tissue, a selective trade-off exists. Selection in favor of increased brain size is thought to increase cognition and sensory abilities utilized in predator detection. However, selection in favor of decreased brain size allows for the allocation of energy to structures that aid in predator evasion and defense, as well as reproduction and feeding. This study addresses the possibility that introduction of rainbow trout has led to alterations in brain structure and size, and if so, in what directions.

130-4 MASONJONES, HD; ROSE, E*; ELSON, J; University of Tampa, FL; *erose@ut.edu*

Nocturnal surveys of seahorses, Hippocampus erectus, reveal increased densities and seasonal recruitment patterns

Although the field of nighttime ecology remains understudied, nocturnal surveys can play an integral part in assessing fish assemblages. While little is known about seahorse nocturnal behaviors, congregations were documented at night in an isolated saltwater lake in the Bahamas. Population surveys for seahorses and their potential predators, octopus and crabs, were conducted in Sweetings Pond, Eleuthera, Bahamas, at midnight and midday during March and August 2018, using belt transects organized perpendicular to the shoreline and increasing in depth. Nocturnal surveys reported densities (1.2 seahorses/m-2) significantly higher than those reported on the same transects during the day (0.2 ind/m-2) and in previous studies in Sweetings Pond (0.14 ind/m-2). Predator densities followed a similar pattern with higher densities observed during the night. Sex ratios were consistently male-biased, and the frequencies of fish in different reproductive categories were significantly influenced by time of day. Daytime populations were made up of 70% males, with a high frequency of pregnant males in March, whereas nocturnal populations saw an increase in number of females observed. Seasonal recruitment was detected for the first time in this population, with an increase in juveniles detected in the shallow ends of transects during nocturnal surveys in March. Seahorses were also perched significantly higher in the water column during the night regardless of reproductive category, depth, or season. Considering *H. erectus* is listed on the IUCN Red List as Vulnerable, the drastic increase in population size due to changes in detectability, changes in sex-ratios, and presence of juveniles during nocturnal surveys has crucial implications for understanding their ecology and conservation.

134-2 MATHERNE, M*; HOWINGTON, O; LENAGHAN, O; HU, D.L; Georgia Tech Department of Mechanical Engineering, Georgia Tech Departments of Mechanical Engineering and Biology; *mmatherne3@gatech.edu*

The Effect of Nectar on the Honey Bee Pollen Pellet Removal Force

Honey bees (*Apis mellifera*) carry pollen back to their hive by mixing it with nectar and forming it into a pellet, which they carry in the corbicula, or pollen basket, on their hind legs. It is unknown how this method works across the range of sizes and shapes of pollen grains. In this study, we have filmed bees removing pollen pellets in the hive and conducted experiments to measure the force to remove them. We show that the more dried out the pellet is, the more force is required to remove it. We explain this difference in removal force using fluid mechanics principles. We also investigate the relationship between the amount of nectar in a pellet and the size and shape of the pollen grains. By studying the mechanics of pollen pellet formation, we hope to give insight into how honey bees are such effective pollinators.

107-4 MATOO, OB*; MONTOOTH, KL; University of Nebraska-Lincoln, Lincoln, NE, University of Nebraska- Lincoln, Lincoln, NE; *omatoo2@unl.edu*

Ethanol, Flies and Metabolism: Linking Genotypes to Phenotypes

Coincident with its out-of-Africa expansion, *Drosophila* also evolved capacity to live in ethanol-rich vineyards and orchards. However, sensitivity to alcohol varies among individuals within and across populations of *Drosophila*. Multiple genes and their interactions with the environment (G X E) underlie alcohol related fitness phenotypes. Furthermore, the bioenergetic responses to ethanol by mitochondrial oxidative phosphorylation (OXPHOS) require proteins from both the mitochondrial and nuclear genomes, creating the potential for inter-genomic gene-by gene (G X G, or epistasis) interactions to underlie variation in alcohol-induced phenotypes. Not surprisingly, therefore, the genetic bases of a complex trait like ethanol metabolism remains poorly understood. Here, we addressed this question by using *Drosophila* larvae with different nuclear and mitochondrial genetic backgrounds reared under developmental ethanol exposure. We demonstrated that ethanol induces oxidative stress, mitochondrial dysfunction (elevated basal respiration, proton leak, depolarization of mitochondrial membranes), and compromised whole-organism energy read-out (reduced lipid reserves and decreased pupation height). Thus, altered energy metabolism resulted in increased energy expenditure for basal maintenance in *Drosophila* larvae; but these effects were largely modulated by the underlying genetic architecture in both the natural isolates as well as in the larvae with mito-nuclear genotypes. These data correlate genetic variation with ethanol induced physiological trade-offs and provide comparative insights about how genetic variation among different ecotypes could potentially allow them to adapt to dynamic ethanol environments.

56-7 MATSUDA, SB*; CHAKRAVARTI, LJ; CUNNING, JR; VAN OPPEN, MJH; GATES, RD; Hawaii Institute of Marine Biology, Australian Institute of Marine Science, Shedd Aquarium; *shayle@hawaii.edu*

Coral (Acropora tenuis) background symbiont, Gerakladium>, competes with Durusdinium as dominant symbiont at elevated temperatures in multiple-genus symbiont-choice

Corals that take-up algal symbionts from the environment anew each generation (horizontal transmitters) may have a winnowing period during which specific symbiont associations become established from initially diverse infections, and this process could be modulated by the environment. *Acropora tenuis*, a common horizontal transmitting coral on the Great Barrier Reef, associates with a stress-sensitive species of *Cladocopium* and a stress-resistant species of *Durusdinium* as adults. We examined infection of *A. tenuis* larvae with four genera of Symbiodiniaceae with different thermal maxima (*Cladocopium*, *Durusdinium*, *Fugacium*, and *Gerakladium*) over two weeks at three different temperatures (27C, 30C, & 31C). Larvae were exposed to a single genus or an assortment of all four and individual larvae were flash frozen at days 3, 7 and 14. The type and number of symbionts/larva was measured in individual larvae by digital droplet PCR. All four genera were successful at initially infecting larvae at all temperatures in single infections and mixed infections. At 27C, *Durusdinium* was the dominant symbiont in 68% of larvae at day 3, and 79% at day 14. However, at 30C and 31C, larvae were dominated by either *Gerakladium* or *Durusdinium* at approximately equal frequency (approx. 40-43% each) by the end of the trials. *Fugacium*, which has the highest thermal maximum in culture, did not proliferate within the larvae at any temperature. If sea surface temperatures continue to warm during the onset of symbiosis, symbionts that were relatively rare or absent in *A. tenuis* adults, like *Gerakladium*, may begin to compete, which could have implications for holobiont performance under thermal stress.

4-2 MATTHEWS, DG*; DIAL, TR; LAUDER, GV; Harvard University; *davematthews@g.harvard.edu*

Suction feeding in zebrafish is improved by upregulated Wnt signaling

Among fishes, feeding mode is often considered the major axis of divergence and has been shown to produce extraordinarily rapid adaptive radiations. This behavioral evolution is often accompanied by a morphological shift in the craniofacial skeleton. One example of this can be found in the divergence between ecologically dissimilar species of cichlids from Lake Malawi, where the phenotypic novelty in the derived craniofacial morphology can be attributed in part to increased endogenous Wnt/β-catenin signaling. This developmental shift appears to be highly conserved as a similar morphological changes have been shown in zebrafish by increasing Wnt signaling. However, we have little idea how the resultant morphological shift is associated with functional variation. Here we experimentally manipulate Wnt expression in larval and juvenile zebrafish, then directly measure the resulting functional effects on suction feeding ability. We first use lithium chloride (LiCl) treatments to temporarily upregulate Wnt signaling at either three or fifteen days post-fertilization. We then raise these zebrafish to thirty days, the end of their larval period, and test their feeding performance using high-speed video to measure jaw kinematics and the flow velocity field. Finally, we compare morphological and kinematic variation between treated and control individuals. We find that zebrafish treated with LiCl can have improved feeding performance compared to the control fish. However, this effect depends on the age at which they received LiCl. Furthermore, there are differences in the craniofacial morphology and feeding strike kinematics in treated fish, suggesting that Wnt mediated morphological shifts can alter post-development feeding performance. This result gives us insight into the functional effects of rapid morphological shifts and therefore into the evolution of ecological novelty in fishes.

96-1 MATTHEWS, M*; CROWLEY, CJ; AIELLO, BR; SIKANDAR, UB; SPONBERG, S; Georgia Tech; *meganmatthews10@yahoo.com*

The Answer is Blowing in the Wind: Flower Wake Downwash Can Reduce Aerodynamic Forces in Insect Flight

Flying insects interact with changing aerial environments that may challenge aerodynamic performance. Both floral pollinators and the flowers they seek are affected by changes in airflow. Recent studies have begun to explore how animals alter behavior in response to unsteady air, but we do not know if these conditions represent the airflow behind natural flowers. Wind may blow from multiple directions and evidence suggests that flowers can re-orient to face downstream which means that pollinators would often fly through flower wakes. To investigate the features of a natural flower wake, we used 3D particle tracking velocimetry (3D-PTV) to measure the flow downstream of *Petunia* hybrids varying in diameter from 2-4.6 cm. The 3D wakes for all flowers showed an unsteady region of reduced wind velocity, comparable in size to the flower diameter, that extended 3-6 cm downstream. The unsteady region was present in all flower sizes, but we found that wakes of large flowers were dominated by a steady downwash. Flowers with d=4.6 cm induced a 10°-20° deflection of the freestream airflow that persists up to 2 cm above the petal height. Next, we determined the aerodynamic consequences of the steady induced wake angle for a hawkmoth hovering downstream with a blade-element model (BEM). At 0.7 m/s, a 20° difference in the incoming airflow results in a 9% loss in vertical force due to changes in effective angle of attack. During pollination, insects must reach the flower and maintain contact while interacting with the deflected flower wake, but the reduction in force suggests that animals would need to alter flight posture and/or kinematics to maintain performance, even at low wind speeds. Our work shows that flower wakes can incur significant losses in flight performance for pollinators.

P1-59 MATZ, MV; University of Texas at Austin; *matz@utexas.edu*

LD networks, a new approach to detect sites under polygenic selection, applied to characterize patterns of introgression among coral ecomorphs.

Polygenic selection (selection on multiple loci contributing to the same phenotype) is expected to result in covariance of allelic states among phenotype-associated variants; in other words, it should give rise to linkage disequilibrium (LD) among sites in the absence of physical linkage between them. Here, I used this idea to identify sites under selection against introgression between ecomorphs of the great star coral (Montastrea cavernosa) from the Florida Keys. This species comes in four genetically distinct but hybridizing ecomorphs: two of them are specialized for deep reef habitat (>15 m) but are sympatric with respect to each other, the third is offshore-specialized, and the fourth one is inshore-specialized. To identify co-varying groups of sites, I adopted the Weighted Gene Coexpression Networks Analysis (WGCNA) to analyze the matrix of allelic correlations (pairwise r-square estimated with the EM algorithm using ngsLD software). WGCNA identified five groups of covarying sites ("modules"), four of them capturing derived alleles resisting introgression in each of the four ecomorphs, and the fifth one capturing sites that are selected for the ancestral state in the deep habitat. The new approach ("LD networks") inherits the main advantages of WGCNA: (1) it is model-free, meaning that it does not require the researcher to specify which samples correspond to which deme or environmental condition; (2) post hoc, it allows simultaneous evaluation of large number of factors for possible role in shaping polygenic selection signatures.

S7-2 MAURO, AA*; GHALAMBOR, CK; MAURO, Alexander; Colorado State University; *amauro@colostate.edu*

The transcriptomic basis of a trade-off between salinity tolerance and competitive ability in the Trinidadian guppy

The factors determining the geographic distribution of organisms has long been of interest to organismal biologists. Eco-physiological studies have shown that what limits an organism's range in nature is not often one single factor, but rather the tolerance to multiple biotic/abiotic factors that vary across an organism's range. With the advent of modern genomic sequencing we can not only document the genes underlying environmental tolerance, but also the mechanistic basis for why they serve as evolutionary barriers to range expansion. Here we investigate the range limit of the Trinidadian guppy, *Poecilia reticulata* which is restricted to freshwater in Trinidad despite its ability to survive in brackish water in the lab and other parts of its range. Transplant experiments and behavioral studies show that salinity and competition with a closely related species, *Poecilia picta* , interact antagonistically to limit *P. reticulata's* range. This negative interaction is perhaps mediated by the fact that *P. reticulata* becomes subordinate to *P. picta* when in brackish water. In addition to documenting this interaction at the phenotypic level, we also investigated it at the transcriptomic level. We looked at transcriptome wide gene expression in the gills and brain of *P. reticulata* in different salinities and in different competitive environments to investigate if the negative phenotypic interaction is due to an antagonistic interaction between the transcriptomic responses underlying osmoregulation and aggression. Our genotype-to-phenotype approach can help to understand the complex pleiotropic trade-offs associated with different environmental challenges.

P2-132 MBOG, RM*; WILLIAMS, J; KRAJNIAK, KG; Southern Illinois University Edwardsville; *rmbog@siue.edu*

The effects of temperature on contraction of smooth muscle in the earthworm Lumbricus terrestris and its action in response to acetylcholine

Lumbricus terrestris" is an anecic earthworm that experiences different thermal environments. Most experiments examining the effects of neurotransmitters on their smooth muscles have been performed at room temperature. Since these animals are found at cooler temperatures, we decided to examine how temperature affects the contractility of their isolated crop-gizzards. Since acetylcholine (ACh) stimulates the contractility of crop-gizzards at room temperature, we also examined their responses to this molecule at various temperatures. We placed the organs in temperature-regulated tissue baths and recorded spontaneous contractions. Temperature was varied from 20^{o}C to 15^{o}C and 10^{o}C, then back up to 15^{o}C and 20^{o}C. We recorded any changes at each temperature. We then placed crop-gizzards in constant-temperature tissue baths and applied increasing acetylcholine concentrations. The resulting data were used to create ACh log-concentration response curves. Results from the first experiments showed the baseline contraction amplitudes dropped when moving from 20^{o}C to 15^{o}C and 10^{o}C, and rose when the temperature increased from 10^{o}C to 15^{o}C and 20^{o}C. The contraction rates dropped at 10^{o}C and then rose at 15^{o}C and 20^{o}C. ACh caused an increase in both contraction rate and amplitude. Temperatures of 10^{o}C and 20^{o}C caused a decrease in ACh efficacy and potency on the contraction amplitude compared to 15^{o}C and room temperature, while 10^{o}C and room temperature caused a decrease in ACh efficacy and potency on contraction rate compared to 15^{o}C and 20^{o}C. Our results suggest that the earthworm smooth muscle spontaneous contractility and responses to ACh decreased at 10^{o}C, while at warmer temperatures the responses were more variable.

P3-228 MCALISTER, J/S*; PRESTWICH, K/N; College of the Holy Cross; *jmcalist@holycross.edu*

A liberal arts approach to introductory biology: Introductory sequence that gives full time to modern organismal biology

In 2012, members of the Biology Department at Holy Cross expanded the introductory curriculum from two to three courses. Our main motivation was to provide a thorough, principles-based introduction to biology at all levels of the biological size and complexity hierarchy. A major stimulus was an increasing concern that our students were not being exposed sufficiently to modern organismal biology. For many students, unfamiliarity began in high school and was not helped by an introductory curriculum that increasingly emphasized exciting, theoretically rich discoveries only at small and large scales; functional organismal biology was being squeezed out of our introductory curriculum. We now offer a three-semester sequence consisting of an introduction to cellular and molecular biology (CMB), an organismal-focused course entitled *Mechanisms of Multicellular Life*, and a final course dealing with biodiversity, ecology, and evolution. *Mechanisms of Multicellular Life* uses a comparative approach to examine structural and functional solutions to the problems faced by animals and plants related to size, movement, exposure to physical forces, mode of existence, habitat, and evolutionary history. We also introduce students to the importance of biophysical and mathematical approaches to biology in addition to the familiar role of biochemistry. The result has been a proportional increase in enrollment in upper-level organismal courses by students who are better prepared to tackle modern approaches to organismal form and function. Our poster will focus on the philosophy and details of the *Mechanisms of Multicellular Life* course and on the usefulness of a three-course curriculum, especially at liberal arts institutions.

S9-1 MCBRAYER, L; MCELROY, E*; SUSTAITA, D; Georgia Southern University, College of Charleston, University of California at San Marcos; *mcelroye@cofc.edu*

Introduction: Applied Functional Biology: linking ecological morphology to conservation and management

A growing number of researchers work at the interface of organisms and their environment. Too often, academic scientists overlook insights that organismal, or functional, biologists can bring to the understanding of natural history, ecology, and conservation of species. Likewise, natural resource managers are frequently concerned with population sizes, while ignoring key functional traits that might explain fluctuations in population size. Our intention for this symposium is: 1) bring to light current and future research in functional and ecological morphology that also involve issues of concern to wildlife management and conservation, and 2) show how such studies can result in measurable outputs useful to regulatory agencies. Symposium topics will reveal past, present, and future collaborations between functional morphologists/biomechanists and conservation/wildlife biologists. Presenters will demonstrate specifically how data gathered to address fundamental academic questions regarding the causes and consequences of organismal form and function can also help address issues of conservation and wildlife management.

S9-7 MCBRAYER, LD*; ORTON, RW; NEEL, LK; KAUNERT, MD; TUCKER, DB; WILLIAMS, SC; Georgia Southern University, University of Texas Arlington, Arizona State University, Ohio University, Arizona State University; *lancemcbrayer@georgiasouthern.edu*

Integrating Studies of Function and Ecology to Inform Conservation and Management

The Ocala National Forest covers roughly 383,000 acres, 60% of which is critically threatened Florida scrub habitat. Florida Scrub is home to many threatened or endangered species such as the Red Cockaded Woodpecker, Florida Scrub Jay, Gopher Tortoise, Indigo Snake, Sand Skink and Florida Scrub Lizard. The Ocala National Forest is predominantly managed for timber and pulp industries via clear-cutting of sand pines on a 20 to 30 year schedule. Yet within the Ocala, seven long leaf pine sand hills are managed via periodic prescribed fires to ensure survival of certain threatened and endangered species. These contrasting management practices provide fertile ground for comparisons of the ecology and evolution of a variety of functional traits at the population level. I will present data from several studies to serve as a case study in how hypothesis driven functional biologists may work in such systems to the benefit of managers, conservation biologists, and basic scientists alike. This case study may also serve as an example of how junior faculty might establish a research program that serves multiple purposes. I will highlight initial work on foraging behavior and diet in the Florida Scrub Lizard that began to assess the effects of management practices. This work helped to frame subsequent studies on locomotion, population biology, predation, and physiology. Collectively, these studies allow managers to assess the impacts of management decisions on target (e.g. Red Cockaded Woodpecker) and non-target species (Florida Scrub Lizards). Recently, a new 20-year management plan was adopted such that past and future data will significantly inform the effectiveness of management practices, while also serving as an excellent system to test hypotheses on local adaptation and population level variation in functional traits.

P3-169 MCCAHON, SL*; SHANKAR, A; WILLIAMS, C; University of Alaska Fairbanks, Institute of Arctic Biology, Fairbanks, AK; *smccahon2@alaska.edu*

Effects of short photoperiod on sleep and carbohydrate consumption in diurnal grass rats

Four to six percent of all Americans are affected by seasonal affective disorder (SAD), a form of recurrent depression triggered by reduced exposure to sunlight. In addition to being a seasonal mood disorder, SAD has also been associated with circadian dysfunction, weight gain, and increased carbohydrate consumption. In this study, we are using a diurnal rodent model, the Nile grass rat (*Arvicanthis niloticus*) to determine how well this species' symptoms parallel those of humans that are diagnosed with SAD. Grass rats are known to exhibit depressive-like behaviors under short photoperiods; however, their sleep patterns and carbohydrate consumption in response to different photoperiods are unknown. We monitored sleep-wake behaviors using piezoelectric sheets, and measured weight, sucrose consumption, and liver fat content in 45 grass rats in response to short photoperiod (4:20 LD) and neutral photoperiod (12:12 LD) conditions. We found that short photoperiod conditions caused sleep disruption, and that sucrose consumption significantly affected sleep bout duration. For animals under short photoperiod conditions, activity onset occurred 8 hours before lights on (12 hours before lights off), followed by a resting phase, and then by higher intensity activity during the light phase. We found no effect of photoperiod on sucrose consumption, but preliminary results show that liver fat content was higher in animals exposed to the short photoperiod. The grass rats with access to high concentrations of sucrose had higher liver fat across both photoperiod treatments. Our findings suggest that complex interactions between photoperiod, sucrose consumption, and sleep activity should be accounted for when determining grass rats' suitability as a rodent model for SAD.

P3-144 MCCARTER, M.G*; LOUDON, C.; University of California, Irvine; *marlom@uci.edu*

Mechanical damping of cricket antennae

Many insect antennae, including those of house crickets (*Acheta domesticus*), are long and slender. These mechanosensory structures are used for tactile sensing; as such they readily bend in response to physical contact with objects in their environment. We analyzed the recovery of antennae deflecting around a fixed obstacle at four distances along the flagellum, and determined that 1) antennae exhibited elastic recoil, for both ventral and dorsal deflections, with antennae returning to their original position, suggesting there is a "resting shape" and 2) antennae barely oscillated if at all while returning from deflection, with the tendency to oscillate decreasing with a more distal deflection. This lack of oscillation demonstrates that antennae are mechanically damped. The damping decreases oscillation of the antenna after deflecting, hastening the return to the resting position and allowing the cricket antenna to more quickly respond to new mechanical stimuli. Measurements were made on restrained live crickets, with the head and joints associated with the scape and pedicel held rigid with epoxy, allowing only the flagellum to bend. The geometry of the curved antennae during bending at each distance suggests flexural stiffness (or EI) of the flagellum decreases in the distal direction.

25-3 MCCARTY, B*; MATTHEWS, M; SPONBERG, S; Georgia Institute of Technology; *bmccarty@gatech.edu*

Flexibility Maintains Leading-edge Vortex Structure on Manduca Wings

The leading-edge vortex (LEV) is a canonical aerodynamic mechanism in the flapping flight of insects, mammals, and birds across a variety of scales. While the *in vivo* LEV in insects is a coherent vortex that remains bound to the wing near the leading edge (with a diameter less than 50% the local chord length), in laboratory models with rigid wings this coherence is disrupted and the vortex grows (exceeding 80% the local chord length), a phenomena known as bursting. Bursting has been shown to reduce LEV lift, but it remains unknown how this impacts insect flight performance. Additionally, insect wing flexibility is known to increase lift. Its impact on vortex structure is unexplored, but its known role in force production suggests that flexibility distribution in insect wings could contribute to maintaining higher-lift unburst LEVs. To test this, we mounted freshly removed *Manduca sexta* wings on a motor rotating at a constant velocity to generate coherent LEVs at Re $O(10^3)$ and observed the fluid structure with smoke visualization. Freshly mounted wings consistently featured unburst LEVs, whereas desiccated wings (measured to be roughly twice the stiffness) created burst LEVs, suggesting that the compliance and flexibility gradient of insect wings contribute to the structure of LEVs. We next measured differences in local angle of attack between fresh and desiccated wings – fresh wings showed a near-linear increase in local angle of attack from root to tip, while desiccated wings featured a near-constant angle of attack outside of a sharp increase across the 40%-60% span region. Bursting occurs near the mid-span point on the wing where this sharp increase in angle of attack was observed. Combined, these results imply that the flexibility distribution of the fresh *Manduca* wing helps maintain LEV structure.

96-6 MCCASKEY, EN*; LEHNER, K; TAYLOR, I; BENFEY, PN; GOLDMAN, DI; Georgia Tech, Duke University; *emccaskey@gatech.edu*

Rice Root Tip Circumnutation Facilitates Exploratory Behavior

Circumnutation is the oscillatory movement of a variety of plant organs including roots. Little is known about the function of below-ground circumnutation, particularly in root-heterogeneity interactions. Root tip traits that allow for exploration may be advantageous, as roots can encounter heterogeneities in their environment that prevent productive growth. Previously we studied hard surface exploration in circumnutating wild type (WT) and non-circumnutating mutant rice roots using a high-throughput automated imaging system. In experiments with rigid plates containing holes embedded in a clear gel-based medium, we observed that a root coiling behavior in non-circumnutating mutant rice roots prevented effective root-surface exploration. WT roots had higher success in finding holes, enabling deeper growth. To reveal the sensitivity of these exploration dynamics to substrate parameters, in this work we use the gel-based media to create an environment consisting of two gel layers with varying stiffness. This environment can model soil horizons with varying compaction. Roots were grown in either a soft gel upper layer to a stiffer gel bottom layer, or the opposite. WT roots displayed less than 50% success in growing deeper in both treatments. When the roots did not penetrate the lower substrate, they grew along the gel interface, showing similar exploratory dynamics as in the rigid plate experiments. However, when non-circumnutating mutant roots grew from a stiff to soft gel layer, they had a 90% success rate in penetrating deeper compared to below 60% percent success from soft to stiff. Our data indicates that WT circumnutating root tips are sensitive to environmental heterogeneities such as changing soil compactness, and that circumnutation facilitates an exploratory behavior when such heterogeneities are encountered.

S1-1 MCCLINTOCK , JB*; AMSLER, CD; BAKER , B; MORAN , A; WOODS , HA ; University of Alabama at Birmingham , University of South Florida , University of Hawaii at Monoa, University of Montana ; *mcclinto@uab.edu*

Introduction to the Symposium: New Frontiers in Antarctic Marine Biology

The present symposium builds on three former SICB symposia that highlighted aspects of the marine biology of Antarctica, each taking place a decade apart, the first in 1988 and subsequent symposia in 2000 and 2010. In this fourth symposium, the term 'New Frontiers' in the title is uniquely appropriate for two fundamental reasons. First, technological advances have greatly facilitated the advancement of polar science over recent years. And second, unprecedented global climate change has both dramatically impacted Antarctic marine biological systems, and rendered the coastal and offshore waters of the Southern Ocean a global model for the study of the biological impacts of warming and ocean acidification. Just as the eleven studies presented in this symposium highlight a new generation of Antarctic marine biologists, they similarly highlight how technological advances and climate change are influencing new frontiers in Antarctic marine biogeography, chemical ecology, physiological adaptation, microbial ecology, planktonic systems, and fjord ecology. If there is one grand take-home message from this symposium it is the field of Antarctic Marine Biology is becoming increasingly relevant to sustaining our own global biology. This symposium is supported in large part by NSF award OPP-1925160 from the Antarctic Organisms and Ecosystems Program.

P2-123 MCCONNELL, I*; SCHULZ , J; MEDINA, K; Occidental College ; *imcconnell@oxy.edu*

Analysis of synthetic cone snail venom through a novel zebrafish spinal motility assay

Cone snails are a family of venomous predatory gastropods that use a harpoon-like radular tooth and peptide neurotoxin containing venom to paralyze their prey. We used amplicon sequencing to identify a non-glycosylated venom peptide (c4g) from the species *Conus catus*. From this, we have synthesized and folded active venom peptide. This study focuses on investigating the activity of the folded, active peptide via a novel zebrafish spinal motility assay developed in the lab. Through decapitation of larval fish, this novel assay removes any descending inputs from the hindbrain, allowing for a focus directly on spinal motor circuits. It also results in the removal of the heart, thereby ceasing blood flow, allowing for the peripheral application of the venom exclusively. Utilizing this assay, we can correlate the subsequent movement of the zebrafish spines with specific neuronal circuit activation. For example, application of c4g confers neuroexcitatory behavior with body bends in the spines, mimicking the escape response and "C-starting" behavior of live fish. These episodes of activity differ from the coordinated swimming movement elicited by control NMDA application, suggesting a target distinct from the central pattern generators (CPG) for swimming. Interestingly, the assay responses do not fully account for the sustained paralytic effect of the cone snail toxins in live, stung fish prey, inferring the possible requirement for hindbrain descending glutamatergic drive for full tetanic paralysis. Consequently, we are employing other neuroexcitatory peptides and antagonists in the larvae assay, as well as additional neurophysiologic techniques such as patch clamping and calcium imaging to elucidate a specific molecular target for the synthetic venom peptides and the neuronal circuits they regulate.

P3-221 MCCUE, MD*; ARBUTINA, L; LIGHTON, JRB; Sable Systems International; *mmccue@sablesys.com*

A new model for introducing undergraduate biology students to energy budgets

At the very highest levels *Respirometry* (the measurement of respiratory gases to determine metabolic rates) is a combination of science and art that requires advanced mathematics and expensive equipment – neither of which are tractable to the undergraduate laboratory teaching environment. To address this issue, we developed an easy-to-use respirometry system paired with a flow-through facemask and respirometry tent. We gave it to a 19-year-old biology student and asked her to measure her EE during various activities (i.e., sitting, standing, reading, texting, cycling, and crunches) for 4 weeks. Paired-tests of EE between modalities (mask; 5-min vs. tent; 10-min) showed no significant differences while sitting ($p=0.487$), laying ($df=18$, $p=0.370$), or reading ($p=0.160$). Furthermore, the similar outcomes in EE between the mask and tent measurements permitted comparisons of more complex activities where only the tent (e.g., crunches) or the mask (e.g., cycling) were used. No differences were found in EE between different body positions (laying vs. sitting; $df=38$, $p=0.968$), or different light activities such as reading vs. texting (t-test: $p=0.414$, $df=18$). Interestingly, standing EE was 15.2% higher than sitting ($df=18$, $p=0.033$), and the two forms of exercise (crunches vs. cycling) revealed 3.4-fold differences in energy expenditure (df=18, p

P2-199 MCCUE, MD*; KLOK, JC; LIGHTON, JRB; HAMMOND, KA; Sable Systems International, University of California Riverside; *mmccue@sablesys.com*

Energetics of Peromyscus treadmill running at different speeds, inclines, and environmental temperatures

Deer mice (Peromyscus maniculatus) forage over long distances in habitats characterized by extreme temperatures, hypoxia, and low primary productivity. The goal of this study was to quantify locomotion costs at different speeds (20, 25, and 30 m/min), temperatures (10 or 21°C), and inclines (0° or +25°). Using a Sable Systems respirometry treadmill we measured VO_2 and VCO_2 in mice [n=12 f, n=8 m] A) 10 minutes before exercise, B) while running for four minutes at each increasing speed, and C) a 15-min recovery period. During each trial mice ran 260 meters in distance and with the 25°-incline they vertically climbed 120 meters. Mice showed a transient (~2 minute) increase in VO_2 (and RER) during the onset of exercise. At 21°C the VO_2 remained constant with increasing velocity. Interestingly, the VO_2 of 10°C mice running at both 0° or 25° inclines decreased with running speed, and by the end did not differ from those running at 21°C. Incline had a negligible effect on VO_2. Mice running at 10°C at 30 m/min at a 25° incline did not differ from those measured in the same mice during the first five minutes of rest, suggesting the mice used locomotor muscle activity to offset thermoregulatory energy expenditure.

P2-144 MCCUE, MD*; LIGHTON, JRB; Sable Systems International; *mmccue@sablesys.com*

^{13}C-Glucose oxidation testing in laboratory mice: effects of dose, temperature, and nutritional state

Glucose is the predominant fuel source for most animal tissues. We employed an experimental approach called glucose oxidation testing to quantify glucose oxidation in real time. Laboratory mice (*Mus musculus*) were given IP injections of trace amounts of ^{13}C-U-glucose (75-600ug) after which we measured both the rates of CO_2 production (VCO_2) and the isotopic enrichment of the breath ($^{13}CO_2$) at 1Hz frequency using the new Sable Systems Stable Isotope Gas Analyzer. We conducted dose response (75-600ug) trials at 22°C and fixed-dose (300ug) trials at three temperatures (10, 22, and 30°C) and different nutritional states (fed vs. 24h-fasted). The $^{13}CO_2$ increased within 90-seconds and peak values occurred approximately 15-30 minutes later. The dose responses were isometric across the range examined suggesting no mass action effects of the tracer. In fed mice we observed lower $^{13}CO_2$, but the differences were counterbalanced by the increased VCO_2 caused by cold temperatures; thus, temperature had no effect on net glucose tracer oxidation rates. Nutritional stress (fasting) generally caused attenuated and protracted oxidation kinetics resulting in a 40% reduction in tracer oxidation in mice exposed to 22°C and 30°C. We expect this approach will be useful to investigate differences in glucose oxidation in various animal models.

P1-106 MCCULLOCH, KJ*; KOENIG, KM; Harvard University, Harvard University ; *kmcculloch@g.harvard.edu*

Regulatory logic of the retinal determination gene network in the starlet sea anemone, Nematostella vectensis

Much of metazoan morphological diversity is due to dynamic expression of transcription factor networks in development. Despite this remarkable diversity, animal development is accomplished by relatively few, related transcription factor families. The evolution of these gene regulatory networks remains poorly understood. How networks assemble in association with a particular phenotype, how changes to these networks alter phenotype in evolution, and how networks are coopted into new traits are fundamental unanswered questions in biology. It has been difficult to address questions like these due to a lack of functional evidence for particular network-phenotype associations in multiple animal lineages, and for distinct phenotypic associations within a single species. The retinal determination network (RDN) specifies eye cell fates in *Drosophila* and vertebrates, comprised of the core genes: *Pax, Six, Dach,* and *Eya*. These genes have well-understood regulatory relationships in eye development. Members of this network are expressed in association with photoreceptive tissue in many animal lineages, and the RDN is found in multiple other phenotypic contexts. However it is not clear if this gene network evolved with the origin of visual systems or in another phenotypic context then later was co-opted into visual system development. Our goal is to understand the regulatory state of the RDN in the sea anemone *Nematostella vectensis* and its functional relationship to cell fate. We use a combination of CRISPR knockouts and shRNA knockdown experiments followed by in situ hybridization and real time quantitative PCR to functionally interrogate the network hierarchy and its relationship to cell type development. This genetic analysis in a basal eumetazoan is necessary for understanding how gene networks evolve and bring about phenotypic change.

P1-123 MCCUTCHEON, MM*; KOCOT, KM; University of Alabama, University of Alabama and Alabama Museum of Natural History; *mgmccutcheon@crimson.ua.edu*

Uncovering the Biodiversity of New Zealand Aplacophorans

Aplacophorans are shell-less, worm-shaped molluscs that inhabit benthic marine habitats around the world. Fewer than 500 species of aplacophorans have been described to date but the true number of species is estimated to be tenfold higher. This is in part because simply identifying most aplacophorans to the genus and species level requires characterization of internal anatomical structures, such as the radula, ventral foregut glands, and reproductive organs using histology. Oceania is one of the most understudied areas in the world with respect to aplacophoran biodiversity. In particular, there are only three described species of aplacophorans from New Zealand, but examination of collections from the National Institute of Water and Atmospheric Research (NIWA) and the Museum of New Zealand Te Papa Tongarwera has revealed many more species that are new to science or have not been previously reported from New Zealand waters. In order to improve our understanding of the biodiversity of New Zealand Aplacophora, and the biodiversity of New Zealand as a whole, we have been studying collections NIWA and Te Papa Tongarewa using histology, light microscopy, DNA barcoding and scanning electron microscopy to identify and describe species from these collections. Here we present preliminary data from the characterization completed thus far. After grouping the collection into morphospecies, there are at least 10 caudofoveates and 12 solenogasters, most of which are new to science. We will present the description of two new species, *Proneomenia taniwha* and Proneomeniidae sp. indet., both of which belong to Proneomeniidae, a family not previously reported from New Zealand. We conclude with plans for future work in assessing the aplacophoran biodiversity of New Zealand.

1-1 MCDONALD, MS*; COHEN, JH; PORTER, ML; University of Hawai'i at Mānoa, University of Delaware; *marisam7@hawaii.edu*

Evidence for Ultraviolet Vision in Larval Stomatopod Crustaceans

Stomatopod crustaceans are known for having one of the most complex visual systems in the animal kingdom. While the adults have historically received the majority of attention, limited work has been focused on larval stomatopods. Stomatopod larvae must survive as planktonic organisms for days to months before settling. One key aspect for survival is the visual system, which is used for a wide range of important biological tasks. It has been generally understood that pelagic crustacean larvae with compound eyes have a single spectral class of photoreceptor. However, recent evidence suggests that stomatopod larvae have the anatomical and molecular structures to support ultraviolet vision. Based on this, the visual physiology of stomatopod larvae was examined using electroretinogram recordings. This work was completed in summer 2019 at the Keys Marine Lab in Long Key, Florida on two species of larval stomatopods. Larvae were dark-adapted and the response of the eye to brief (75 ms) flashes of broadband ultraviolet (peak 330 nm), blue (peak 510 nm), and orange (peak 570 nm) light was recorded. Additional measurements of broadband blue and ultraviolet light were completed under chromatic adaptation with a dim orange light. While larvae were most sensitive to blue light, this chromatic adaptation revealed a secondary response to ultraviolet light, indicating that larvae have sensitivity to ultraviolet light that is higher than is predicted by visual pigment templates. This is some of the first physiological evidence for ultraviolet vision in larval stomatopods, and larval crustaceans more generally. This work is significant as UV vision assists in a variety of behaviors in other marine organisms, and may be important to stomatopod larval ecology.

98-3 MCDONNELL, A.J; MOORE, C.L; SCHUETTE, S. ; MARTINE, C.T*; Chicago Botanic Garden, Bucknell University, Lewisburg, PA, Western Pennsylvania Conservancy, Pittsburgh, PA; *ctm015@bucknell.edu*

A harbinger of good things to come in academic/non-academic partnerships: Population genomics and conservation of Erigenia bulbosa (Apiaceae) in Pennsylvania.

Erigenia bulbosa, perhaps better known as the harbinger-of-spring, is one of the earliest-blooming wildflowers in eastern North America. In Pennsylvania, *E. bulbosa* exhibits an east-west disjunct distribution where widespread western populations are contiguous with the Midwestern range and a handful of populations in the eastern part of the state are restricted to the lower Susquehanna River valley. The isolation of the eastern populations suggests a possible conservation concern for those plants, with an assumed higher risk of fluctuations in numbers of individuals and the potential for lower levels of genetic diversity. As a consequence, regulatory considerations have created confusion during the environmental review process and left the Pennsylvania Department of Conservation and Natural Resources in the difficult position of justifying regulations that vary by region. To better understand population dynamics of the species, botanists from Bucknell University and the Western Pennsylvania Conservancy are engaged in a collaborative effort to couple field-based assessments *E. bulbosa* with a population genomics approach. Using single nucleotide polymorphisms from throughout the genome obtained via genotyping by sequencing (GBS) methodology, we find support for isolation of the disjunct populations and expect that populations in the East will continue to be threatened by land use and development along the Susquehanna River valley. This project is an important example of the strength of academic and non-academic partnerships in fostering outcomes that inform conservation of rare and special taxa.

P2-22 MCDONNELL, AJ; WETREICH, H; CANTLEY, JC; JOBSON, P; MARTINE, CT*; Chicago Botanic Garden, Bucknell University, Lewisburg, PA, San Francisco State University, CA, Northern Territory Herbarium, Alice Springs; *ctm015@bucknell.edu*

Solanum plastisexum, an enigmatic new bush tomato from the Australian Monsoon Tropics exhibiting breeding system fluidity.

An Australian bush tomato that has evaded classification for decades has been described as a new species from the Ord Victoria Plain biogeographic region in the monsoon tropics of the Northern Territory. While now recognized as an andromonoecious species, the taxon has been found exhibiting multiple reproductive phenotypes: with solitary perfect flowers, a few staminate flowers, or with cymes composed of a basal hermaphrodite and an extended rachis of several to many distal staminate flowers. Given this apparent ability to exhibit elements of three different plant breeding systems, we have chosen the name *Solanum plastisexum*. This name, for us, is not just a reflection of the diversity of sexual forms seen in this species. It is also a recognition that this plant is a model for the sort of sexual fluidity that is present across the plant kingdom – where just about any sort of reproductive form one can imagine (within the constraints of plant development) is present. In a way, *S. plastisexum* is not just a model for the diversity of sexual/reproductive form seen among plants – it is also evidence that attempts to recognize a "normative" sexual condition among the planet's living creatures is problematic. When considering the scope of life on Earth, the notion of a constant sexual binary consisting of two distinct and disconnected forms is, fundamentally, a fallacy.

95-7 MCDONOUGH, CE*; PITNICK, S; DORUS, S; Syracuse University; *mcdonouce@gmail.com*

Molecular evolution and sex-biased expression of Drosophila melanogaster female reproductive tract tissues

For species with internal fertilization, the complex interactions between the female reproductive tract (FRT) and male ejaculate(s) are critical to fertility, influence intraspecific variation in reproductive outcomes, and contribute to reproductive barriers between species. In contrast to the extensively studied male traits of sperm and seminal fluid proteins, the FRT, and particularly the molecular relationships among the discrete tissues within this system, remains poorly characterized. In order to develop a more complete understanding of FRT contributions to ejaculate-female interactions, we have taken a systems-level approach to characterize the spatio-temporal transcriptome of the *Drosophila melanogaster* FRT. The FRT is composed of 5 tissues which have a combination of distinct and redundant functions such as ejaculate processing, sperm storage, ovulation, and oviposition. We identified gene expression signatures that distinguish the FRT tissues and provide molecular support for their specific physiologies and functions. We further found that genes with tissue-specific expression and secretion signal annotation were more rapidly evolving. The characteristics of these genes resemble those found in accessory gland proteins of male seminal fluid and thus are likely candidates for their female counterparts. We also examined the expression of sex-biased genes within the FRT. Although we did find support for a small number of somatic reproductive female-biased genes unexpectedly, the greater trend was for FRT enriched genes to be male-biased. We hypothesize that this expression pattern is indicative of a molecular and biochemical continuity between the male and female reproductive environments.

P2-233 MCDUFFEE ALTEKRUSE, A*; HARLEY, CM; LI, J; EDON, JA; ZEMKE, D; Metropolitan State University; *cindy.harley@metrostate.edu*

More is not necessarily better: Physical therapy differentially influences crawl quality and quantity in Hirudo verbana

Locomotor training has proven integral to recovery following nerve cord lesions in humans and animals alike. While we know that locomotor training aids these individuals, we do not understand the mechanism behind this recovery at the cellular level. Through the use of an invertebrate model, the leech Hirudo verbana, we are taking a closer look at this process of recovery. Leeches have two primary locomotor behaviors—swimming and crawling. Following nerve cord transections leeches lose the ability to crawl and instead swim seemingly ceaselessly. However, over time, they regain the ability to crawl and to suppress swimming behavior despite that the nerve cord does not reattach. Can physical therapy help leeches to regain normal crawling behavior earlier? We have developed several physical therapy regimes to examine this question. We have found that crawl quantity and crawl quality are separable features. Quantity can be increased to reach pre-lesion levels through a physical therapy regimen which prohibits swimming during recovery. However, this therapy does not result in coordinated (quality) crawls. Instead crawl quality is impacted by placing individuals in a device which approximates their position during crawling. This device does not aid the leeches in regaining quantity of crawls. Furthermore, the device is ineffective if the leech is passively moved through the device instead of actively. This suggests that leeches must actively be involved in their recovery following lesion, and that crawl quantity and quality are controlled through different neural mechanisms.

P3-27 MCELROY, KE*; BOORE, J; LOGSDON, JM; NEIMAN, M; Iowa State University, Ames, Providence St. Joseph Health and the Institute for Systems Biology, Seattle, University of Iowa, Iowa City, University of Iowa, Iowa City; *kyle.e.mcelroy@gmail.com*
Effects of asexuality on repetitive element evolution in a freshwater snail
The evolutionary mechanisms underlying the immense variation in genome architecture remain unclear. Repetitive DNA, including transposable elements (TEs), mobile DNA sequences that replicate and insert themselves in a host genome, are a major source of this genomic variation. Understanding the conditions that influence the accumulation of repetitive DNA is thus of central importance to understanding genome evolution. Sexual reproduction is a hallmark eukaryotic trait and transitions to asexuality are expected to have significant consequences for genome evolution. How asexuality impacts TE evolution is complicated because (1) the reduced efficacy of selection should result in greater TE accumulation in asexuals relative sexuals, but (2), TEs should be lost to genetic drift in asexual populations because TEs cannot spread to new lineages in the absence of sex. Here we evaluate genomic consequences of asexuality in *Potamopyrgus antipodarum*, a freshwater New Zealand snail characterized by frequent coexistence of closely related phenotypically and ecologically similar sexual and asexual individuals. We used whole-genome sequence data from natural populations to compare genomic loads of TEs and other repetitive elements in sexual vs. asexual lineages. While we did not observe an effect of reproductive mode on TE variation, we found a striking pattern of increases in copy number for tandemly repeated rRNA genes (rDNA) and histones – which we discovered are joined in an organization apparently unique to *Potamopyrgus* – in asexuals relative to sexuals. The rapid and a repeated accumulation of rDNA-histone sequences asexual *P. antipodarum* indicates that asexuality may have important consequences on genome evolution.

95-5 MCENTEE, M*; KRZYSZCZYK, E; FOROUGHIRAD, V; FRèRE, C; MANN, J; Georgetown University, Washington, DC, University of the Sunshine Coast, Queensland, Australia; *mhm95@georgetown.edu*
Fitness and mortality costs to females in a system with allied sexual coercion
Female Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) are subject to high costs of reproduction, both during consortships, in which they experience allied sexual coercion from males, and during lengthy periods of gestation and lactation. Male dolphins cooperate in alliances to herd and aggress on females in order to increase mating access. Females must meet the high energetic demands of prolonged maternal investment in each offspring; gestation is one year and lactation averages 4 years. Here, we examine the effects of allied sexual coercion and maternal investment on reproductive fitness and survival in Indo-pacific bottlenose dolphins in Shark Bay, Australia. Nearly 20% of adult females in this population never successfully raise a calf to weaning. Mean age of first birth is higher for reproductively unsuccessful females (17.5 years) than for successful females (13.3 years), indicating that condition at the onset of reproduction could influence reproductive trajectory ($t(36.5) = 4.5$, $p < 0.001$). Females who are reproductively unsuccessful spend more time with adult males at the onset of sexual maturity than successful females do, suggesting that unsuccessful females may be subject to increased costs of coercion (GLMM, $p < 0.001$). Additionally, reproductively unsuccessful females have shorter lifespans than successful females ($\chi 2$ (1)= 16.8, $p < 0.001$). Taken together, these findings indicate that females who fail to raise a calf to weaning are then subject to increased risk of harassment and coercion from males, reducing their ability to recover condition and ultimately increasing their risk of mortality.

103-6 MCENTIRE, KD*; POLJAN, M; VELA, S; THOMPSON, ML; BAUM, A; Trinity University, San Antonio; *kmcentir@trinity.edu*
Do I Match? Exploring Self-Awareness of Color for Background Matching in Texas Horned Lizards
Camouflage through background matching is a common anti-predator strategy. There are multiple evolutionary mechanisms that could result in accurate crypsis. First, animals that passively match their surroundings are more likely to survive a predator encounter and pass on their traits. Alternatively, animals in complex backgrounds could move to an area where they are less conspicuous. The second option implies the animal has some awareness of their own color. This concept has not been extensively explored. Texas Horned Lizards (*Phrynosoma cornutum*) are known to use color patterns for camouflage, but the evolutionary mechanism leading to this crypsis remains unknown. We are using a lab-based study to estimate the lizard's tendency to background match by placing individuals in an experimental tank with three background colors (black, brown, and white) then exposing them to a predator cue. By recording the amount of time they spend in each color patch and seeing if it changes in response to a predator cue, we can estimate their self-awareness of color and its use as an anti-predator strategy. As a secondary avenue, we created an agent-based model predicting the predation rate of *P. cornutum* following both mechanisms. Preliminary trials suggest the lizards do not actively background match but may take cue from their natal environment as the captive born juveniles tended to favor the lighter background matching the substrate they grew up with. The model suggests decreased predation rates with active background matching, but needs to be validated with additional studies. This information can inform ideal release locations for captive rearing and release programs.

139-6 MCGOWAN, CP*; SCHWANER, SJ; LIN, DC; University of Idaho, Washington State University; *cpmcgowan@uidaho.edu*
Muscle Dynamics During Hopping on Hard and Sandy Surfaces
Desert kangaroo rats (*D. deserti*) are soft sand specialists that rely on sand dunes to construct their burrows. However, throughout the territories in which they forage, kangaroo rats can experience a wide range of substrates and obstacles, including hard and soft sand, rocks, and dense shrubs. The mechanical demands of hopping on these different surfaces can vary greatly. When hopping on soft sand, mechanical energy is lost to the substrate as the sand shifts under the animals' feet. This energy must be replace by mechanical work generated by muscles. The goal of this study was to determine how the lateral gastrocnemius (LG), a large ankle extensor muscle, contributes to the additional work required for hopping on soft sand. We used sonomicrometry and tendon force buckles to quantify the mechanical output of the LG as kangaroo rats hopped on a custom-built rotary treadmill with hard and sandy surfaces. Preliminary results showed that there were no differences in gait timing between hard and sandy surfaces and the ankle extensors produced similar peak forces (hard: 9.96 +/- 0.77 N, sand: 9.45 +/- 1.13 N). However, due to a slight reduction in LG muscle strain, the net work developed by the LG tended to decrease when hopping on sand (0.93 +/- 0.25 mJ), relative to the hard surface (0.68 +/- 0.14 mJ). These unexpected preliminary results suggest at least two possibilities: 1) kangaroo rats use proximal muscles to replace the energy lost to the environment; 2) kangaroo rats do not loose energy when hopping on sand, but rather hopping mechanics are similar to hopping on hard surfaces.

P1-246 MCGRATH, MR*; HOWEY, CAF; University of Scranton; *margaret.mcgrath@scranton.edu*
Ambient Light at Night (ALAN) and the Stress Response of Green Anoles
Animals in urban areas may be exposed to constant ambient light at night (ALAN), which could affect stress levels within these individuals. Glucocorticoids are hormones that mobilize glucose in the bloodstream, and thus energy, so that animals can respond to environmental stressors. The objective of this experiment was to examine the effects of ALAN on glucocorticoid levels in green anoles (*Anolis carolinensis*) that are exposed to ALAN and control lighting. We hypothesized that baseline glucocorticoid levels will be elevated as a result of the stress that ALAN induces, and due to the chronic nature of this stressor, stress responsiveness may be reduced. To address this question, we reared 24 *A. carolinensis* in two treatment groups. The Control Group was exposed to a 12:12 Light:Dark cycle. The Experimental Group was exposed to twenty-four hours of ambient light. Both groups were exposed to similar temperatures, humidity levels, and UV light. After six weeks, we drew blood and performed competitive immunoassays to measure baseline glucocorticoid levels. Additionally, we measured stress responsiveness by measuring glucocorticoid levels following a 30-minute stressor. Of the 12 *A. carolinensis* in each group, we measured glucocorticoid levels for half of the sample size at midday and the other half at midnight. Results from this study may demonstrate the effects of increasing urbanization and inform our understanding of an environment's effect on the animals' physiology.

P2-48 MCHUGH , K/A*; STEVENS, D/R; BAKER, J/A; FOSTER, S; Clark University , ; *kmchugh@clarku.edu*
Stress, Asymmetry, and Evolutionary Change in a Population of Threespine Stickleback (Gasterosteus aculeatus) with Respect to a Novel Predator
As environments across the globe change at unprecedented rates, organisms must cope with these changes. The primary evolutionary mechanisms for coping with environmental changes include phenotypic plasticity and selection. Plasticity can be used as a short-term solution to immediate change, and selection primarily a long-term solution that allows populations to cope with environmental change over generations. However, the success of these mechanisms are dependent upon the available variations of phenotypes that can be produced. Phenotypes that are available to plasticity or selection are affected by factors that produce phenotypic variation. One such factor is stress, which is thought to increase under novel conditions. An example of a phenotype whose variation is thought to be affected by stress is bilateral symmetry. In bilaterally symmetrical organisms, there is some background level of fluctuating asymmetry (FA); the random deviation from typically expected symmetrical development under given environmental conditions. Under stressful conditions, increases in FA result from developmental instability (DI) and thus there is an increase in phenotypic variation in these typically symmetrical traits. One important factor in ecosystem changes is the introduction of novel predators. In this study we will examine how the introduction of northern pike (*Esox Lucius*), and the increased stress it is thought to cause, will morphologically affect the threespine stickleback (*Gasterosteus aculeatus*) population in Scout Lake, Alaska. Using preserved samples of stickleback from 1998-2000 (pre-pike) and 2001-2009 (subsequent to pike establishment), we will examine this prey population's morphology for fluctuating asymmetry (FA). We predict that FA in this threespine stickleback population will increase subsequent to pike introduction.

60-1 MCINROE, BW*; BOLAS, T; KO, I; FULL, RJ; UC Berkeley; *bmcinroe@berkeley.edu*
Reconfigurable control modules enable rapid burrowing in a decapod crustacean
Animals have innovated a multitude of strategies to locomote over and in natural substrates. To develop principles of adaptive locomotion in complex, dynamic environments, we studied the Pacific Mole Crab (*Emerita analoga*), a decapod crustacean capable of multimodal locomotion in the highly dynamic intertidal zone. *E. analoga* uses five pairs of multifunctional appendages to burrow rapidly into saturated, flowable intertidal substrate. We hypothesize that these controllable components can be represented as simple models (templates) that can be recruited in series or parallel towards robust and adaptive burrowing. Using granular particle image velocimetry (PIV) and refractive index matched substrates, we identified a set of potential control modules used by *E. analoga* to manipulate and make ingress into wet substrates. To further reveal the structure of these burrowing control modules, we measured limb kinematics as a function of depth. We found that limb cycle frequency of the anteriorly excavating appendages decreased from 3.7 ± 0.2 Hz at penetration to 2.2 ± 0.2 Hz at submersion. However, when the uropods were restricted, limb cycle frequency of the same appendages remained almost constant from penetration (3.1 ± 0.1 Hz) to submersion (3.0 ± 0.3 Hz), suggesting compensation. Finally, we propose a set of simple terradynamic template models that provide insight into the control affordances of the burrowing modules. Our findings begin to elucidate the structure and robustness of the burrowing control modules employed by mole crabs and suggest bioinspired design and control principles that may enable new burrowing behaviors in legged robots.

113-4 MCKEE, AA*; SOTO, AP; CHEN, P; MCHENRY, MJ; University of California, Irvine; *amberle.mckee@gmail.com*
The role of vision and flow sensing in schooling behavior
We are interested in how schooling fish use visual and flow-sensitive lateral line inputs. We used rummynose tetras (*Hemmigrammus rhodostomus*), a small freshwater schooling fish, to examine schooling behavior in light and dim conditions both with and without the lateral line (by chemical treatment). We performed an automated kinematic analysis of video recordings to measure schooling metrics including the polar order, nearest neighbor distance, and swimming speed. We found that schooling behavior was indistinguishable between fish without a functional lateral line and the control group. These results suggest that schooling kinematics do not depend on flow sensing. However, long-duration recordings revealed that fish without a functioning lateral line do not school as frequently as control fish. Therefore, vision is sufficient to form and maintain a school, but flow stimuli influence whether groups of *H. rhodostomus* initiate schooling.

P3-91 MCKINLEY, CN*; LOWER, SE; Bucknell University, Lewisburg, PA; *cnm006@bucknell.edu*
Using transcriptomics to identify candidate genes involved in predatory behavior of femme fatale fireflies
Identifying the genetic basis of phenotypic variation within and across species is a key objective of genetic research. With the advent of inexpensive genomic sequencing and the development of bioinformatics tools, it is possible to identify candidate genes related to phenotypic variation across a wide array of organisms. However, much of this work has been limited to model systems with a plethora of tools for genetic manipulation and functional characterization. Fireflies are an excellent system for studying phenotypic variation because of their wide behavioral diversity. Many fireflies have a single species-specific flash pattern that is used for mate identification and choice, do not eat as adults, and the variety of light signal patterns is hypothesized as a primary driver of reproductive isolation and speciation. However, fireflies in the *Photuris* genus are aggressive mimics - females of these species mimic the flash patterns of prey species to lure males in to eat them and thus, have multiple flash patterns. Most Photuris species are known for this predatory behavior and the genetic basis for this variation has yet to be studied. To explore this, we compared selective constraint on genes between a predatory firefly, *Photuris quadrifulgens*, with those from a non-predatory firefly, *Photuris frontalis*, using publicly-available transcriptomes derived from head tissue. We identified nine gene families evolving under positive selection, including genes involved in digestion, vision, and detoxification. These results highlight the utility of comparative methods to identify candidate genes in non-model organisms, which is crucial in understanding phenotypic variation in many organisms, not only in model systems.

P1-152.5 MCKINNEY, JE*; LUDINGTON, S; O'CONNELL, LA; Stanford University, Stanford; *jmckinn@stanford.edu*
Nonapeptide Regulation of Begging and Aggressive Behavior in a Social Tadpole
All animals need to evaluate social situations and respond with appropriate behavior that results in a beneficial outcome. Inappropriate social decisions can potentially result in outcomes that reduce reproductive fitness. Despite the importance of adaptive behavioral output, little is known about how social decisions are made in the brain, especially in neonates. Research across vertebrates has identified two key neuropeptides: vasopressin, which mediates the "fight or flight" response, and oxytocin, which facilitates pair bonding and affiliation. We tested the role of these neuropeptides in mediating neonate social decision-making in tadpoles of the Mimetic poison frog, *Ranitomeya imitator*. In this species, tadpoles beg parents for an egg meal and aggressively fight conspecific tadpoles in defense of resources. A previous study linked vasopressin to aggression and begging behavior in tadpoles. We tested the role of both neuropeptides in three different behavioral paradigms where tadpoles begged to a stimulus female, fought with conspecific tadpoles, and displayed neither behavior when a novel object was introduced. After quantifying the begging behavior displayed by the tadpoles, the tadpole brains were isolated and immunohistochemistry was used to visualize a marker of neural activation (pS6), oxytocin, and vasopressin. While we found a role for vasopressin in tadpole behavior, activation of oxytocin neurons did not change. My current work is focusing on brain specific knock-down of these nonapeptides to determine the functional role of these behaviors. Overall, this work suggests that vasopressin, but not oxytocin, regulates affiliative and aggressive tadpole behaviors.

125-4 MCMAHON, E*; YOUATT, E; BRAITHWAITE, V; CAVIGELLI, S; The Pennsylvania State University, The Pennyslvania State University; *ekm5112@psu.edu*
Stability of behavioral traits and associated physiology
Within groups, many individuals maintain distinct behavioral phenotypes, or temperaments, with some being reliably more exploratory, social, aggressive, active, or bold than others. These temperaments can influence individual survival, reproductive success and offspring survival i.e. fitness. While research has been conducted on characterizing temperament traits among species, there is still little information on the underlying physiological mechanisms. The objective of this study was to determine the relative stability of multiple behavioral traits and identify underlying physiological profiles. To identify the five temperament categories discussed by Reale et al. (2007) we conducted five behavioral tests repeated 3 weeks apart in a sample of 54 Sprague-Dawley rats. We used the Novel Social Arena, Novel Object Arena, Partner Preference, Social Interaction and Resident Intruder tests. To measure stress physiology, we conducted an acute restraint test and measured glucocorticoid (CORT) responses. Innate immunity and basal CORT were measured during an 8-hour period after injecting rats with lipopolysaccharide. To measure adaptive immunity, rats were injected with keyhole limpet hemocyanin (KLH) and relative hindfoot swelling (RHS) measured in response to re-exposure 29 days later. Specific behaviors were correlated across time in similar tests suggesting stable temperaments. Lower levels of exploration, activity, and sociability were associated with higher CORT reactivity. Additionally, lower levels of exploration, boldness, and sociability were associated with higher RHS following KLH re-exposure. Our findings suggest that some temperaments are more consistent than others and that physiological mechanisms differ with each behavioral phenotype. This may account for differential temperament fitness across environments.

P2-216 MCNAMARA, A*; DUNHAM, NT; YOUNG, JW; STANTON, DW; WOOD, J; SHAPIRO, LJ; University of Texas, Austin, Cleveland Metroparks Zoo, Northeast Ohio Medical University, UT Austin; *allison.mcnamara@utexas.edu*
Comparative platyrrhine walking kinematics across natural, discontinuous substrates
Wild primates navigate arboreal habitats that include multiple, inconsistent substrates with diverse characteristics. However, our understanding of primate quadrupedal gait kinematics is limited to mostly laboratory data on single substrate use. We present a comparative analysis of wild platyrrhine quadrupedal gait kinematics on discontinuous, natural substrates to further investigate the adaptive context in which unique aspects of primate quadrupedalism evolved. We collected high-speed video of platyrrhines in Amazonian Ecuador and quantified kinematic adjustments to substrate discontinuities. We coded footfall events and substrate characteristics for locomotor bouts containing multiple strides and multiple substrates (n=56) and examined the effect of substrate discontinuities on kinematics. *Saimiri sciureus* adjusted timing between touchdowns of forelimb pairs and between ipsilateral fore-hind pairs in response to substrate discontinuities, but *Lagothrix lagothricha* did not adjust interlimb timing. *Saimiri* used more asymmetrical walking gaits when moving across discontinuous substrates whereas *Lagothrix* used significantly more diagonal sequence symmetrical walking gaits. Our results demonstrate that quadrupedal walking is more diverse and flexible than previously documented in laboratory studies, and that taxa adjust kinematics differently – perhaps reflecting unique morphological adaptations to arborealism (e.g., prehensile tails). Primate gait evolution may have favored kinematic flexibility, permitting animals to respond to discontinuities and substrate changes in their environment. Funding: NSF Grants BCS-1640552, BCS-1640453

P2-174 MCNAMARA-BORDEWICK, NK*; MAAS, AE; BLANCO-BERCIAL, L; TARRANT, AM; Barnard College, Bermuda Inst. Ocean Sciences, Woods Hole Oceanogr. Inst.; *atarrant@whoi.edu*

Oceanic Copepods Fine-Tune Metabolic Activity During Diel Vertical Migration

Diel vertical migration (DVM) of zooplankton between shallow and deep waters profoundly impacts the transport of nutrients and carbon through the water column. Despite the acknowledged importance of this so-called active flux to ocean biogeochemistry, these contributions remain poorly constrained, in part because daily variations in metabolic rates are not considered or are modeled as simple functions of temperature. This project is part of a larger study that uses transcriptomic, proteomic, physiological and biochemical methods to characterize the metabolic consequences of daily physiological rhythms and DVM for a model zooplankton species, the abundant subtropical copepod *Pleuromamma xiphias* . We sampled copepods at 6-hour intervals during their migratory cycle and measured rates of oxygen consumption, ammonium excretion, fecal pellet production and metabolic enzyme activity. Fecal pellet production was highest during late night, consistent with several hours of feeding near the surface. Similarly, activity of glutamate dehydrogenase (corresponds to nitrogen excretion) and citrate synthase (pace-setting enzyme for citric acid cycle of aerobic respiration) were highest during the night. Surprisingly, oxygen consumption rates were highest in copepods collected from deep water during mid-day. In addition, the activity of the electron transport system, which typically correlates to oxygen consumption rate, did not change over the daily cycle. These results show that activity of metabolic enzymes and metabolic rates both vary during diel vertical migration, but that peaks in cellular enzymatic activity and organismal physiological rates may be offset. This potential lag would have consequences for using enzymatic markers to predict physiological rates.

52-4 MCTERNAN, MR*; SEARS, MW; Clemson University; *mmctern@g.clemson.edu*

Thermal and hydric balance: how salamanders respond to interacting stressors

It remains unclear how strategies used by salamanders to maintain thermal and hydric balance vary in response to one another, and whether this relationship varies geographically. Behaviorally, salamanders cease activity once they dehydrate to a certain threshold (the water limit threshold). Likewise, they will cease activity when they perceive themselves as becoming too warm (the voluntary thermal maxima). The cessation of activity prevents lethal levels of dehydration or heat stress, but also limits potential activity. Salamanders in warmer environments compensate by increasing cutaneous resistance to water loss to remain active. In this study, we will characterize the relationship between thermal limits and water loss using *Plethodon metcalfi* collected along an elevational gradient. We will first address how dehydration stress affects thermal maxima by measuring the voluntary and critical thermal maxima of salamanders at various hydration states. Additionally, we will measure resistance to water loss to test whether thermal limits vary in relation to water tightness. We will then place salamanders into two different acclimation treatments—a warm and dry treatment versus a cool and wet one. Measurements on acclimated animals will allow us to assess the plasticity of these traits, and whether acclimation alters the relationship between them. A better understanding of how salamanders balance thermal and hydric stress may further elucidate the capacity of this group to survive in a warming climate.

61-4 MCWHORTER, TJ; University of Adelaide; *todd.mcwhorter@adelaide.edu.au*

The Karasov effect: functional studies of nutrient absorption in endotherms at the extreme

The capacity of animals to assimilate energy depends on both mechanisms of nutrient absorption and gastrointestinal morphology. Flying vertebrates must fuel high metabolic demands while minimizing mass of digesta and gut size. Small birds and bats have shorter small intestines, less small intestine nominal surface area, shorter digesta retention times, and rely to a greater extent on non-mediated paracellular nutrient absorption than similarly sized nonflying mammals. In this talk, I will focus on functional studies of water-soluble nutrient absorption in volant endotherms at the extreme: hummingbirds and migratory passerines. Hummingbirds have exceptionally high mass-specific metabolic rates, and more than 35 years ago Bill Karasov and Jared Diamond showed that they have the highest mediated glucose transport rate amongst vertebrates. In vitro techniques also indicated that passive permeability to glucose was very low. In later in vivo studies, we found that the passive permeability of hummingbird intestines to glucose is much higher than previously reported, suggesting that they must rely partly on passive, non-mediated nutrient absorption to meet their high metabolic demands. Passerine birds migrating long distances arrive at stopover sites to refuel having lost as much as 50% of their initial body mass, including losses to the gastrointestinal tract that may serve as a reservoir of protein catabolised for fuel during flight, and show delays of 2-3 days in regaining mass. We found that a small passerine newly arrived at a migratory stopover had increased paracellular nutrient absorption, which when combined with extended digesta retention time may thus allow these birds to maintain higher digestive efficiency during initial stages of refuelling while digestive organs are rebuilt.

49-2 MCWILLIAMS, S*; KARASOV, W; BAUCHINGER, U; University of Rhode Island, Kingston, RI, USA, University of Wisconsin, Madison, WI, USA, Jagellonian University, Krakow, Poland; *srmcwilliams@uri.edu*

Spare capacity and phenotypic flexibility in the digestive system of a migratory bird: defining the limits of animal design

Flexible phenotypes enable animals to live in changing environments and knowing the limits to and the required timescale for this flexibility provides insights into constraints on energy and nutrient intake, diet diversity, and niche width. We exposed white throated sparrows (Zonotrichia albicolis), yellow-rumped warblers (Setophaga coronata), and cedar waxwings (Bombycilla cedrorum) to experimentally manipulated ambient temperatures over different timescales, which forces endotherms such as birds to modify their food and energy intake as they maintain a constant body temperature. We then quantified the extent of phenotypic flexibility in the digestive system of this migratory bird (i.e., food intake, digestive efficiency, gut anatomy, retention time of digesta, rates of nutrient absorption) in response to both rapid and gradual increases in energy demand. Immediate spare capacity decreased from ca. 50% for birds acclimated to relatively benign temperatures to < 20% as birds approached their maximum sustainable energy intake. Ultimate spare capacity enabled an increase in feeding rate of ca. 126% as measured in birds acclimated for weeks at -29 C compared to +21 C. Increased gut size and not tissue-specific differences in nutrient uptake or changes in digestive efficiency or retention time were primarily responsible for this increase in capacity with energy demand, and this change required > 1-2 days. We conclude that the pace of change in digestive organ size may often constrain energy intake and for birds dictate the pace of their migration. Supported by NSF (IOS-0748349 to S.R.M.) and NSC Poland (2015/19/B/NZ8/01394 to U.B.)

S9-11 MEHTA, RS*; DALE, KE; University of California, Santa Cruz; *rmehta2@ucsc.edu*

Linking Fitness and Functional Roles Inside and Outside a Marine Protected Area Around Catalina Island

The effectiveness of Marine Protected Areas (MPAs) on the general health and conservation of single species, habitats, and community interactions is of great biological and recreational interest. However, the high species diversity of southern California kelp forests limits our ability to make general conclusions about MPA effectiveness across a variety of species. Since 2015, we have contributed to the efforts to understand the role of MPAs in kelp forest ecosystems by studying the connection between fitness traits and functional morphology related to feeding for the California moray, *Gymnothorax mordax* . We chose to compare morays in Blue Cavern Onshore State Marine Conservation Area, which prohibits the take of any species, to those morays living in nearby coves where recreational fishing is permitted. Overall, we found that morays within the MPA were longer, older, heavier, and found in higher densities. As a potential consequence of higher densities, morays within and outside the reserve had similar body conditions, and morays within the MPA exhibited lower growth rates than those outside the MPA. Although morays within the MPA had larger size-corrected vertical and horizontal gape distances, indicating the ability to eat larger prey, morays within the MPA had significantly fewer stomach contents and smaller prey in their stomachs than those outside. Our research efforts show that while the MPA is positively related with age, size, and density of California morays, the MPA may not necessarily increase the fitness of this benthic marine predator. Instead, conditions in the MPA appears to favor alternative feeding strategies, potentially due to morphological variation.

64-4 MEKDARA, PJ*; NASIMI, F; TYTELL, ED; Tufts University; *prasong.mekdara@tufts.edu*

Sensorimotor integration in the control of dorsal fin movements during swimming

Fish fins are highly flexible, which allows them to form complex shapes that can offer hydrodynamic performance benefits. The flexibility in their fins allow fish to be highly maneuverable, permitting behaviors such as obstacle avoidance, predator escape, and backwards swimming. Fins also serve a sensory role, with many sensory receptors embedded in the rays, but we know relatively little about how the sensory information affects the muscular control patterns. Our research focuses on the dorsal fin of bluegill sunfish, which has a soft posterior portion that functions during locomotion as a highly flexible control surface, and presumably also as a flow sensor. To quantify sensorimotor integration in the fin's movements, we recorded activity in the dorsal inclinator muscles with and without a lidocaine treatment that numbs the sensory receptors. We quantified activity in the inclinator muscles and in red axial muscle during steady swimming at a low and high flow tank speed in three conditions: before fin numbing treatment, during fin numbing with lidocaine, and after lidocaine wash-out. During normal steady swimming, fish activate their dorsal inclinator muscles to stiffen their fins to resist lateral bending of the soft dorsal fin caused by resistive fluid forces imposed by the water. Activity of the dorsal inclinator muscles was variable when the fins were numb, with increased duration in each fin burst cycle, likely stiffening the fin. Our study shows that fish use sensory feedback for precise fin control during normal steady swimming, but without normal sensory inputs, they tend to stiffen the fin to make it more robust to mechanical perturbations.

100-2 MELICHER, DM*; YOCUM, GD; RINEHART, RP; USDA ARS, Fargo, ND; *dacotahm@gmail.com*

Transcriptomic response to long-term storage under a fluctuting thermal regime in Drosophila melanogaster

Insect storage under fluctuating thermal regimes (FTR) increases longevity and maintains fecundity in many species. We assessed mortality of *Drosophila melanogaster* during long-term storage under FTR. At 20-day intervals females were collected and sequenced out to 100 days as well as cold and warm temperature controls. Mean longevity was approximately 7 times longer under FTR. After 60 days fertility in females drops significantly. We show the persistent, long term transcriptomic response to storage under FTR, focusing on metabolism, oxidative stress, modification of membrane fluidity, and anti-oxidant activity.

S9-8 MENDELSON III, JOSEPH/R; Zoo Atlanta & Georgia Institute of Technology; *jmendelson@zooatlanta.org*

The Interface of Taxonomy, Systematics, Genetics, and Conservation

The phrase "conservation of biodiversity” underscores that the diversity of life must somehow be identified, evaluated, measured, or perhaps enumerated in order to be conserved. These realities invite discussion (and sometimes disagreements) about a diverse, but conceptually related, array of related issues including species definitions, purposeful or inadvertent effects on population genetics, and issues along a continuum of shifting-baseline phenomena. In order to conserve biodiversity, in many contexts, stakeholders must agree on the evaluated components of that biodiversity.

33-1 MENDEZ-NARVAEZ, J*; WARKENTIN, K; Boston University, Smithsonian Tropical Research Institute; *javier0620@gmail.com*

Nitrogen Excretion Plasticity and Reproductive Colonization of Land by Frogs: Multiple Strategies to Avoid Ammonia Toxicity

Ammonia excretion is cheap but requires water; excreting urea helps terrestrial vertebrates conserve water and avoid ammonia toxicity. The desiccation risk and waste-disposal problems created when frogs evolved terrestrial eggs offer opportunities to test the role of nitrogen (N) excretion plasticity in transitions to life on land. We hypothesize that terrestrial early life stages alter N-excretion in response to drying or high ammonia levels. We studied 3 frogs that independently evolved terrestrial development: gelatinous arboreal egg clutches of *Agalychnis callidryas* (*Ac*) and *Hyalinobatrachium fleischmanni* (*Hf*) and terrestrial foam nests of *Leptodactylus fragilis* (*Lf*). Dry conditions increased ammonia concentration in all 3 species. With extended terrestrial development, *Hf* embryos and tadpoles in *Lf* foam nests began excreting urea. In *Lf* this was crucial to avoid ammonia toxicity. We hypothesize these animals precociously upregulate the urea cycle enzymes CPS1 and Arginase; enzymatic analyses to date support Arginase upregulation in *Lf*. Urea was present in some *Ac* clutches at oviposition, but appears not to be synthesized by embryos. Still, ammonia remained surprisingly low in dry *Ac* clutches, well below toxic levels, suggesting an alternative pathway to avoid toxicity. Initial results suggest upregulation of glutamine synthesis by *Ac* embryos under dry conditions. Overall, our results suggest that terrestrial early life stages of frogs use different plastic mechanisms to avoid ammonia toxicity in different lineages.

29-4 MENDOZA, E*; OLBERDING, J/P; AZIZI, E; University of California, Irvine; *emendoz7@uci.edu*

Temperature dependence of elastic recoil mediated by a mechanical advantage latch

Changes in temperature alter muscle kinetics and these effects can be observed during whole-organism performance. Some organisms use elastic recoil, which is far less sensitive to temperature, to power thermally robust movements. However, some systems (e.g. frog jumping) remain sensitive to temperature despite well-documented utilization of elastic mechanisms. For jumping frogs, the latch controlling the storage and release of elastic energy arises, in part, through dynamic changes in mechanical advantage (MA). Here we use an *in-silico*/*in-vitro* muscle preparation to understand how changes in temperature affect the flow of energy from muscles to tendons, and ultimately to the body, in a system using an MA latch. We use an *in-vitro* preparation of the plantaris longus muscle-tendon unit (MTU) that interacts with an *in-silico* model of a limb with changing MA and a mass being accelerated through a real-time feedback controller. We quantify the amount of energy stored in and recovered from elastic structures and the additional contribution of direct muscle work after unlatching. As expected, colder MTUs take longer to develop force and overcome the MA latch. Additionally, warmer MTUs continue to develop force far beyond what is needed to overcome MA before the mass has reached an appreciable velocity, storing more energy in elastic structures. We also find that the contribution of direct muscle work after unlatching is substantial and increases significantly with temperature. Our results suggest that the degree of thermal robustness achieved by a spring actuated system depends strongly on the nature of the latch that mediates energy flow and the inertia of the mass being accelerated.

P2-207 MENDOZA, E*; SCHWANER, J; FREYMILLER, G; MCGOWAN, C; CLARK, R; AZIZI, E; University of California, Irvine, University of Idaho, San Diego State University, San Diego State University; *emendoz7@uci.edu*

Kinematics of kangaroo rat foot-drumming

Seismic communication is the generation and transmission of vibrations through natural substrates to convey information. Seismic communication is widespread in terrestrial animals; in kangaroo rats, it is characterized as a foot drum (high frequency drumming of the hind feet) or a foot roll (drumming with two feet simultaneously or alternating onto the substrate). These behaviors are described in the context of territoriality, predator deterrence, and to alert offspring, highlighting the importance of these signals to the survival and reproduction of kangaroo rats. Previous studies with oscillograms revealed that some species of kangaroo rats foot drum at ~90 Hz, which exceeds the capacity of typical skeletal muscle (25-30 Hz), but the mechanics of this behavior remains undescribed. Here we use 3D high-speed video recording of foot drumming desert kangaroo rats (*Dipodomys deserti*) in the wild to describe kinematics and test whether kangaroo rats might need a specialized anatomical feature to foot drum. We found that kangaroo rats foot drum at ~6 Hz and foot roll at ~16 Hz. At the start of a foot drum, the ankle flexes and reaches a height that is ~20% of the animals height. Then the ankle extends and hits the ground to produce the drum sound, then flexes slightly to reposition. The frequency of foot drumming by the kangaroo rats does not exceed muscle capacity, and these animals mainly generate the ‘drum' from their ankle joint. Our preliminary data suggest that desert kangaroo rats do not require a specialized feature to foot drum. Future work will investigate how kinematic modulation allows this species to communicate a range of diverse signals.

P1-218 MENEGAZ, R*; ROSSITER, JA; LAROCQUE, H; BOLEY, A; KILE, R; SAAVEDRA, R; University of North Texas Health Science Center, Fort Worth; *rachel.menegaz@unthsc.edu*

Diet-Related Plasticity in Rodent Masticatory Muscles

The musculoskeletal system is dynamic, adapting to changes in biomechanical loading through the process of functional adaptation. Hard, mechanically resistant diets increase the strains experienced by the feeding complex, inducing growth and remodeling. Here we test the hypothesis that the consumption of hard diets by growing individuals results in larger adult chewing muscles with an increase in type II muscle fibers. Male Sprague-Dawley rats were raised from weaning to adulthood in four treatment groups (n=5/group). Two groups were raised on stable diets of either "hard" pellets or "soft" meal. Two variable diet groups were weaned onto a hard/soft diet then switched to the opposite diet at the experimental midpoint. Fixed in-situ cranial muscles were diceCT scanned and semi-manually segmented in 3D Slicer. Isolated masseter muscles were processed for ICH with anti-myosin heavy chain (MHC) antibody, and ImageJ was used to collect type I and II fiber counts and areas. Results indicate that animals raised on variable diets, regardless of the timing of these diets, tend to have larger chewing muscles as adults. This is particularly pronounced in the superficial masseter and temporalis muscles. These results suggest that intra-individual variability in muscle use, as well as the timing and intensity of that use, is important for maximizing muscle growth. Additionally, in rats raised on harder diets, a greater percentage of the masseter is composed of type II muscle fibers due to an increase in type II fiber area and a decrease in type I fiber number. The trade-off between fiber number and area may indicate a need for increased force production generated during feeding on a hard diet. Future studies are needed to investigate ontogenetic changes in masticatory muscle plasticity.

P3-106 MERGES, CR*; CRAIG, K; PIRTLE, T; The College of Idaho, Caldwell, ID; *colton.merges@yotes.collegeofidaho.edu*

Exposure to cAMP and cGMP Inhibits Heart Rate in Daphnia Magna

The freshwater crustacean, *Daphnia Magna*, was exposed to 100 µmol concentration of 8-bromo-cAMP or 8-bromo-cGMP using a profusion system that administered the chemical messenger analog at a rate of 1.5 mL/sec. We hypothesized that the heart rate of *Daphnia Magna* would increase to the way cyclic nucleotides modulate the heart rate of the myogenic hearts of vertebrates. *Daphnia Magna* were pinned in place using cactus spines and allowed to equilibrate for 20 minutes before data collection. Heart rate was measured by taking a control heart rate before administering the chemical and compared to the heart rates at 5, 10, 15 and 20 min intervals after exposure. During each time interval, we took a 15-second video (100 frames/second) recording using an inverted microscope at 40x magnification that was equipped with recording capabilities. Heart rates were then determined in beats per minute by counting each systole during the 15-second video recording. Our results yielded a statistically significant inhibition of heart rate, compared to controls, when exposed to cAMP during the 15 and 20-minute time intervals and cGMP during the 10, 15 and 20 min time intervals. (P value of less 0.01 for cAMP and 0.05 for the 10 min and 0.01 for the 15 and 20 min intervals for cGMP; repeated measures non-parametric ANOVA). We concluded that both cAMP and cGMP play a significant role in determining heart rate of *Daphnia Magna* that is opposite of hypothesis. After 20 minutes of exposure to cAMP *Daphnia Magna* had a decreased heart rate by 30.4% from the control mean and cGMP decreased heart rate by 21.8% from the control mean. We are currently investigating if cyclic nucleotides have a positive inotropic effect and if the modulation of chronotropic effects of cyclic nucleotides is concentration dependent.

P2-55 MESROP, LM*; GOODHEART, JG; LEUNG, NL; OAKLEY , TO; University of California, Santa Barbara , University of California, Santa Barbara; *lmesrop@ucsb.edu*

Gut Feeling: Characterizing the Origin and Divergence of Cell Types in the Light Organ of Bioluminescent Ostracods.

Throughout their evolutionary history, organisms have evolved a myriad of novel complex traits to increase their survival and reproductive success. However, the mechanism underlying the origin and diversification of novel traits is still roughly unresolved. Here, we introduce morphological and genetic studies on the origin of the upper lips of Cypridinid ostracods, which the ostracods use for bioluminescence and luminous courtship signals. The light reaction involves a substrate, luciferin, and a luminesce enzyme, luciferase, each of which is synthesized in separate gland cells in the upper lip and discharged in a mucus-like substance. Previous histology suggests specialized cell types exist in the upper lips of luminous ostracods for separately secreting enzymes, substrates, and mucus, but non-luminous lineages have fewer cell types which makes this taxon a tractable model system to study the evolution of novel traits. The close proximity to the mouth and the flexible movement of the upper lip during feeding suggest the upper lip may secrete digestive enzymes to aid in the ingestion of food. Given the relationship between luciferase and digestive enzymes, we predict that cells involved in the production of luciferase differentiated from digestive glands in the gut. We demonstrate through immunohistostaining and confocal microscopy, the localization of luciferase within the light organ and in vesicles surrounding the gut parenchyma. Our preliminary results suggest that bioluminescent cell types in the upper lip may have diversified from digestive cells in the gut parenchyma. Our study has implications for understanding the emergence of novel functional traits in organisms.

113-5 MHATRE, N; Western University; *natasha.mhatre@gmail.com*

Active amplification in tree cricket hearing

Model system choice can be arbitrary and yet has a profound effect on what is considered 'textbook behavior'. Traditionally, field crickets have been the textbook model system in insect acoustic-communication research; in behavior, neurobiology, or indeed, sensory biophysics. Tree crickets are a very similar group that also use sound for mate attraction. My recent work on their auditory biophysics has not strayed phylogenetically far from the 'textbook model'; I have only changed subfamilies from the Gryllinae to the Oecanthinae. Yet it turns out that tree cricket hearing is quite different. Field crickets use resonant mechanical tuning as a filter for conspecific sound and are mechanically linear. Tree cricket ears are very different: they are not mechanically tuned, instead they use a physiological mechanism that actively amplifies a selected range of frequencies. This amplification mechanism renders their hearing highly non-linear, and provides an unusual level of flexibility. For instance, their auditory sensitivity changes depending on the loudness of sound, and even in the presence of other sounds of different frequencies. The frequency selectivity of this amplification mechanism changes with temperature and it can even be turned 'on' and 'off' for extended periods of time. In my talk, I will describe some of the interesting biophysics and biomechanics that underlies this auditory system. But mainly I hope to highlight that tree-crickets are only one new model system, from a very diverse group of acoustically and seismically communicating invertebrates, all of which hold out great potential for further rewriting the textbook on communication systems.

76-5 MICHEL, KB*; BISHOP, PJ; CUFF, AC; ALLEN, V; HUTCHINSON, JR; Royal Vet College UK; *kmichel@rvc.ac.uk*

Skeletal kinematics and muscle function during locomotion in tinamou, Eudromia elegans

The archosaurs are a clade of reptiles that underwent repeated evolutionary acquisition of bipedality throughout their 250 million year history, including the most speciose lineage of bipeds, the birds. Studies of avian locomotion can therefore illuminate locomotor evolution in archosaurs, and the biomechanics of striding bipedalism in general. We collected synchronised marker-based XROMM (biplanar high speed X-ray video) and ground reaction force data to investigate locomotion in *Eudromia elegans* across a range of walking and running speeds. As palaeognaths, tinamous complement previous studies of other avian species, and can help assess the ancestral state for hindlimb form and function in crown-group birds. Our data show that tinamou use hindlimb kinematics that are largely comparable to those recorded in other species (e.g., guineafowl, ostrich), although some differences do exist, such as markedly greater long-axis rotation of the tibiotarsus. In order to better understand the underlying musculoskeletal mechanisms that control limb movement, we also synthesised our experimental data with a three-dimensional musculoskeletal model of the tinamou hindlimb. The model was based on anatomical dissections, iodine-contrasted micro-tomographic scans and measured segment inertial properties, and includes all the major muscles of the hindlimb. Feeding the experimentally recorded data into the model, we used inverse dynamics to estimate external joint moments, and static optimization to estimate muscle activation patterns during the stride cycle. Our preliminary simulations produced activation patterns consistent with experimental electromyography data, lending confidence to the use of these models for extinct archosaurian bipeds. Further simulation using dynamic optimization approaches will allow us to explore the importance of tendon stretch and recoil in birds during locomotion.

11-3 MICHELS, NO*; HRABIK, TR; MENSINGER, AF; University of Minnesota Duluth; *miche498@d.umn.edu*
To Flee or Not to Flee: A Comparison of Predator Avoidance Behaviors Under Varied Light and Predatory Conditions
The quantity and quality of information during predator-prey interactions is influenced by a variety of environmental factors, as well as sensory and locomotory abilities of the pair. Previous studies focus on one predator within the environment, but prey face many attackers. Mottled sculpin are a native benthic fish similar to the invasive round goby. The goal here is to determine if one prey species has an advantage avoiding predators and if this advantage is light and/or predator dependent. The effects of predation and light level on prey behavior were examined using two piscivores, burbot and/or smallmouth bass in a crossed design (2 burbot, 2 bass, and 1 of each) which preyed on round gobies or mottled sculpin. Trials were performed under natural light intensities and wavelength of downwelling light. The probability of detection for each prey species for either predator was not significantly different. Only 7% of the detected gobies were captured and 72% of the captured gobies were retained. Comparatively, 23% of detected mottled sculpins were captured with 93% being retained. Almost double the number of mottled sculpin were consumed than round gobies within the same period. Both prey species alternate between fleeing or remaining immobile. Fleeing appears to benefit round gobies via reducing predator detection, but also helps avoid pursuing and attacking predators. Mottled sculpin often remain immobile, but initiate flight responses when predators are in close proximity which greatly increases the chances of detection, pursuits, and attacks. Few studies have tested prey reactions under multiple predatory conditions, and it appears that avoidance strategies differ between predators and have a considerable impact on survival probability.

88-2 MIKEL-STITES, MR*; STAPLES, AE; MAREK, P; Virginia Tech; *mmikelst@vt.edu*
Hearing Better When Lopsided: Tympanal Asymmetry May Enhance Hearing in the Parasitoid Fly Ormia ochracea
Ormia ochracea is a parasitoid fly endemic to the Americas. Gravid females respond phonotactically to calls of their male *Gryllidae* cricket hosts. Surprisingly, *O. ochracea* can locate their hosts with an azimuthal precision of 2°— equal to that of humans — in spite of their small size, which should prohibit this level of precision because of fundamental constraints imposed by the physics of sound propagation (Mason *et al*., *Nature*, 2001). Miles *et al*. demonstrated that the fly's two tympanal membranes are mechanically coupled, which increases the interaural time delay (ITD) between the tympana, allowing the fly to resolve nanosecond time differences, and greatly increasing the precision with which she can locate her larval hosts (Miles *et al*., *J Acoust Soc Am*, 1995). Here, we present the first measurements documenting tympanal size asymmetry in *O. ochracea*. We measured 38 tympanal membranes in 19 specimens and found a mean asymmetry of 5.6% in tympanal area between the left and right sides. We hypothesized and then demonstrated mathematically that this slight asymmetry should provide an additional significant increase to *O. ochracea*'s sound localization abilities, beyond that provided by the mechanical coupling of the tympana. We introduced a tympanal size asymmetry into the mathematical model of hearing in *O. ochracea* provided by Miles *et al.* and showed that an asymmetry of just 5% can increase the ITD by an order of magnitude compared to the symmetric case, and can similarly significantly increase the interaural amplitude difference (IAD) in *O. ochracea*. The ITD and IAD are the two quantities used by the fly to determine its prey's azimuthal location. Thus, the small asymmetry present in tympanal sizes in the fly may provide a significant advantage in sound localization.

86-2 MIKUCKI, E*; BUCHANAN, J; JULICK, C; MONTOOTH, K; LOCKWOOD, B; University of Vermont, Vanderbilt University, University of Nebraska - Lincoln, University of Nebraska - Lincoln; *emikucki@uvm.edu*
The Effects of Winter Warming Stress on Metabolic Activity in Diapausing Pieris rapae Butterflies
Due to harsh environmental conditions and limited food availability, overwintering organisms are dependent on a store of energy reserves that consists mostly of lipids to sustain them until spring. To compensate for this limitation, metabolic activity of overwintering individuals is characteristically low. Winter warming poses potential threats to overwintering organisms as metabolic activity is expected to increase due to increases in biochemical reaction rates, which may cause organisms to deplete their energy stores more quickly. To better understand the effects of winter warming on metabolic activity, we used stop-flow respirometry to measure resting metabolic rate after winter warming exposures in diapausing *Pieris rapae* pupae. We report that warmed individuals had a higher respiratory quotient (i.e., the ratio of carbon dioxide produced to oxygen consumed) than did control individuals, indicating that they switched from using lipid reserves to other reserves such as carbohydrates and/or proteins during recovery from heat stress. We also measured metabolic rates in real time during exposure to winter warming conditions to characterize thermal reaction norms across a range of temperatures. As predicted, metabolic activity increased with increasing temperature. Because metabolic rates increased and pupae switched to metabolizing energy resources (i.e., carbohydrates and proteins) that are likely to be more limited and, our results indicate that winter warming may cause diapausing pupae to deplete energy reserves. This research provides insight into the physiological consequences of winter warming on diapausing insect species and how these organisms may respond as environmental temperatures continue to increase during the winter months.

P1-47 MILADIN, JR*; STEVEN, JC; COLLAR, DC; Christopher Newport University; *jenna.miladin.17@cnu.edu*
Abiotic ecological niche parameters are associated with leaf and flower size in Silene
Environmental conditions are widely recognized to influence leaf shape and size in plants, while flower morphology is typically attributed to coevolution with pollinators. However, abiotic factors impose functional demands that may influence the evolution of both leaf and flower traits, potentially leading to correlated evolution of habitat and pollinator type. In this study, we test associations between habitat and flower and leaf morphology in 17 species of the genus *Silene*. This sample of species contains herbaceous annuals and perennials that vary in pollinator type and ecological niche as well as morphology. We collected one to two plants per species and measured leaf length and width, calyx length and width, and internode length on each specimen. We also used ecological niche models to estimate average rainfall in the wettest and driest part of the year for each species range. We found that species growing in environments with less rainfall in drier months have a narrower leaf shape and smaller leaves overall. In addition, species with more precipitation in the wettest months also have longer calyces. Generally, greater precipitation is correlated with larger leaf and flower size among the species we collected. The influence of precipitation on flower size has implications for transitions to new pollinators in species colonizing drier habitats.

137-7 MILES, DB; Ohio University; *urosaurus@gmail.com*
Can morphology predict the conservation status of iguanian lizards?
The integrity of regional and local biological diversity is under siege as a result of an multiple anthropogenic threats. The conversion of habitats, such as rain forests, into agricultural ecosystems reduces the area available to support species populations. In addition, fragmentation of the remaining habitats may render the environments unsuitable for survival or reproduction of species. Rising temperatures and altered rainfall patterns lead to additional challenges for species. The ability of conservation biologists to ascertain the threats to a species requires data on changes in distribution, abundance, life history and ecology. The IUCN uses these data to assess the a risk status for species. However, to date only 105,700 species have been assessed. Many species remain data deficient or yet to be assessed. In this study I ask whether a readily available database can be used to predict a species risk status. Morphological traits are an ideal proxy for making inferences about a species ecology. Past studies have shown that morphology can predict habitat use, foraging behavior and physiological performance among species. Here, I tested whether the patterns of covariation in 15 morphological traits can predict the risk status of over 400 species of lizards in the infraorder Iguania. I summarized the patterns of covariation using a Principal components analysis. Results from a phylogenetic ANOVA revealed that Vulnerable, Threatened, and Endangered species were larger, differed in body width and leg length as well as jaw length. A classification analysis confirmed the trends obtained with the PCA scores. I used the classification function to make predictions for species that had not yet been assessed by the IUCN species specialists groups. Because of the functional link between morphology, performance, and ecology, an ecomorphological approach may be a useful tool for rapid assessment of data deficient species.

P1-83 MILLER, NA*; FOLTZ, SL; Radford University ; *nmiller215@radford.edu*
Correlating nest defense behaviors in eastern bluebirds (Sialia sialis) and tree swallows (Tachycineta bicolor) with features of the nesting site and nest stage.
One of the fundamental goals in an organism's life is to reproduce. Raising young is an energy intensive enterprise. The older the young are, the more energy the parents have invested in them. Thus, older offspring could be considered more valuable and this increased value may make parents more likely to increase offspring defense. In this study, we looked for correlations between parental nest defense behaviors, nest stage, time of year, and environmental features at the nest boxes of eastern bluebirds (Sialia sialis) and tree swallows (Tachycineta bicolor), two species of cavity nesting birds common in southwest Virginia. This study followed populations breeding at two sites for three years. We monitored nest stage and observed the parental defense behaviors, such as dives and beak clicks, associated with each nesting stage. Analysis of previous seasons' behavioral data suggests that parents of both species increase nest defense behaviors as their nests advance from the incubation to nestling stage. Analysis of environmental factors and how they correlate with nest defense behaviors is on-going, but we expect heightened nest defense behavior at late-season nests, especially when temperatures are moderate and boxes have nearby perches, both environmental features that may reduce the energetic costs and risk of nest defense. Understanding how offspring age and local environment impact parental investment may illuminate previously overlooked trade-offs of reproduction in cavity-nesting songbirds.

P1-270 MILLER, A*; AGYEI, D; JILANI, C; JOSHI, D; ODAKA, Y; OWEN, P; TRAN, M; WILSON, K; University of Cincinnati Blue Ash College, Ohio; *amy.miller@uc.edu*
Effects of Plant-based Diet on the Gut Microbiota in Rusty Crayfish (Faxonius rusticus)
Although they carry cellulase-producing bacteria in the digestive tract, crayfish (*Astacoidea* and *Parastacoidea* superfamily) also produce endogenous, enzymatically active cellulase (glycosyl hydrolase family 9, GHF9) in the digestive gland of the hepatopancreas. Crayfish are omnivores but prefer food of plant origin. Therefore, we tested here the effect of strict plant-based feeding on the distribution of cellulase-producing bacteria in the gut microbiota of Rusty Crayfish (*Faxonius rusticus*), which is an invasive species that has expanded its niche from Ohio River basin to twenty-seven states including the state of Oregon, the west side of the Continental Divide. Prior to beginning feeding trials, excrements were collected from housing vessels for microbial composition analysis. After three weeks of feeding regimens, that included plant- or protein-based diets, excrements were again collected from housing vessels. The microbial composition of feces was subsequently analyzed by culturing, followed by biochemical assays. Our data showed that the proportion of cellulase-producing bacteria was significantly increased in both cohorts, yet the rate of the increase was much higher in the group of the plant-based feeding. Interestingly, the population of gram-negative bacteria was significantly reduced in both groups, indicating that the majority of the cellulase producers were gram-positive bacteria. The identification of the cellulase producing microorganisms is currently under investigation using 16s rRNA gene amplicon sequencing.

S3-2 MILLER, CT; University of California, Berkeley; *ctmiller@berkeley.edu*
Developmental Genetic Analysis of Tooth Number Variation in Sticklebacks
Patterning of the dentition varies widely across different vertebrates, typically reflecting adaptations to diet. To begin to understand the developmental and genetic basis of evolved differences in dental patterning, we have been using the threespine stickleback (*Gasterosteus aculeatus*) system. Ancestral marine sticklebacks have repeatedly evolved major increases in tooth number in derived freshwater populations, likely reflecting shifts in diet to larger prey in freshwater environments. The increases in tooth number in multiple freshwater populations occur late during development, and are associated with an increased tooth replacement rate. We have used genome-wide linkage mapping to identify the genetic basis of evolved differences in tooth patterning. We mapped one genomic region controlling evolved increases in tooth number to an intronic tooth enhancer of the *Bone Morphogenetic Protein 6* gene. Ongoing work seeks to further determine the genetic circuitry that regulates tooth patterning, to understand how cis-regulatory changes affect tooth replacement, and to identify specific cell populations involved in tooth formation and replacement. Our genetic studies support the hypothesis that tooth replacement is regulated by homologous genetic circuitry that regulates mammalian hair regeneration, suggesting that an ancient genetic network regulates regeneration of multiple vertebrate epithelial appendages.

P2-231 MILLER, FM*; GELLER, JB; KAHN, AS; CONNOLLY, TP; Moss Landing Marine Laboratories, Moss Landing, CA; *fmiller@mlml.calstate.edu*

Impact of wave intensity on Mytilus californianus byssal thread strength

The rocky intertidal zone is one of the most punishing ecosystems and requires organisms to overcome a multitude of stressors in order to survive. An adaptation for attachment employed by mussels are byssal threads. Byssal threads are proteinaceous filaments that anchor a mussel to the rock surface. The byssal threads consist of a elastic proximal region, a stiff distal region and a adhesive plaque that is attached to the rock surface. The tenacity of byssal threads fluctuates in response to a variety of factors in nature including seasonal wave action, reproductive cycles, and the mussel species. *Mytilus edulis* byssal threads increase in tenacity in the late winter and early spring when compared to the summer months. The reproductive cycles of mussels may also impact byssal thread tenacity through the allocation of energy. Different species of mussels have different ranges of byssal thread tenacity. *Mytilus californianus* has a higher byssal thread tenacity compared to *M. edulis* and *Mytilus trossulus*. Byssal threads' properties and strong adhesive plaques has led to an interest in creating synthetic byssal threads for use as a dynamic material and waterproof adhesive. While the adhesive plaque has attracted study for use as a waterproof adhesive, few studies have focused on the influence of environmental factors on the composition, structure, and function of the threads. Through this research, the mechanisms that are responsible for the adaptability of the byssal threads will be identified and the role wave exposure has on the mussel byssal thread amino acid sequences and mechanical and morphological characteristics will be determined.

P1-22 MILLER-CREWS, I*; MATZ, MV; HOFMANN, HA; Department of Integrative Biology, The University of Texas at Austin; *imillercrews@utexas.edu*

2bRAD-seq Paternity Testing Pipeline for Complex and Mixed DNA Samples

As next-generation sequencing technologies have become ever more powerful and affordable, they have begun to replace short tandem repeats (STRs) for genotyping in many fields of study. 2bRAD sequencing (2bRAD-seq) is a DNA sequencing technique developed for ecological population genomics that utilizes type-2b restriction enzymes to generate consistent, uniform fragments across samples. This technology is relatively inexpensive, effective with low DNA inputs, robust, and reliable. Here, we developed a bioinformatics pipeline for advancing paternity testing by using 2bRAD-Seq for interpreting related individuals in DNA mixtures in conjunction with probabilistic genotyping-by-sequencing genetic testing while dealing with additional constraints of high-degree of inbreeding, limited genomic resources, and need to create sibling DNA mixtures. We present a novel approach to partial paternity assignment, which utilizes a relative combined paternity index adapted for next-generation sequencing data and an identity-by-state matrix-based clustering method for pedigree reconstruction. The combination of these two parentage assignment methods overcomes two major obstacles faced by other genetic testing methods: 1) It allows detection of any biases that might arise from closely related or inbred individuals in the alleged parent population (e.g., in laboratory strains); and 2) it can successfully resolve pooled (i.e., mixed) DNA samples of multiple offspring (e.g., when sampling entire clutches). The unique advantages of 2bRAD-Seq allow for straightforward expansion to other species regardless of genomic resources available.

S7-8 MILLIGAN-MYHRE, KCA; University of Alaska Anchorage; *kmillig1@alaska.edu*

Using an evolutionary model organism to reveal host genetic influence on host-microbe interactions

Interactions between hosts and their microbiota involve multiple host systems and complex signaling between microbiota members. These interactions are balanced by host factors, including the immune system, hormones, diet, and more, and microbiota community interactions, both between members and between the microbiota and the host. When this balance is disrupted, the microbiota community shifts and the host often develops inflammatory or developmental diseases. Disruption can be caused by a combination of genetic or environmental factors. To determine the role of host genes in the ability of the microbiota to stimulate host immune responses and development, we adapted the evolutionary model threespine stickleback (Gasterosteus aculeatus). We characterized the microbiota in wild populations and determined that the host selects for and against specific members of the environmental microbiome based on their genetic background. We isolated over 300 microbes and created mock communities that reflect the microbiota identified by sequencing. We also manipulated the microbiota in developing fish from three different populations, and quantified immune system, somatic, and behavioral development in treated and untreated fish. We found that populations that shared ancestors but have evolved in different microbial and environmental conditions have different developmental trajectories when their microbiota is disrupted. These combined results indicate that populations are selecting for individual microbes, and may vary in their abilities to regulate microbial membership and response to microbes based on their genetic background.

83-4 MILLION, KM*; PROFFITT, MR; REESE, SJ; Indiana University, Bloomington, Howard University; *millionk@iu.edu*

MHC-based Olfactory Signals and Mate Choice in Darters (Etheostoma)

Genes of the Major Histocompatibility Complex (MHC) have been implicated in mate choice in a wide range of vertebrate taxa, with females of many species tending to prefer mates with MHC genotypes dissimilar to one's own. However, this preference has not been observed in all taxa studied, and the factors that influence MHC-based mate choice in vertebrates is still an open question. We hypothesized that differing reproductive behaviors between species may affect whether females make MHC-based mate choices and what their preferences may be. We tested this hypothesis using two co-occurring species of Darters (small North American native fish) with differing reproductive behaviors. In Fantail Darters (*Etheostoma flabellare*), males provide parental care, while in Rainbow Darters (*Etheostoma caeruleum*) no parental care is provided. We performed mate choice experiments in which we presented females of both species with pairs of identical painted male models along with olfactory stimuli from live males with differing MHC genotypes, one with an MHC genotype similar to the focal individual's and one with a dissimilar genotype. We measured the focal individuals' preference for the males using the amount of time the individual spent in each of two preference zones. Our early results indicate that females of both species tend to prefer the scent of males with the opposite MHC genotype, but the strength of that preference differs between the species. We are currently evaluating our follow-up experiment testing whether females of either species prefer males with rare or common MHC genotypes within their local populations. Our research will provide insight into whether female MHC-mediated mate choice is influenced by differing reproductive behaviors and differing criteria for mates.

15-7 MIN, Y*; BALLERINI, ES; KRAMER, EM; Harvard University, Cambridge, MA, Sacramento State University, Sacramento, CA; *yamin@g.harvard.edu*

Understanding Floral Meristem Termination by Exploring Genetic Architecture Underlying Stamen Whorl Numbers in Aquilegia

Plants have the ability to generate new leaves continuously throughout their entire lifespan due to the persistent activity of stem cells in their vegetative meristems. During the reproductive phase, the floral meristem (FM) produces all floral organ primordia in sequential whorls or spirals. Unlike the vegetative meristem, the stem cell activity of FMs will always terminate at a specific time point during primordia initiation, since each flower only has a finite number of organs. Variation in the timing of FM termination (FMT) is an essential source of generating floral morphological diversity, but how this process is fine-tuned at a developmental and evolutionary level is still poorly understood. *Aquilegia* is a well-suited system for investigating this fundamental process, since flowers from different *Aquilegia* species have identical numbers of all floral organs except for stamens. Therefore, the variation in the timing of FMT can be represented by the variation of stamen whorl numbers in the flowers. We generated a F2 population by crossing *A. canadensis* and *A. brevistyla*, which are sister species with mean stamen whorl numbers of 9.15 and 7.16 per flower, respectively, and performed quantitative trait loci (QTL) mapping. We have phenotyped 4265 flowers for their stamen whorl numbers and conducted whole genome sequencing in 364 F2 individuals. Initial mapping revealed five major QTLs that are responsible for an estimate of 48% variation in stamen whorl numbers. Fine-mapping is currently in progress and we will be conducting functional studies of promising candidate genes. This is the first study to investigate the nature of variation in the timing of FMT, and our results will provide critical insight into how floral morphological diversity is generated at the meristematic level.

16-5 MINEO, PM*; HEBERT, AK; BENNETT, KF; GUENTHER, MF; KSIAZEK-MIKENAS, K; RAIMONDI, SL; Elmhurst College; *Patrick.Mineo@Elmhurst.edu*

Implementing Vision and Change into the first-year biology sequence for majors.

The Department of Biology at Elmhurst College recently revised the introductory biology sequence for first-year students following the recommendations of *Vision and Change in Undergraduate Biology Education* (AAAS, 2011). To align our course learning outcomes with these recommendations, we adopted a new textbook, *Integrating Concepts in Biology*, designed based on the core concepts and competencies outlined in Vision and Change. The classroom in this course sequence is largely "flipped”, in which students complete in-depth learning objective homework before class, and spend class time analyzing the results of experiments connected to "Big Ideas” outlined in the textbook. In addition to a focus on scientific process, experimental design, and data analysis in the classroom, the laboratory component was transformed to include authentic research projects (Guenther et al. 2009). In this talk, I will discuss the structure of the course, as well as preliminary results of several assessments, including The Biology Concept Inventory (BCI), BIO-MAPS (designed to assess the core concepts and competencies of Vision and Change), and data indicating improved student outcomes and lower rates of students dropping, withdrawing or failing the courses. I will also share the successes and challenges encountered by both instructors and students in this course (especially in regards to achieving buy-in), as well as future directions.

P2-182 MINEO, PM*; PARLIN , A; DO AMARAL , JPS; SCHAEFFER , PJ; Elmhurst College, University of Cincinnati, University of Cincinnati Clermont College, Miami University ; *Patrick.Mineo@Elmhurst.edu*

How does diet composition affect thermal preference and the aerobic scope of digestion?

Growth and survival in reptiles are strongly influenced by the thermal landscape of the habitat, and the thermal dependence of physiological functions requires behavioral trade-offs between basking, foraging, and locating mates. Diet composition has the potential to play an important role in thermal preference. However, detailed studies linking thermal physiology and food composition to digestion efficiency have received little attention. Therefore, our aim was to determine how the composition of the diet affects both thermal preference and the relationship between preferred body temperature and the aerobic scope of digestion. To determine how diet affects thermal preference, we measured the preferred body temperature of wall lizards (*P. muralis*) that were fed either a high protein or high carbohydrate diet. Preliminary results indicate that lizards fed a high carbohydrate diet select body temperatures 2 °C higher (29.9 ± 2.5 °C) than those fed a high protein diet (27.4 ± 3.1°C). The 10th and 90th percentiles of body temperatures selected in lizards fed a high carbohydrate diet were 22.3 ± 1.7deg&;C and 36.3 ± 1.5°C, and 19.2 ± 1.4°C and 35.7 ± 2.1°C in lizards fed a high protein diet. Therefore, in addition to selecting higher body temperatures, lizards fed a high carbohydrate diet select a narrower range of body temperatures compared to those fed a high protein diet. Future experiments will measure the aerobic scope of digestion at several temperatures between 22.5 and 37.5°C to determine how differences in the preferred body temperature while digesting different diets relates to the aerobic scope of digestion.

128-4 MINICOZZI, MR*; AXLID, E; WILSON, T; BUCK, CL; VON HIPPEL, FA; Minnesota State University Mankato, Northern Arizona University; *Michael.Minicozzi@mnsu.edu*

Sodium perchlorate causes behavioral changes in developing zebrafish larva

Sodium perchlorate ($NaClO4$) is a strong oxidizing agent with a variety of military and industrial uses. Its widespread use and water solubility have made perchlorate a common contaminant of surface and ground waters across the United States. Perchlorate is an endocrine disruptor that inhibits thyroid hormone production. Here, we investigate the effects of sodium perchlorate on behavioral patterns in zebrafish (*Danio rerio*). Because behavior is tightly linked to brain development, a change in behavior of fish exposed to perchlorate could have important neurological implications for both humans and wildlife. We reared groups of 24 fish in three perchlorate concentrations (10ppm, 30ppm and 100ppm) and a control treatment (0ppm). At 5 and 10 days post-fertilization (dpf), we quantified their movements under three lighting conditions (lights on, lights off, and strobing) using a NOLDUS system. After conducting a principal components analysis, two major relationships were observed: at 5dpf, fish exposed to perchlorate moved significantly more under the lights on condition than did control fish. At 10dpf, fish in the control group moved more than did fish in any of the perchlorate-exposed groups under the lights off and strobing conditions. In both cases, the fish exposed to perchlorate showed a significant alteration in behavior as compared to the control group. The results from the 5dpf trial are especially notable because zebrafish normally show more activity in dark environments, and the observed behavior would likely make them more susceptible to predation under natural conditions. Further studies are necessary to determine the underlying mechanisms responsible for altered zebrafish behavior, and to examine the generalizability to other animals and people.

134-3 MITCHELL, CT*; DROTLEF, D; DAYAN, CB; SITTI, M; STARK, AY; Villanova University, Max Planck Institute; *cmitch23@villanova.edu*

Peeling the layers back: Examining the roles of capillary adhesion and material softening on gecko and gecko-inspired synthetic adhesive performance in variable temperature and humidity

The strong, yet reversible adhesive performance of geckos has been admired for many years. However, despite significant interest, there is still uncertainty about the governing adhesive mechanisms. For example, adhesive performance in variable temperature and humidity challenges two leading adhesion hypotheses: capillary adhesion and gecko setal softening. Both hypotheses consider variable relative humidity, but neither fully explain the interactive effects of temperature and humidity. Interestingly, gecko-inspired synthetic adhesives (GSAs) have shown similar adhesive performance in the same variable temperature and humidity environments. These GSAs represent a more controllable system that can be leveraged to test both hypotheses independently. Therefore, we conducted a comparative study between live geckos and GSAs in variable temperature and humidity to investigate the roles capillary adhesion and material softening have on gecko adhesion. In our gecko experiments, we identified an optimal range of environmental conditions for gecko adhesion. However, our GSA data remained relatively static across the same environmental conditions. This disparity in adhesive performances points towards both capillary adhesion and material softening playing significant roles in gecko adhesion, and only capillary adhesion affecting GSA adhesive performance. These results will help drive predictions into how geckos utilize various habitats, aid in the fabrication of new GSAs for robotics, biomedical, and commercial applications, and highlight an opportunity to use the gecko adhesive system as a model to explore an understudied area of basic surface science: temperature and humidity effects on micro and nanoscale systems.

63-3 MITCHEM, LM*; VILELLA-PACHECO, Z; FORMICA, VA; BRODIE III, ED; University of Virginia, University of Puerto Rico - Arecibo, Swarthmore College; *lm7en@virginia.edu*

Females Prefer to Associate with the Chemical Cues of Aggressive, Winning Males After Competition

Males often gain access to females by winning agonistic interactions, but females have the ultimate choice of who to mate with. We used *Bolitotherus cornutus* (forked fungus beetles) as a system to determine which behavioral traits are favored for male competition and if females prefer to associate with the chemical cues of winning males. In two separate experiments, we first observed male behaviors in dyadic competition trials. We found that relative body size and absolute aggression predicted whether a male emerged as a winner or loser. Our results support the large body of research showing that body and weapon size determine success in agonistic interactions. We also report here that initiation of aggression is important for winning agonistic interactions. In our second experiment, we placed females in arenas with filter papers containing chemical cues of two males and measured the time each female spent associated with the cue of either male. Next, we allowed the two males to interact and determined winners and losers. We then placed females in new preference trials following male-male interactions and measured the amount of time they spent on winning and losing male chemical cues. Females did not prefer to associate with either future winning or future losing males before male-male interaction but changed their preference to avoid losing males after male-male interaction. Taken together, our results indicate that male reproductive success in *B. cornutus* is driven by the outcomes of male competition. Larger, more aggressive males likely gain more opportunities to mate via winning competitions and female avoidance of losing males.

37-8 MIYASHITA, T*; GESS, RW; COATES, MI; University of Chicago, Chicago, IL, Albany Museum, Makhanda, South Africa; *tetsuto@uchicago.edu*

The Evolutionary Origin of the Filter-feeding Larval Phase in Lampreys

The ontogeny of lampreys holds a special place in the historical development of ideas about the early evolution of vertebrates. Ammocoete larvae of living lampreys (cephalochordate-like, sand-burrowing filter feeders) have served as a model for primitive vertebrates, whereas the eel-like, typically blood-sucking adults are considered specific to that lineage. This recapitulatory view of lamprey ontogeny has long predicted the last common ancestor of all living vertebrates to be an ammocoete-like filter feeder. If the Ammocoete Model is correct, a filter-feeding larval stage should have existed in lamprey stem taxa. We test this prediction using newly discovered specimens of *Priscomyzon riniensis* from the Devonian Witpoort Formation of South Africa. Seven specimens form an ontogenetic series from a 15 mm-long individual (slightly larger than living lamprey hatchlings) to an adult. None of these specimens has any skeletal correlates of filter feeding. Instead, traits associated with the predatory life mode of living adult lampreys are present in all of specimens, including: prominent eyes; oral sucker; keratinous teeth; tectal cartilages; short branchial region; and pericardial closure of branchial basket. Therefore, *Priscomyzon* likely had no ammocoate stage. To test whether the absence of the ammocoete stage is (a) a tip state unique to *Priscomyzon* or (b) a general condition of the lamprey stem, we compared three other Paleozoic stem lampreys (*Hardistiella*, *Mayomyzon*, and *Pipiscius*) with the *Priscomyzon* series. The smallest specimens of each taxon closely resemble the late larva to post-metamorphic juvenile stages in *Priscomyzon*, which implies that the ammocoete larval stage of living lampreys represents a secondarily evolved condition, convergent with cephalochordates due to feeding habits.

P3-151 MOHAMMADI, S*; WALDROP, LD; HASSANALIAN, M; Chapman University, New Mexico Tech; *smohammadi@chapman.edu*

Investigation on aquatic animal colors and skin temperature on skin friction drag reduction

There is currently a growing interest in the area of drag reduction. Skin friction can be reduced by heating the surface of an object, and it has been suggested that the dark-on-top and white-on-bottom patterns of many aquatic swimmers, such as dusky dolphins and orcas, may reduce drag. In this study, we investigate this common color pattern in terms of their thermal effects on drag reduction. To model the effects of color on the surface temperature of the aquatic animals, we model the animal a flat plate which is immersed in water with a turbulent analytical solution for heated boundary layers. A thermal analysis on a model animal body was carried out with consideration towards the marine and atmospheric characteristics of these aquatic animals' swimming routes. The surrounding fluxes including the water flux, sun irradiation, and core temperature are considered in an energy balance to determine the skin temperature of the top side of the animal's body. We tested this plate with combinations of colors on top and bottom. We find that the common color scheme of many aquatic animals (black on top and white on bottom) results in a 7% reduction in skin-friction drag. This study provides evidence that this color scheme in fast marine animals, such as billfish, whales, and sharks, evolved in part to reduce the drag on high-performance swimmers. This method of drag reduction can be considered as an effective factor in skin drag reduction of underwater robots.

P3-176 MOLINA, R*; KOLONIN, A; ASPBURY, A/S; GABOR, C/R; Texas State University; *rcm116@txstate.edu*

Western Mosquitofish Social Behavior Varies with Levels of Land Use Conversion

High urbanization corresponds with an increase of impervious cover, and alters freshwater communities, which can lead to urban stream syndrome. In this study we focused on the effects of urbanization on the behavior of populations of Western Mosquitofish, *Gambusia affinis*, a generalist species with a world-wide distribution and often locally high abundance. We tested the hypothesis that fish from more urbanized streams, surrounded by higher levels of impervious cover will behave differently from fish from less urbanized streams. We collected female fish from four streams varying in levels of urbanization, determined by the percentage of impervious cover, agricultural development, and undeveloped land within a 2.2 km buffer radius of each site. The fish acclimated in the lab for a period of 42-48 hours, and then we placed individuals in a small enclosure holding tub with an opening to a larger tub. We recorded if the fish left the enclosure, individual boldness, and exploration duration in the large tub. We then put individuals into a group of four and recorded the shoaling behavior of a randomly selected focal individual, its relative distance to the center point of the other fish, and the duration they were within a 2 cm radius of the other fish. Urbanization level did not have a significant effect on the individual behavior of fish across populations; however, it did affect their shoaling behavior: fish from the rural sites shoaled closer together and stayed within 2 cm of each other for a longer duration. We suggest that fish found in higher levels of urbanization may be less social than those found in more rural streams.

P2-71 MOLINA, EM*; MENDONCA, MT; Auburn University ; *emm0044@auburn.edu*

Inhibition pattern of testicular steroidogenesis by dichlorodiphenyldichloroethylene (DDE) during chronic and acute exposure

Persistent organic pollutants, such as dichlorodiphenyltrichloroethane (DDT), can remain in the environment at sub-lethal levels for decades. Analysis of soil from a DDT abatement site (Redstone Arsenal, a military installation, potentially impacting the watershed supplying Huntsville, AL) in 2017 documented levels that were still significantly above the Total Threshold Limit Concentration for DDT and DDE (i.e. >1ppm) indicating their potential to affect vertebrate reproduction living in that habitat. DDT breaks down to DDE, an endocrine disruptor that competitively binds to androgen receptors, potentially affecting reproduction. We investigated the effects of DDE on steroidogenesis in male rodents. Rats were exposed daily to one of five doses of DDE (0, 10, 20, 50, 100 µg/L; N= 6/dose). After 4 weeks of exposure, serum testosterone (T) levels were significantly (i.e., p = to or < than 0.05) lower in animals exposed to the 10µg/L dose, but not reduced at the higher exposure doses. Interestingly, when testicular tissue from males from each exposure dose was challenged *in vitro* with luteinizing hormone (LH), it was again the 10µg/L dose group that exhibited a significantly reduced response to the LH. We then tested a two week daily exposure regime with a range of lower DDE doses (0, 0.001, 0.01, 0.1, 1, 10 µg/L; N=5/dose) on pre-pubertal vs. pubertal rats. Even with the lower dose exposure for a shorter period, pubertal rats exposed to the 0.1, 1 and 10 µg/L doses exhibited significantly lower serum T, significantly lower *in vitro* basal testicular T, and significantly lower *in vitro* testicular LH responsiveness. Pre-pubertal rats were even more sensitive, showing significant reductions in these same parameters even at the 0.001 and 0.1 µg/L doses.

P1-265 MONIZ, L/E*; LYONS, K; HOOPES, L; LEWIS, J/M; BEDORE, C/N; Georgia Southern University, Statesboro, Georgia Aquarium, Atlanta; *lm19828@georgiasouthern.edu*

Lipid Metabolites as Energy Stores in Batoids

Batoids (rays and skates) fulfill an important ecological niche as mesopredators in marine ecosystems, transferring energy from lower trophic levels and making it available to apex predators. Lipids (fatty acids and sterols) are one mechanism whereby energy is stored and transferred through trophic levels. Lipid metabolites are transported in blood plasma to tissues based on necessity, therefore blood lipid concentrations provide a snapshot of the energy usage in an animal at a given point in time. Triglycerides (TAG) are one type of lipid stored in the liver, which under oxidation to provide energy for other tissues. However, the means by which rays recruit and utilize TAG is not well-understood. The purpose of this study was to establish baseline concentrations of TAG in three wild-caught ray species. Blood samples were collected from Gymnura micrura (smooth butterfly ray; n=12), Hypanus say (bluntnose stingray; n=9), and Hypanus sabinus (Atlantic stingray; n=15) from commercial trawls. Plasma concentrations of TAG were quantified using a colorimetric assay. Gymnura micrura had a significantly greater ($p<0.05$) plasma TAG concentration (1.724 mmol/L± 0.573 SEM) than H. say (0.948 mmol/L ± 0.206 SEM) and H. sabinus (0.755 mmol/L ± 0.134 SEM). Results from this study can provide a basis for future research to investigate the influence of specific ecological factors, such as activity level, ontogeny, and seasonality, on lipid metabolite concentrations.

15-3 MONROE, JG*; MCKAY, JK; Max Planck Institute for Developmental Biology, Colorado State University; *greymonroe@gmail.com*

From satellites to sequences: investigating drought adaptive life history evolution in plants

Explaining variation in life history strategies has been a central challenge of ecology and organismal biology for at least 250 years. To test classic theory of drought as a driver of adaptive plant life history strategies, we have been integrating diverse data and approaches including satellite imagery, herbarium specimens, whole genome sequencing, and transgenic experiments. In this seminar, I present recent research on the ecology and functional genomics of drought adaptive life history evolution. First, we tested classic life history theory by integrating satellite¤based drought detection with herbaria occurrence records to study life history evolution at phylogenetic scales. By comparing historical drought regimens, we observed that annuals occur in environments where droughts are significantly more frequent. We also found evidence that annual plants adapt to predictable drought regimens by escaping drought¤prone seasons as seeds. In addition to macroevolutionary patterns of life history evolution, we were also interested to understand drought as a driver of intraspecific variation. Thus, we developed novel approaches to study natural loss-of-function alleles associated with drought histories. The genes we identified exhibit population genetic signatures of adaptive evolution and shared associations with flowering time phenotypes in directions consistent with longstanding adaptive hypotheses seven times more often than expected by chance. We then confirmed predicted phenotypes experimentally in transgenic knockout lines. This research has yielded valuable insight into the evolution of life history strategies; validating long standing theoretical predictions about drought as important agent of selection and also providing surprising results about the functional genomics of this evolution.

P1-261 MONTANO, D.F*; KANATOUS, S.B; Colorado State University; *dmontano@rams.colostate.edu*
Are you what you eat? Do lipids cause an intracellular response within skeletal muscle cells?
Lipids have been repeatedly shown to influence aerobic ability in mammalian models, such as marine mammals' reliance on lipids to power dives. The expression of the oxygen-binding protein myoglobin has been suggested to facilitate aerobically-powered dives and contribute to the effective distribution of a finite oxygen supply. Multiple studies have demonstrated that lipid present in the media influences myoglobin regulation in C2C12 cells, driving expression of the protein in conjunction with other elements. However, it is still unclear if the mere presence of the lipids influenced the cell to upregulate myoglobin or if the cell metabolized the lipids, adapting itself to its metabolic environment. Ultimately, does lipid presence influence the ability of cells to adapt conditionally in order to metabolize lipids effectively? Evidence indicating direct links of an intracellular response in the cell based on lipid uptake remains to be explored. We are unaware of the specific conditions or variables that drive myoglobin expression, or how the cell itself utilizes fats to create a physiological response. Preliminary results measuring protein expression and fat availability seem to indicate little to no response, suggesting alternate mechanisms to be elucidated for fatty acid transport, metabolism, and subsequent intracellular responses and expression. Studying metabolic adaptation on a cell culture level will direct future projects studying cellular response to different fatty acids, metabolic flux, and effects of lipid metabolism on aerobic capacity in mammalian models. This research has applications to studying the whole animal system, from prey capture to processing, in order to better understand ecological and biological cues within a changing environment that allow for success of animal populations in the wild.

P1-223 MONTUELLE, SJ*; TEWKSBURY, C; WILKINSON, K; OLSON, R; WILLIAMS, SH; GERSTNER, G; University of Michigan School of Dentistry, University of Michigan, Ohio University, Ohio University Heritage College of Osteopathic Medicine; *montuell@umich.edu*
Variability in Mammalian Chewing using Functional Data Analysis: Differences in Jaw Pitch Amplitude and Velocity throughout the Chewing Cycle
Mammalian chewing is based on precise jaw movements that align teeth so that the food is processed until it can be swallowed. Movement modulation from one chewing cycle to the next is key to responding to changes in food properties and position, but for mammals, modulation may hinder rhythmicity. Between-cycle variability resulting from modulation is traditionally evaluated by comparing predetermined time points (e.g., phase transitions). However, chewing movements are continuous in time and thus so is their variability. We use functional data analysis to quantify variability in the amplitude and velocity of jaw pitch (opening-closing movements) continuously throughout the gape cycle during chewing in three mammalian species (pigs, raccoons, skunks). In all 3 species, both the amplitude and velocity of jaw pitch is most variable as the jaw opens and closes, whereas is is least variable during the power stroke. Stereotypy during the power stroke may minimize occlusal force unpredictability whereas variability during opening and closing may provide greater flexibility in manipulating the food bolus depending on its positioning and/or properties. In addition, skunks and raccoons appear to be more variable in jaw pitch velocity than pigs. Compared to the more permissive morphology of the pig temporomandibular joint (TMJ), the hinge-like TMJ of carnivorans may be more stable for accommodating greater modulation in jaw velocity without risking dislocation.

51-5 MOON, H*; ANDERSON, T; TRAVERS, M; LOEW, E; PORTER, M; University of Hawaii at Manoa, Kauai Endangered Seabird Recovery Project, Cornell University; *hmoon@hawaii.edu*
How Do Seabirds See Light? Visual sensitivity and light attraction in Hawaiian seabirds
Artificial lights at night cause high mortality in fledgling seabirds due to attraction and subsequent grounding. Seabirds species of concern on Kaua'i are the Hawaiian Petrel (*Pterodroma sandwichensis*), Newell's shearwater (*Puffinus newelli*), and the Wedge-tailed shearwater (*Ardenna pacifica*). *P. newelli* fledglings have the highest rates of light attraction on Kauai of all three species of concern, suggesting differences in behavior and/or vision between species as well as between fledglings and adults. Previous studies on migratory birds suggest that the color of light can affect attraction. To understand visual sensitivity, light color, and light attraction, the speed and strength of response of the retina to different colors of light was measured in all three species of concern. Seabirds attracted to light and rescued by Save Our Shearwaters were anesthetized, then retinal response to flashing LED lights was measured using electroretinography. Up to five different intensities of light were tested using three different colors of light- ultraviolet (385nm), blue (450nm), and white light (peak at 594nm). Seventeen juveniles representing all three species of concern and three adult *A. pacifica* were tested in the first year. Preliminary results suggest each species responds quickest to white light and slowest to UV light. *P. newelli* have the strongest response to blue light, and *A. pacifica* have the strongest response to white light, indicating interspecific differences in visual sensitivity. These results have implications for conservation management of artificial light near seabird colonies.

P2-31 MOORE, A J; Stony Brook University, Stony Brook, NY; *andrew.j.moore@stonybrook.edu*
Empty Space & Morphospace: Vertebral Pneumatization is Correlated with Serial Variation in Vertebral Shape
Postcranial skeletal pneumaticity is the invasion and resorption of bone by epithelial extensions of the respiratory anatomy into vertebrae and other postcranial bones, and is a hallmark innovation of birds and their ornithodiran ancestors. Various lines of evidence suggest that pneumatic spaces arise in part by environmentally-mediated opportunism of pneumatizing epithelia, with the biomechanics of a bone delimiting the extent of pneumatization that can be safely tolerated. Variably pneumatized birds have quantifiable differences in the cortical thickness and trabecular architecture of their vertebrae, but it is not known whether gross vertebral shape also varies with extent of pneumaticity. Because differences in bone shape necessarily entail biomechanical differences, and given the evidence that pneumatization of a bone is mediated by feedback from its biomechanical milieu, I hypothesize that extent of pneumaticity is correlated with vertebral shape. I test this hypothesis using geometric morphometric methods on three-dimensional models of vertebrae from the neognath bird family Ciconiidae (storks), focusing on whether serial variation in vertebral shape corresponds to variation in pneumaticity. Pneumatization (the fraction of total vertebral volume occupied by air space) shows substantial variation along the axial column, and is strongly correlated with serial variation in vertebral shape ($R^2=0.498$, $p<0.001$). More elongate vertebrae are significantly less pneumatic than craniocaudally shorter, more upright vertebrae, a pattern that cannot be explained by variation in vertebral size. This finding indicates that not all vertebral shapes are equally amenable to pneumatization, and is consistent with the hypothesis that the functional and biomechanical idiosyncrasies of a vertebra are important determinants of the degree to which it is pneumatized.

P1-132 MOORE, CL; MCDONNELL, AJ; SCHUETTE, S; MARTINE, CT*; Bucknell University, Lewisburg, PA, Chicago Botanic Garden , Western Pennsylvania Conservancy, Pittsburgh, PA; *ctm015@bucknell.edu*

Prairies in Pennsylvania?: Assessing the conservation status of Baptisia australis var. australis through natural history and metapopulation lenses.

In Pennsylvania *B. australis* var. *australis* (L.) R. Br. (Fabaceae) is comprised of two metapopulations along four waterways: the Allegheny River, Youghiogheny River, Clarion River, and Red Bank Creek. Despite the location of these watersheds within the greater Ohio River drainage, there is still considerable distance between the metapopulations. Because of its limited distribution and small number of extant populations, *B. australis* var. *australis* is considered state-threatened in Pennsylvania. The riparian prairie habitat that Pennsylvania *Baptisia australis* var. *australis* is restricted to is also in decline and considered vulnerable in the state. This work carries with it two main objectives: 1) Better understand the ecology and natural history of these metapopulations, including assessment of the status of the species in the state, and 2) Determine the genetic structure of known native populations and how this relates to the spatial structure of subpopulations. This research utilizes tools such as aerial imagery, field surveys, and herbarium collections to examine the natural history of the species. In addition, ddRAD is used to collect population genetic data for use in analyses meant to gain insight into the metapopulation dynamics of this riparian taxon. The research will inform the conservation status of *Baptisia australis* var. *australis* in Pennsylvania, and clarify lingering uncertainties about gene flow in riparian plant populations. The project seeks to combine field opportunities surveying rare plants with the Pennsylvania Natural Heritage Program and genetic work at Bucknell University to answer broader conservation questions.

P2-51 MOORE, AG*; NEWBREY, MG; MARTíN-ABAD, H; BOYD, C; HOGANSON, J; BAIR, MA; Department of Biology, Columbus State University, Columbus, GA, Universidad Autónoma de Madrid, Madrid, Spain, North Dakota Geologic Survey, Bismarck, ND, Emeritis Curator at North Dakota Heritage Center, Bismarck, ND, Department of Earth and Space Sciences, Columbus State University, Columbus, GA; *moore_abby@columbusstate.edu*

Earliest known material of Amia, bowfin, from the Sentinel Butte Formation (Paleocene), Medora, North Dakota

Amia calva is an icon in the field of comparative osteology, yet we have a poor understanding of the evolution of the genus because many fossil amiid bones have gone unidentified. Here we identify new material of the genus, *Amia*, with evidence of two unidentified species. Fossils of the two unidentified species of *Amia* were found in the Sentinel Butte Formation, a geologic formation of Paleocene age (~ 60 million years ago) near the town of Medora, North Dakota. The specimens are classified as *Amia* because the coronoid tooth plates exhibit conical teeth and the parasphenoid exhibits a long tooth patch that extends anteriorly past the ascending rami of the bone. This new *Amia* material is distinguished from other species based on three criteria. First, the parasphenoid tooth patch is extremely wide posteriorly, reaching the lateral margins of the bone, but very long and narrow anteriorly. Second, the gular plate is uniquely shaped, not being truncated posteriorly but rather tapering both anteriorly and posteriorly. Third, the teeth of coronoid tooth plates are robust, unlike those of other species of *Amia* which are thinner and more elongated. The frontals of each specimen are very different in shape and proportions suggesting two different taxa. One of these taxa could attain a large size with a total length well in excess of 1 m. Together, these taxa highlight the necessity to document the evolutionary history of this long and important lineage of *Amia*.

21-5 MORA, Y/A*; SUSTAITA, D; FARABAUGH, S/M; Department of Biological Sciences, California State University San Marcos, Institute for Conservation Research, San Diego Zoo Global; *mora074@cougars.csusm.edu*

Analysis of Loggerhead Shrike wing-flashing movements during hunting

The Loggerhead Shrike (*Lanius ludovicianus*) is a medium sized predatory, insectivorous and carnivorous songbird. When hunting, Loggerhead Shrikes have been observed to perform wing-flashing movements prior to attacking their prey. Several hypotheses have been proposed for this behavior in shrikes and other species. Our research focuses on the effect wing-flashing movements have on prey capture performance. We approached this by analyzing videos of captive San Clemente Loggerhead Shrikes during feeding. We found that males tended to perform wing flashing more than females, and juveniles tended to perform wing-flashing more often than adults. All of the individuals filmed performed wing-flashing when attacking lizards, whereas relatively fewer performed the behavior when attacking crickets and mice. The rate of wing movements varied among prey types, with crickets eliciting higher rates than lizards and mice. In general, shrikes captured their prey in fewer attempts after performing wing-flashing, suggesting that these wing movements increase prey-capture efficiency. A larger proportion of prey reacted to the onset of attack, and relatively fewer seemed to react to the wing-flashing behavior itself. However, prey capture success was greater when prey seemed to react to wing-flashing, suggesting a potential role for these wing movements in making prey more accessible. Our results point toward yet another innovative tool deployed by shrikes for accessing their diverse arthropod and vertebrate prey.

82-8 MORALES, OJ*; WALKER, N; WARNE, RW; BOYLES, JG; Southern Illinois University - Carbondale; *vincere90@gmail.com*

Consequences of pharmacologically induced corticosterone hormone on body temperature and body condition in the banner-tailed kangaroo rat.

Anthropogenic environmental change such as habitat fragmentation and climate change poses challenges to animal homeostatic functions due to its unpredictable nature. The hypothalamus-pituitary-adrenal (HPA) axis release corticosterone (CORT) to help maintain homeostasis, mobilize energy reserves, and promote immediate survival during times of stress. However, chronic exposure to environmental stressors may influence long term changes to animal body condition and thermoregulatory patterns in increasingly harsher habitats. The banner-tailed kangaroo rat is an ecosystem engineer and keystone species in the Chihuahuan desert. Its seed caching strategies and relatively large burrows contribute immensely to soil quality, moisture retainment, and vegetative diversity. Using corticosterone implants to mimic environmental stressors, we pharmacologically stressed banner-tailed kangaroo rats with CORT and control implants to assess changes to their body condition over a two-month period during the summer of 2019. We further measured body temperature, an easily measured proxy of energy expenditure, and body condition of another set of kangaroo rats in relation to pharmacologically induced stress to assess for differences in thermoregulation. Preliminary results suggest marginal differences in heterothermy among animals treated with CORT but no significant differences in fat, lean mass, or water content among treatments. Changes to fat content and lean mass was not significantly affected by treatment however there was a marginally significant interaction between time and fat content.

S9-12 MORAN, C J*; GIBB, A C; WARD, D L; The Citadel, Northern Arizona University, United States Geological Survey; *cmoran3@citadel.edu*

Integrating studies of anatomy, physiology and behavior into conservation of imperiled cyprinid fishes of the Southwestern United States

Cyprinid fishes endemic to the Southwest have been subject to anthropogenic pressures that caused many of these species to become threatened or endangered. The foremost pressures on these fishes are habitat modification through and the introduction of non-native competitors/predators. The prevailing management strategy for many of these fishes is captive breeding/rearing and release into altered habitats. However, captive-reared fish typically suffer low survival following release. We suggest that, by combining morphological, physiological and behavioral data, management agencies can improve the survival of repatriated fishes. Recent measures of performance metrics and behaviors of fish in the *Gila* sp. complex in the lab and in smaller waterways have generated specific predictions about success of individuals of particular body sizes under certain conditions. For example, *Gila* individuals below a certain size are more likely to be consumed by non-native predators, than individuals above a particular body size; therefore, the probability that re-introduced native fishes survive after they are placed in a waterway will increase with increasing body size. Similarly, higher water flows will favor the retention of *Gila* sp. (based on their swimming performance); this finding suggests that controlled flooding or a return to natural hydrologic conditions would aid in native fish recovery. We conclude that understanding performance metrics associated with anatomical and physiological adaptations can allow managers to manipulate habitats to better suit native fishes. Taking a whole ecosystem management approach allows managers to not only improve the success of native fishes but return native habitats to original conditions.

137-4 MORAN, C J*; HUDSON, D; GERRY, S P; The Citadel, Maritime Aquarium, Fairfield University; *cmoran3@citadel.edu*

Implications of muscle performance on the management of recreationally and commercially important fishes.

Many fisheries in the Northeastern United states are seasonal as cooling temperatures in the fall trigger many species to migrate offshore away from summer fishing grounds. Once established, the seasons of "open fishing" are difficult to change. By understanding the physiology of commercially and recreationally important species managers can make more informed decisions as to seasonal activity of these species. As a case study, we examined a series of performance metrics related to routine activities in a seasonally active species from New England. The overfished tautog (*Tautoga onitis*) make short migrations to offshore wintering habitats where they undergo winter dormancy. We analyzed muscle performance, feeding kinematics and the escape response at a range of relevant temperatures in order to establish a comprehensive view of how temperature impacts this species and its associated fishery. Based on the research we present here we can provide managers a more accurate picture as to how temperature and future climate warming will impact seasonal distribution and activity. Understanding the seasonality of fish behavior and physiology is integral in a management strategy.

53-3 MORENO, KR*; WEINBERG, M; YOVEL, Y; HARTEN, L; CZIRJáK, SL; SALINAS-RAMOS, VB; HERRERA MONTALVO, LG; Department of Zoology, Tel Aviv University, Tel Aviv, Israel, Leibniz Institute for Zoo and Wildlife Research, Berlin, Germany, Department of Agriculture, University of Naples Federico II, Naples, Italy, Institute for Biomedical Investigation, Universidad Nacional Autónoma de México, Mexico City, Mexico; *Kelsey.R.Moreno@gmail.com*

Sickness in Fruit Bats: Unique Immune Reaction Reflects a Unique Social Behavior

The immune response's first line of defense, the acute phase reaction, contributes to the early control of infections, yet little is known about its adaptations to successfully cope with bacterial infections, particularly in fruit bats. We investigated physiological and behavioral aspects of the acute phase response in the Egyptian fruit bat (*Rousettus aegyptiacus*) by injecting a bacterial Lipopolysaccharide (LPS) in comparison with a saline buffer (PBS) control. We tested 11 experimental animals and 10 control in a closed colony, then extended our findings' validity with 5 free ranging bats housed in our open colony. Bats were monitored via on-board trackers, video, weights, and blood draws. Experimental individuals displayed marked differences in food consumption, body weight, body temperature, movement, probability of exiting to forage, maximum distance traveled, total distance traveled, sociality, and Haptoglobin. These changes bear similarity to other known mammalian acute phase responses, but displayed a far more intensive amplitude. Such severity of response indicates strong reaction to bacterial infection; far different than the antiviral response found in this species and the reaction found in insectivorous bats. Moreover, because Egyptian fruit bats are highly social, their solitude sickness behavior is a clear deviation from the norm.

P1-28 MORISAWA, R*; DERKARABETIAN, S; BOYER, SL; Macalester College, Harvard University ; *rmorisaw@macalester.edu*

Phylogeny of the New Zealand harvestman genus Rakaia (Arachnida, Opiliones, Cyphophthalmi, Pettalidae) based on Ultra-Conserved Elements, with a description of new species

We produced an updated phylogeny of mite harvestman (Arachnida, Opiliones, Cyphophthalmi) belonging to the genus *Rakaia* based on sequence capture of Ultra-Conserved Elements (UCE), highly conserved regions of the genome shared across distant taxa. *Rakaia* is the most speciose and widespread mite harvestman genus in New Zealand; previous efforts to understand phylogenetic relationships within this group have been limited in terms of taxonomic sampling and number of loci. The degradation associated with many museum collections rules out the option of Sanger sequencing critical specimens; however, sequence capture methods allow sequencing of hundreds of loci across the genome from collections from as early as the 1860s. We sequenceded UCEs from 61 *Rakaia* specimens from all of the known species but one through a protocol that splices, amplifies, and hybridizes DNA for sequencing. Morphological and geographical data were used in tandem with molecular DNA data to identify undescribed species and test biogeographic hypotheses.

P3-97 MORNINGSTAR, S; MASLIKOVA, V*; REAMS, B; SHORT, C; MASHANOV, V; JAHAN-MIHAN, A; HAHN, DA; HATLE, JD; Univ of North Florida, Univ of Florida; *jhatle@unf.edu*

Dietary and storage protein thresholds for reproduction in grasshoppers

Diets ideally should match the needs to yield increased reproduction and extended lifespan, a result of attaining thresholds of nutrition and storage faster. A challenge is to design the dietary protein to the species' needs. Approximating an approach using exome-matching in fruit flies, we designed a diet that matched the amino acid (AA) profile of grasshopper vitellogenin (Vg), the precursor to egg yolk protein. This 'Vg-balanced' diet was then fed to female lubber grasshoppers, which have large reproductive responses to adult diet. For example, only 1gm lettuce daily is insufficient for reproduction, whereas ad libitum lettuce feeding is over 4gm daily. Each individual (n=90) in the present study was fed 1gm lettuce and ad libitum artificial diet (0P:35C) daily. Four groups were created by feeding additional foods: 1) a solution of AA matched to the composition of Vg (group ID: Vg-balanced & 1gm), 2) an isonitrogenous solution with AA out of proportion from Vg (Unbalanced & 1gm), 3) buffer and unlimited access to lettuce (Buffer & ad-lib), and 4) buffer only (Buffer & 1gm). Age of oviposition and number of eggs both differed across all groups. Buffer & ad-lib had the highest yield, followed by Vg-balanced & 1gm, Unbalanced & 1gm, and Buffer & 1gm. In contrast, body mass and fat body mass, both after oviposition, did not differ across the three groups fed 1gm lettuce daily. Therefore, the isonitrogenous diets exhibited a difference in reproduction but not somatic growth. With hemolymph samples, we will test for reproductive thresholds of body mass, amino acid ingestion, vitellogenin, and protein storage.

P1-53 MOROZ, MJ*; KEMP, ME; University of Texas at Austin; *mjmoroz@utexas.edu*

Fossil bats' (Myotis velifer) jaw morphology changes through time and with climate change in Hall's Cave, Texas

The cave myotis, *Myotis velifer*, is a species of insectivorous bat distributed throughout the Southwestern US and Mexico. Fossils are known from several localities, including the well-known Hall's Cave in Kerr County, TX. Hall's Cave represents a continuous fossil record from the Last Glacial Maximum (18 kya) to the present, tracking significant warming and drying trends in local climate. Variation in body size across clines in *M. velifer's* distribution has been observed in the present: bats in warmer, drier climates are smaller on average, while in cooler, wetter climates bats are larger. Previous studies capitalized on these modern trends and used linear measurements of fossils from Hall's Cave as indicators of paleoclimate through time and found a trend of decreasing body size in *M. velifer* from the earliest occurrence to the present. Simple linear measurements of the skull may not capture changes in morphology, however, meaning that evolutionary change in skull morphology could have occurred without detection in this previous study; furthermore, recent studies of bat skulls have shown the importance of morphology for enhancing fitness. In this study, we use geometric morphometrics to quantify changes in *M. velifer* mandible shape through time in Hall's Cave. Preliminary data shows that mandible morphology differs between the oldest and youngest *M. velifer* fossils in Hall's Cave and that variation is greatest in the temporomandibular joint, which may have implications for changing bite force through time. By quantifying variation in mandible shape using geometric morphometrics, we can study the impacts of past and future climate change on this species.

P1-170 MORRELL, A*; BARTLAM-BROOKS, H; BENNITT, E; WILSON, A; Structure and Motion Lab, The Royal Veterinary College, London, UK , Okavango Research Institute, University of Botswana; *amorrell@rvc.ac.uk*

Navigation of zebra between grazing grounds and distant water sources in Botswana, Africa

Long-range movements come at a significant energetic expense for animals in hostile environments. The cost of failure to reach desired locations is severe, meaning precise timing and navigational strategies are essential for survival. Spatiotemporal mapping of these journeys can give insight into the mechanisms behind such phenomena. We report detail of how zebra route between grazing grounds and a single river water source in the Makgadikgadi National Park (MNP), Botswana, during the dry season (April-October). Twenty-six female zebras were fitted with custom built global positioning system and inertial measurement unit (GPS-IMU) collars. Data were collected over an 18-month period, spanning two dry seasons. Zebra grazed over 20 km from the river and returned to drink every 3-5 days. Throughout the dry season, drinking and grazing sites changed location in a consistent pattern. The movement between sites was always comparatively directed, although animals were not loyal to individual routes. Ongoing work includes analysis of track networks via photogrammetry, measurements of track use and investigation of zebra reliance on navigational landmarks to examine the importance of existing track use for navigational purposes. These preliminary data, coupled with ongoing analysis, provide crucial insights to understanding large-scale spatiotemporal movements in zebra, and potentially other African migratory herbivores, forming a stronger foundation for future conservation efforts in the MNP and elsewhere.

27-3 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*

Developmental mechanisms shaping crocodylian snouts

Crocodylian skull shape is tightly associated with dietary ecology. A continuum of snout lengths exists in living crocodylians, from short & blunt faces in the dwarf crocodile (*Osteolaemus tetraspis*) to dramatically elongated snouts in the tomistoma (*Tomistoma schlegelii*). The evolution and function of snout shape has been widely explored, but the developmental programs which underlie differences in snout length have yet to be revealed. Comparative developmental studies in birds and mammals (e.g., Darwin's finches and bats) have revealed facial elongation can be achieved by maintaining or increasing the rate of cell proliferation in the facial mesenchyme and/or delaying skeletal differentiation. Our previous work showed heterochrony was critical in the evolution of crocodylian skull ontogeny. We now aim to study cellular dynamics (cell proliferation and cycling) and gene expression at key developmental stages in three species with distinct snout lengths: *Alligator mississippiensis*, *O. tetraspis*, and *T. schlegelii*. Integrating *in ovo* EdU labeling with *in situ* hybridization allows us to assess if temporal and spatial shifts in the expression of genes controlling skeletogenesis can explain differences in cranial ontogeny. Our data show differences in proliferation rate at the tip of the snout can be detected at Ferguson stage 14, prior to differences in facial length. Our results so far suggest cell proliferation decreases earlier in the blunt-snouted species than species with longer faces and may be driven by differential deployment of genes controlling cartilage differentiation (e.g., Bmp4 or CaM).

8-4 MORRISON, E*; DECKARD, T; ADANIYA, K; DEMAS, G; Department of Biology and Center for the Integrative Study of Animal Behavior, Indiana University; *eam10@iu.edu*

Maternal gut dysbiosis via antibiotic administration affects the behavior of offspring Siberian hamsters (Phodopus sungorus)

The acquisition of microorganisms by a newborn mammal during birth and thereafter prime the infant gastrointestinal tract and may have both immediate and lasting effects throughout the lifespan of the offspring. The transfer of beneficial microorganisms from mother to infant is highly dependent on the condition of the maternal gut microbiome. Inadequate establishment of the infant gut microbiome has been linked to lasting health concerns, and dysbiosis within the adult gut microbiome via antibiotic administration has been linked to behavioral and physiological changes. Therefore, maternal intake of antibiotics during breastfeeding may alter the maternal gut microbiome and subsequently impact the offspring. We investigated the consequences of maternal antibiotic administration on behavior and physiology of both dams and offspring Siberian hamsters. Hamsters were given an oral dose of broad-spectrum antibiotic daily from parturition for one week. Offspring from these mothers were then raised to adulthood and mated. We show that maternal care was not directly affected by antibiotic administration. However, the offspring of antibiotic-administered mothers exhibited aberrant maternal behaviors toward their own offspring. Data on changes in the gut microbiome for all three generations and their relationship to adult behavior will be presented. Collectively, these findings provide insight on the intergenerational effects of maternal gut dysbiosis on physiological and behavioral responses of offspring.

15-1 MORRISON , CR*; SMILEY , J; The University of Texas at Austin , University of California San Diego; *crmorrison@utexas.edu*

Using a Portable Hydrogen Cyanide Gas Meter to Uncover a Dynamic Phytochemical Landscape

A major contributor to global biodiversity is the tremendously variable landscape of secondary metabolites characterizing organisms. Crushing or chewing leaves catalyzes a reaction that releases potentially toxic hydrogen cyanide gas (HCN) in over 3000 species of vascular plants representing 110 families of ferns, gymnosperms, monocotyledonous and dicotyledonous angiosperms. These include a diverse group of economically important crops such as cassava, stone fruits, lima beans, bamboo and cashews. Nearly all species of passion vines in the genus *Passiflora* (Passifloraceae) contain HCN-releasing cyanogenic glycosides. These compounds are key drivers of adaptive radiation in *Passiflora* and the highly specialized herbivorous insect taxa that consume them. The conventional method for quantifying cyanide concentration in *Passiflora*, and other biological samples, is the Lambert colorimetric procedure. This procedure can be prohibitive. It requires expensive analytical equipment, substantial investment of time in collecting and processing samples, and is restricted to laboratories that are often away from the field where study organisms occur. Here we present a new method for quantifying HCN concentration of biological samples that is cheap, flexible, efficient, and high throughput. This method is based on a simple apparatus assembled around a portable HCN meter developed for emergency personnel. An evaluation of the accuracy and validity of this method by comparison with the conventional Lambert procedure will be presented. We will conclude by taking this opportunity to showcase the utility of this method by presenting dynamic spatial and temporal patterns of HCN heterogeneity in tropical *Passiflora* that have been discovered using this technique.

110-7 MOSSOR, AM*; AUSTIN, BL; AVEY-ARROYO, JA; BUTCHER, MT; Youngstown State University, Sloth Sanctuary of Costa Rica; *ammossor@student.ysu.edu*

Are sloths horses hanging upside down?: Suspensory adaptations of sloth flexor tendons

Sloths are nearly obligatory in their use of suspensory locomotion and posture, and due to their low metabolic rate, body temperature, and rate of digestion, have an extreme need to conserve energy. It is possible that sloths possess a ‘suspensory apparatus' analogous to that of upright ungulates, thus allowing for largely passive support of their body weight while minimizing muscle energy expenditure. The digital flexor tendons from the fore- and hindlimbs of two-toed (*Choloepus hoffmanni*) and three-toed (*Bradypus variegatus*) sloths were loaded in tension until failure with an Instron machine to test this hypothesis. Tendons displayed low tensile strength and Young's (elastic) modulus, but had moderate stiffness indicating some compromise between strain resistance and joint position control for grip strength. Sloth flexor tendons also had elevated safety factors for suspension involving multiple limb contacts. Overall, the tendon loading curves and material properties were similar to those of generalist mammals (e.g., rats) and also match well with those of equine suspensory ‘ligaments.' These results help explain previous findings in sloths that show low levels of muscle activation in the digital flexors among other major forelimb flexors during suspensory walking and postural hanging. Current evaluations are focused on potential modifications of increased tensile strength in the long limb bones of sloths that further indicate mechanisms that permit suspensory habits in mammals.

111-3 MOUNTCASTLE, AM*; AHLHOLM, PD; STONE, I; FEDERICO, P; NIXON, E; JOHNSON, N; Bates College; *amountca@bates.edu*

Effects of wing size and wingbeat frequency on wing wear in bumblebees

Many flying insects frequently collide their wing tips with vegetation. Repeated collisions can cause the wings to wear down over time, which can reduce flight performance and increase the risk of mortality in bumblebees (and likely other insects as well). However, little is known about how wing size and wingbeat frequency – both correlated with body size – affect the rate of wing wear. To address this question, we used a high-speed motor to artificially induce damage in the wings of *Bombus impatiens* bumblebees by forcing them to repeatedly collide with a leaf surface 500,000 times. We spun wings from two different size groups (large and small) at two different speeds (fast and slow), to independently test the effects of wing size and wingbeat frequency. We found that the rate of wing wear depends on both wing size and rotational velocity, suggesting that insect wings may experience size-dependent selective pressures associated with collision-induced wing damage.

8-1 MRUZEK, JL*; DIMOS, B; MACKNIGHT, N; KATHRYN, C; BRANDT, M; MYDLARZ, LD; University of Texas at Arlington, University of the Virgin Islands ; *joseph.mruzek@mavs.uta.edu*
Linking Disease Resistance in Coral to its Ability to Maintain a Complex Microbiome
Caribbean coral reefs are threatened by disease, and the coral's microbiome, the complex community of microorganisms on the coral's surface, plays a critical role in both disease resistance and progression. The microbiome-disease relationship has been inferred solely through relative abundance and functional profiles of bacterial taxa, but here we go beyond these methods, presenting a look at the structure of the microbiome community. Utilizing co-occurrence networks, we measure the microbiome's connectance, the number of interspecific connections, and its modularity, or groupings of species. A complex microbial community is predicted to be more stable, allowing coral to better resist infection, thus we compare the network topology of the microbiome of two coral genera: *Porites*, shown to be resistant to white plague disease, and *Orbicella*, susceptible to white plague. As Porites is resistant, we predicted a more complex, more disturbance-resistant microbiome, than *Orbicella's* prior to exposure. We also predicted that disease resistant *Porites* would not have altered network topology following exposure, whereas the infected *Orbicella* would have a less connected and more modular microbiome. Prior to disease exposure, we did not find significant differences between the microbiome networks of *Porites* and *Orbicella*, rejecting our first hypothesis. After exposure, there is a significant decrease in connectance and increased modularity only in *Orbicella*, while *Porites* does not show significant changes in network topology, implying that the ability to maintain a structurally complex microbiome is linked to the ability to resist disease.

13-4 MUGEL, SG*; NAUG, D; Colorado State University; *smugel@colostate.edu*
Metabolic Rate Variation Shapes Pace of Life Traits at Both the Individual and the Group Level
Pace of Life (POL) models have recently emerged to integrate covariation among behavioral, physiological, and life history traits along a single fast-slow axis. Variation in metabolic rate, the fundamental biological rate at which organisms acquire, process, and expend energy, is often considered the primary driver of phenotypic covariation that defines POL at an organismal level. The metabolic theory of ecology however suggests that the functional importance of metabolic rate should also drive similar patterns at higher levels of organization, although such ideas have rarely been empirically investigated. Using honeybees (*Apis mellifera*) as an experimental model, we measured a number of behavioral, physiological, and life history traits at the individual and group level. We then adopted a structural equation modeling approach to present evidence of a POL in honeybees consistent with many of the theoretical predictions and the role of metabolic rate in shaping covariation structure. In order to explore similar patterns at the group level, we then bred genetic lines of honeybees with slow and fast metabolic rates based on the malate dehydrogenase locus and then created experimental groups that were homogenously slow, fast, intermediate, and heterogeneously mixed groups of slow and fast bees. We then assayed these groups on some of the same behavioral, physiological, and life history traits that were measured at the individual level as well as some additional group level traits, in resource rich and poor environments. Using a partitioning of variance approach on these trait values across different group compositions, we then investigated the relative selection (non-additive) and complementarity (additive) effects of metabolic rate and how they interact with the resource environment in shaping the pace of life at higher levels of biological organization.

102-4 MUHAMMAD, S*; DICK, MF; WELCH, KC; University of Toronto; *saad.muhammad@mail.utoronto.ca*
Sugar Flux and Metabolism in the Ruby-Throated Hummingbird.
Hummingbirds are one of two flying nectarivores that can uniquely use recently ingested fructose or glucose to power flight. Previous work in our lab suggests that for hummingbirds this could partly be due to muscle physiology having both glucose and fructose transporters, and high hexokinase activity. These may give the hummingbird an ability to metabolize native fructose directly in muscles, unlike other vertebrates. However, the observed hexokinase activity rate is not high enough to support flight direct oxidation in the muscle with fructose. Thus, it is unclear how hummingbirds maintain a high sugar flux, particularly for fructose, while hovering. First, we examined changes in plasma metabolites of fasted birds versus those fed sucrose (glucose and fructose). Our fasted birds showed blood fructose levels of 0.2mM whereas fed birds had around 5mM blood fructose levels. In contrast, blood glucose levels remain similar after one hour of fasting, suggesting fructose levels are much more dynamic than glucose levels in the blood. To explore the differential use of these sugars we examined sugar flux by comparing fed birds given glucose or fructose and fasted birds. Ruby-throated hummingbirds' metabolites were quantified from birds that were fasted, or fed glucose, or fructose. We used LC-MS based metabolomics to determine the metabolite concentrations in highly metabolic tissues (liver, heart, pectoralis muscle). Specifically, we were interested in central carbon metabolism which helped elucidate which pathways fructose and glucoses are using. In addition, relative amounts of glucose transporters and monocarboxylate transporters at the tissues provide support for metabolite data. We also show that the ruby-throated hummingbird has higher capability to use exogenous fructose via different metabolic pathways in tissues, like muscle, than that of mammals.

P3-116 MUKHTAR, V*; DEAROLF, JL; THOMETZ, NM; BRYAN, A; REICHMUTH, C; Hendrix College, Conway, AR, Univ. of San Francisco, CA, Alaska Department of Fish and Game, Fairbanks, Univ. of California, Santa Cruz; *mukhtarvv@hendrix.edu*
Fiber-type profile of the latissimus dorsi muscle of the ringed seal
The ringed seal (*Pusa hispida*) can dive into the ocean and forage in the water column for 8 min and dive 20 to 140 meters deep, which is greater than some other Arctic seal species. To better understand the ringed seal, we need to characterize the physiological profile of the ringed seal and determine how it could contribute to their swimming and diving behavior. The specific feature of the ringed seal that we focused on is the latissimus dorsi (LD) muscle, which is one of the muscles responsible for locomotion. We investigated the fiber-type profile of this muscle in order to ascertain how the structure of the muscle contributes to the diving behavior of the ringed seal. To determine the fiber-type profile of the ringed seal LD muscle, we froze the muscle samples from ten different specimens, cut sections from them using a cryostat, and placed the sections on microscope slides. Afterwards, we stained the sections for their myosin ATPase activity or their reaction to two myosin heavy chain antibodies, which would then be imaged. Imaging ATPase sections allowed us to count how many fast-twitch or slow-twitch fibers there were in the sections. The imaging also allowed us to measure the diameters of the fibers in ImageJ. All of these data will allow us to build a profile of the LD muscle and determine how it can contribute to the swimming and diving behavior of the ringed seal. We also will compare the fiber-type profile of the ringed seal LD with the profile of this muscle in other Arctic seal species, such as the bearded and spotted seal, to better understand the relationship between muscle characteristics and behavior.

104-5 MULLER, U*; SUMMERS, AP; CSUF, UW - Friday Harbor Labs; *fishguy@uw.edu*

SICB Journals - synergy, status, and a call to action

Two journals are published by the Society for Integrative and Comparative Biology SICB: Integrative and Comparative Biology (ICB) and Integrative Organismal Biology (IOB). Both journals serve the SICB community by bringing scientific publishing into the 21st century. In over 50 years of publishing peer reviewed articles based on SICB symposia ICB has become a go to resource for foundational and forward looking work in organismal biology. The brand new IOB is published as an open access journal, and has introduced double-blind peer review, a mindful editorial process focused on constructive guidance, and multilingual abstracts. Both ICB and IOB have built inclusive editorial boards and promote authors and their science through social media. In 2019, both IOB and ICB achieved high scores in both traditional, citation-based metrics as well as complementary social-media based metric: IOB was ranked first among biology journals for its social media metrics (Altmetrics); ICB achieved its highest impact factor to date (3.101). Both journals successfully cooperate to serve the SICB community, and both journals strive to lead through increasing equity and transparency in the scientific publication process. ICB will be on the cutting edge of symposia development by instigating both hybrid symposia and virtual symposia to increase diversity and participation. IOB is soliciting manuscripts on best practices, reviews and commentary adjacent to ICB symposium topics, as well as a diversity of original data manuscripts from all of SICBs divisions. Our journals serve the society in many ways and we count on the membership to think of the journals as places to publish their best work. After the talk we will actively solicit your opinions on new initiatives, such as on equity, accessibility and transparency.

P2-243 MULLINS, H*; DAVIS, J; ARONSON, N; Radford University, Uniformed Services University; *hmullins9@radford.edu*

Jungle Pharmacy: Exploring the Antibacterial and Antitrypanosomal Properties of Ficus insipida

Infections caused by parasitic protozoans continue to affect millions of individuals worldwide, however treatments for these infections have proven to be problematic in a variety of ways. Most treatments use broad-spectrum antimetabolites that do not specifically target the protozoan itself and so result in severe, and sometimes lethal, side effects. Natives in developing countries utilize a vast number of natural medicines for antiparasitic and antimicrobial treatments, and anecdotal stories suggest that some of these may be both efficacious and more target specific than other medications. Prior research from our laboratory suggest that extracts from *Ficus insipida* collected from the Peruvian Amazon potentially has antiparasitic properties in relation to both protistal and bacterial parasites. Here we describe work specifically exploring the impact of *F. insipida* extracts on bacterial growth and colony formation, and reproduction and motility in trypanosomes. We will discuss both potential medical and evolutionary/biochemical implications.

69-2 MUNLEY, KM*; DEYOE, JE; ADANIYA, CH; NOWAKOWSKI, AM; REN, CC; MURPHY, GV; REINHART, JM; DEMAS, GE; Indiana University; *kmunley@indiana.edu*

Melatonin modulates seasonal changes in neurosteroid levels and territorial aggression in male Siberian hamsters (Phodopus sungorus)

Numerous studies have shown that circulating gonadal steroids are positively correlated with aggression during the breeding season. However, it is becoming increasingly clear that alternative neuroendocrine mechanisms are critical in modulating aggressive behavior, particularly for animals that are more aggressive during the short-day photoperiods (SDs) of the non-breeding season. While 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, it is unknown whether local changes in steroid synthesis and metabolism within the brain are ultimately responsible for elevating aggression during the non-breeding season. To investigate the role of MEL in mediating seasonal variation in neurosteroid levels and aggression, we housed male hamsters in long days (LD) or SD, treated them with either timed MEL or saline injections, and quantified aggression after 9 weeks of photoperiodic housing. Furthermore, we assessed whether MEL mediates seasonal changes in steroidogenesis by comparing circulating and neural hormone levels in brain regions that are associated with aggressive or reproductive behaviors using liquid chromatography-mass spectrometry. LD hamsters administered MEL (LD-M) exhibited SD-like levels of aggression. Moreover, LD-M and SD animals reduced circulating DHEA and testosterone levels following an aggressive encounter, whereas LD animals elevated circulating androgen levels. Neurosteroid profiles will also be presented and compared across brain regions and seasonal phenotypes. Collectively, this study provides insight into how MEL regulates seasonal changes in aggression, a behavior that is critical for reproductive success.

S10-6 MUNOZ, MM*; ANDERSON, PSL; HU, Y; PATEK, SN; CAMARILLO, H; Yale University, University of Illinois, Urbana-Champaign, Brown, Duke University; *martha.munoz@yale.edu*

How Predictable and Correlated are Patterns of Form-Function Evolution?

Mechanical relationships shape how organisms can move, feed, and reproduce, thus impacting all aspects of evolutionary fitness. But, can mechanical relationships be used to predict macroevolutionary patterns of morphological diversity? And, how correlated is form-function evolution among different parts of the body? First, I describe previous work connecting mechanical sensitivity, many-to-one mapping, and rates of morphological evolution in various four-bar linkage systems. Then, zooming in on wrasses (Family: Labridae), I describe whether and how feeding and locomotor traits evolve in a correlated or uncorrelated fashion across the labrid tree. The field of evolutionary biomechanics has a rich conceptual history, but remained relatively data limited (particularly with regards to phylogeny) for decades. Now, more than ever, we are uniquely poised to rigorously and quantitatively link biomechanics, ecology, and phylogenetics in a synthetic framework, and derive clear, directional predictions in form-function evolution.

62-6 MUNTEANU, VD*; DIAMOND, KM; MAYERL, CJ; BLOB, RW; Clemson University, NEOMED; *vmuntea@g.clemson.edu*

Humeral Strains During Climbing in Green Iguanas: Testing Biomechanical Release as a Mechanism Promoting Morphological Transitions in Arboreal Vertebrates

The morphology of vertebrate limb bones is generally expected to reflect differences in the functional demands that they experience. Such different demands often arise through changes in habitat. For example, the limbs of arboreal vertebrates are often longer than those of terrestrial relatives, a feature that may improve reach across gaps between branches, but which would be expected to incur a higher risk of bending and breakage during locomotion on the ground. In addition to resulting from changes in habitat, different demands might also arise between the fore- and hindlimbs, which themselves might be affected differently by changes in habitat. To test this hypothesis, we compared previous measurements of *in vivo* strains from the femur of green iguanas during simulated climbing to new measurements of bone strain from the humerus. Trials were conducted for inclined climbing, and walking on a level, compliant surface, to test whether loads under these conditions were lower than those on stiff, level ground. Such a pattern would suggest that "biomechanical release" from loading demands may have facilitated the evolution of longer limbs. We found that both inclined and compliant conditions increased femoral strains when compared to standard level conditions. However, unlike the hindlimb, there was not a consistent pattern of lower or higher bone strains for the forelimb during trials that simulated arboreal conditions. Synthesizing results from the fore- and hindlimbs, biomechanical release seems to be an unlikely mechanism that promoted limb elongation in arboreal taxa. Instead, limb bone adaptations in arboreal habitats seem to have been driven by selective pressures other than their response to loading.

88-6 MURPHY , C.T*; LYONS, K.M; HADDOCK, W.A; MARTIN, W.N; HELLUM, A.M; BREUER, K.S; FRANCK, J.A; US Navy, University of Wisconsin-Madison, Brown University, Brown University; *christin.murphy@navy.mil*

Feature Variations in Seal Whisker Geometries and the Effect on Vortex Structure

Seals use their highly sensitive whiskers to track the hydrodynamic trails of their swimming prey. These whiskers have a unique undulated surface geometry that affects water flow over the structure and influences vortex shedding. Whisker geometry varies between species but the effect of these morphology variations is unknown. By creating whisker models with dramatically modified features, we are able to isolate the effects of specific geometric parameters. Models were tested both computationally and experimentally. For computational fluid dynamics (CDF) simulations, sixteen digital models were generated that isolated seven non-dimensional parameters including undulation wavelength, thickness, slenderness, amplitudes in the streamwise and transverse flow directions, as well as a peak-shift and a symmetry parameter that induce a non-sinusoidal periodic undulation. CFD simulations produced a ranked list of important features that are most influential for reducing drag, root-mean-square lift force, and shifting the frequency spectra. Of these, wavelength was revealed as an important feature. Four physical models (with wavelength as the only variant) were 3D printed and tested in a water tunnel using dye visualization, at the biologically relevant Reynolds number range of 250-800. Flow visualization demonstrated the ability of the undulations to enhance the spanwise momentum transport, reduce the recirculation region, and modify the frequency spectra in the recirculation region behind the whisker.

P1-269 MURPHY, KM*; WATKINS, M; FINGER, JW; KELLEY, MD; ELSEY, RM; WARNER, DA; MENDONçA, MT; Auburn University, Auburn, AL, LA Department of Wildlife and Fisheries, Rockefeller Wildlife Refuge, Grand Chenier, LA; *kmm0155@auburn.edu*

Xenobiotic estradiol-17ß and the microbial gut communities of hatchling American alligators (Alligator mississippiensis)

Environmental estrogens pose serious threats to ecosystem and population health. These pollutants can impact organisms in numerous ways, from disrupting critical hormonal pathways to changing reproductive behaviors. The influence of environmental estrogens on gut homeostasis is poorly studied, but can potentially have negative impacts on individual health and fitness via their effect on the gut microbial community. To quantify the influence of environmental estrogens (i.e. xenoestrogens) on the diversity and abundance of gut microbiota, twenty-three hatchling American alligators (*Alligator mississippiensis*) were randomly allocated across three treatment groups that differed in estradiol intake over ten weeks. These treatments included individuals that were provided rations supplemented with 1 mL/kg of peanut oil (control group), 0.5 µg/kg estradiol-17ß (low treatment), or 1 µg/kg estradiol-17ß (high treatment). These doses are similar to the toxicity threshholds for other freshwater organsims and mimic those found at ecologically relevant concentrations. We predicted that xenoestrogen exposure would increase microbial diversity and abundance within the digestive tract, and that the effect of xenoestrogens on the gut microbial community would be dose-dependent. Microbial samples were collected at the end of the study and were elucidated using 16S rRNA gene-sequencing. Findings from this study will provide insight into the effects of exogenous estrogen exposure on the internal microbial community and aid in understanding the consequences of exposure on health.

60-2 MURRAY-COOPER, M*; OZKAN-AYDIN, Y; AYDIN, E; NACLERIO, N; MCCASKEY, E N; HAWKES, E; GOLDMAN, D I; School of Physics, Georgia Tech, Mechanical Engineering, UC Santa Barbara; *mmurraycooper@gatech.edu*

Robophysical Investigation of Root Nutation through Heterogeneous Environments

Circumnutation, a cyclic endogenous circular pattern exhibited by the tip of a growing root, occurs in a diversity of plants, but its function is not fully understood. A previous study observed that rice roots with circumnutating root tips had a higher probability of finding holes that were uniformly distributed on a horizontal plate than mutant roots that grew without circumnutating (Lehner et al. BioArxiv CITE). To investigate the hypotheses that nutation facilitates substrate penetration and exploration, we built a planar soft robot [Hawkes et al. 2017], which grows from the tip like a plant root and can bend in 2D space by oscillating inflation of the series pneumatic artificial muscles (sPAMs) arranged on the two sides. We studied how tip oscillation affected penetration in a heterogeneous environment, a lattice of rough cylinders (d=8cm) distributed uniformly in a bounded free space (120X120cm^2). Systematic variation of initial robot starting positions horizontally across the lattice revealed that the non-oscillating tip strategy led to a high probability of becoming pinned to obstacles; the robot was unable to grow more than an average depth of 23.8±19.7cm . The oscillating tip penetrated the lattice significantly further on average, 55.2±24.9cm , typically via discovery of "corridors" in the lattice. Even in randomized lattices, the nutation facilitated sustained growth. The results from the robotic root model suggest that oscillatory movement of a growing structure increases its exploratory capabilities in a heterogeneous environment.

P1-81 MUSGROVE, CM*; WATSON, LAR; HINDS, AD; CARVALHO, CM; AMBARDAR, M; Fort Hays State University; *m_ambardar@fhsu.edu*

Relationships among Parental Care, Heterophil to Lymphocyte Ratio, and Reproductive Success in a Songbird

Parental care increases fitness, but it can also be energetically taxing. In species with biparental care, dissimilarity in parental care may require that one individual of the pair provide a majority of the workload. The stress response evolved to allow animals to cope with energetic needs when facing a stressor, and thus is likely an important mediator of parental care. In birds, leukocyte counts, specifically the ratio of heterophils to lymphocytes, can be a reliable proxy for stress. In addition, because leukocyte numbers do not change as rapidly as hormonal measures of stress, H/L ratios are proposed to represent prolonged stress. Such a measurement might be more meaningful in relation to parental care, which is ongoing during the nestling period. We determined relationships among parental care, stress, and reproductive success. We also determined if parental pairs were similar or dissimilar in care behaviors. We predicted that individuals that provided more parental care to offspring would have higher H/L ratios. We also predicted H/L ratios would be negatively correlated with reproductive success. Finally, we predicted that H/L ratios would be higher and reproductive success would be lower for pairs that were dissimilar. Using House Wrens (*Troglodytes aedon*), we determined H/L ratios in blood smears from adult birds. When nestlings were 4-6 days post-hatch, we recorded parental care videos to determine male and female nest visits rates and pair similarity. We weighed nestlings when they were 4, 8, and 10 days post-hatch and determined fledging success as measures of reproductive success. We discuss our findings within the context of long-term stress and parental care.

119-2 MUSSER, JM*; SCHIPPERS, K; NICKEL, M; KOHN, A; MOROZ, L; ARENDT, D; European Molecular Biology Laboratory, Heidelberg, DE, University of Florida, St. Augustine, FL; *jmmusser@gmail.com*

Whole-body single-cell RNA sequencing reveals neural elements in a sponge

Sponges are the sister group to nearly all other animals, and lack a nervous system, musculature, and gut. However, genes encoding important neuronal proteins, including key synaptic proteins, have been found in sponge genomes. Using single-cell RNAseq, single-molecule FISH, and Focused Ion Beam SEM (FIB-SEM) we generate a comprehensive molecular and morphological characterization of cell types in *Spongilla lacustris*, a freshwater demosponge. We identify many specialized cell types bearing functional and regulatory signatures similar to those of other animals. This includes contractile epithelial cells, which we demonstrate experimentally are responsive to nitric oxide signaling, phagocytes involved in innate immunity, and digestive cells that express a nearly complete set of postsynaptic genes. Remarkably, we also find immune cells expressing presynaptic genes and show via FIB-SEM that they send long projections that directly contact and enwrap microvilli of 'postsynaptic' digestive cells. This reveals new evidence linking neuronal and immune function in sponges, and suggests a primordial neuro-immune system cleared intruders and controlled ciliary beating for feeding.

21-1 MUTH, F*; FRANCIS, JS; LEONARD, AS; University of Texas at Austin, University of Nevada, Reno; *felicity.muth@austin.utexas.edu*

Bumblebee cognition and the influence of anthropogenic stressors

Bumblebees are an insect model organism for the study of animal cognition, due in part to their aptitude at learning and remembering stimuli while foraging. However, bumblebees are also in decline, in part due to exposure to pesticides that may alter their cognitive abilities. Thus, now is a critical time to fully understand bee cognition involved in their natural foraging behaviour, and how such cognition may be affected by anthropogenic stressors. In this talk, I highlight my recent findings on bumblebee cognition involved in foraging under ecologically realistic scenarios, as well as how neonicotinoid pesticides may be affecting sensory and/or cognitive traits. In particular, I discuss recent findings that neonicotinoid pesticide effects on learning may be modality-specific and what this might mean for bee cognition and foraging more broadly.

P3-204 MUTSUDDY, A*; STEWART, K; SEROY, SK; Wheaton College, Norton, MA , Heritage University, Toppenish, WA , University of Washington school of Oceanography, Seattle, WA; *mutsuddy_anik@wheatoncollege.edu*

Effects of temperature and habitat on egg hatching time in the marine snail Lacuna vincta

Eelgrass and kelp beds are vital coastal habitats that are potentially threatened by warming ocean temperatures. To fully understand the effects of climate change on these habitats, the community interactions within these ecosystems must be investigated. The marine snail, *Lacuna vincta*, is a common herbivore that exerts significant top-down control in both habitats. We sought to determine how rising ocean temperatures affect aspects of *L. vincta* life history in these environments, specifically egg development time. We exposed adult female snails to three temperature conditions (12°C, 16°C and 20°C) and two habitat types (eelgrass and kelp). Egg masses from these females were collected every two days, maintained in their respective temperature and habitat treatments, and observed daily until they hatched. After 15 days, unhatched egg masses were checked for mortality. Egg mass hatching time and mortality were recorded. Hatching time was not significantly different in either habitat at 12°C or 16°C. Hatching time was only significantly shorter at 20°C for eggs laid on kelp, but not for those on eelgrass. Egg mass size did not affect hatching time. Mortality increased with temperature for egg masses in both habitat types. Our results imply that warming, especially within a near-future range, may only have limited effects on *L. vincta* egg development, suggesting that this aspect of their life history may be potentially resilient to climate change.

P3-149 MVETIMBO-TAMBO, KLO*; TAFT, BN; TAFT, NK; University of Wisconsin Parkside, Landmark Acoustics, LLC; *taft@uwp.edu*

Comparative Fin Ray Stiffness in Coho Salmon

The position of the fins on the body has changed significantly in the evolution of ray-finned fishes. Accompanying these changes in fin position have been changes in fin function. Salmonids like the Coho salmon (*Oncorhynchis kisutch*), have fin placement that is intermediate between more basal ray-finned fishes like sturgeon and more derived fishes like yellow perch. Fin function is largely determined by the relative stiffness and flexibility of the bony segmented fin rays, or lepidotrichia, that support the fins. Little is known about the morphology and stiffness of the paired fins and median fins in fishes in intermediate phylogenetic positions like salmonids. We examined the external morphology and used a three-point bending testing method to quantify stiffness in a sample of fin rays from the dorsal, anal, pectoral and pelvic fins. We used a mixed linear model approach to statistically evaluate the degree of stiffness among fins, but also within individual fin rays along their proximo-distal length. Our previous research has shown that the pelvic fin was the most stiff and pectoral the least stiff in more derived fishes like yellow perch, with median fins stiffness in between. We found the same pattern in Coho salmon. However, we found differences in stiffness of the fin rays among the fins in Coho salmon. In the paired fins, the leading and training edges were more stiff than we would predict based on their size. Alternatively, the fin rays in the median fins were stiffer in the middle versus the edges than we would predict based on size. This suggests that cross-sectional morphology may play an important role in determining the function of lepidotrichia. We also present preliminary results comparing the three-point testing method to a curvature-based testing method.

12-3 MYERS, CR; University of California Los Angeles, 1990; *cmyers614@ucla.edu*

Towards a synthesis on insect host selection and speciation

The study of how insects maintain and modify their selection of host plants is a field of inquiry comprised of many theories. This study aims to provide a novel synthesis on the subject by examining the seminal literature and providing the historical context from which new theories emerged. I examine how the pioneering work of Benjamin Dann Walsh on plant-eating insects led to a theory that extended Darwin's principle of divergence. I demonstrate that Walsh was following Darwin's theories, but also expanding them in a way that accounted for reproductive isolation, something Darwin had not addressed. The study of insect host selection grew with iterations of the same central concept being proposed under different names. Hopkins Host Selection Principle, founded by the work of Andrew Delmar Hopkins, extended Walsh's theory by providing in the field evidence of breeding isolation. By the 1940's, William Homan Thorpe began to establish his theory on the subject, Biological Races. Thorpe's theory promoted conditioning as a mechanism of insect adaptation to host plants. By the 1960's Ernst Mayr wrote about Biological Races under the name of Sympatric Speciation. Mayr was apprehensive to give much weight to the process of sympatric speciation due to its intrinsic nature, scant evidence, and his view that it was based on non-random events. Since the time of Mayr, there has been discordance surrounding sympatric speciation. In light of my synthesis on the subject, there is now clarity on how these historical theories are related. My work demonstrates that the study of insect host selection and speciation, and thus sympatric speciation, is grounded in Darwinian theory. Further, there is now clear evidence of the breadth of historical experimental and theoretical work that has been conducted on the study of insect host driven adaptations.

P2-74 MYRE, B*; GUENTZEL, N; MACKENZIE, DS; TAMU; *bmyre@bio.tamu.edu*

A Novel Approach to an Old Question: Evaluation of Ecological Breeding Strategies in Sea Turtles

Sea turtles have been historically classified as capital breeders, so they should possess a store of energy (e.g., fat) at the beginning of the breeding season that they draw from to fuel reproductive effort. However, several studies have questioned whether they may continue to feed during nesting. We are employing a physiological approach, including lipid mobilization and endocrine endpoints, to assess this hypothesis. These blood metrics in combination with reproductive ultrasound and a newly-validated ultrasound technique for measuring subcutaneous fat depth non-invasively provide new methods to assess energy balance in sea turtles. Reproductively-active turtles, including mating couples and nesting females, were sampled in Ostional, Costa Rica. Female turtles were recaptured when possible during subsequent nesting events in order to monitor blood and ultrasound profiles at several time points during the reproductive season. Results have shown that subcutaneous fat depth and the ketone body beta-hydroxybutyrate (BHB) are detectable and potentially useful metrics for fat mobilization in sea turtles. Fat depth analysis via ultrasound showed that females do not have a significant decline in the fat layer at resampling periods. Also, olive ridleys have no significant change in BHB concentrations early versus late in their reproductive season, in contrast to the expected result of lipid mobilization that should occur under a capital breeding strategy. Analysis of hormones that regulate feeding may provide more dynamic assessment of feeding changes and fat storage. These data indicate that olive ridley sea turtles may instead be income breeders, obtaining nutrients throughout the nesting season.

63-2 NAISBETT-JONES, L*; TSAI, E; LOHMANN, C; LOHMANN, K; Department of Biology, University of North Carolina, Chapel Hill; *lnaisbettjones@gmail.com*

Navigating the Ocean Floor: Magnetic Compass Orientation of a Marine Flatfish

Gulf Flounder (*Paralichthys albigutta*) hatch at offshore spawning grounds and subsequently migrate to nursery habitats along the coast of the southeastern United States. Yet, the means by which juvenile flounder reach nursery habitats has remained enigmatic. Recent studies have demonstrated that migratory fishes such as eels and salmon navigate using Earth's magnetic field. However, whether flounder – or any flatfish – possess a geomagnetic sense has not previously been investigated. We used a magnetic coil system to test whether flounder use Earth's magnetic field for directional or "compass" orientation. Fish tested in a water-filled arena in the unaltered ambient magnetic field oriented toward magnetic west, a direction consistent with their onshore migration. When the coil was used to reverse the direction of the horizontal field, the fish showed a corresponding shift in orientation. These findings demonstrate that Gulf Flounder have a magnetic compass that can be used in orientation, and which may guide young fish as they migrate from the open sea to coastal nursery habitats. These results provide new insight into the migration ecology of flounder and suggest that a magnetic compass may facilitate the diverse migrations of marine flatfish.

24-8 NAMES, G*; KRAUSE, J; SCHULTZ, E; HUNT, K; HEAL, M; HAHN, T; CORNELIUS, J; WINGFIELD, J; Univ. of California, Davis, Univ. of Nevada, Reno, Wittenberg Univ., George Mason Univ., Bangor Univ., Oregon State Univ.; *grnames@ucdavis.edu*

Immunological consequences of circulating corticosterone: an experimental investigation comparing avian malaria-tolerant and -susceptible Hawaii Amakihi (Hemignathus virens)

Infectious diseases are spreading at unprecedented rates, reducing the abundance, distribution, and/or long-term viability of many wild animals. Avian malaria has recently contributed to the decline of several endemic Hawaiian birds. Fortunately, some populations of the native Hawaii Amakihi (*Hemignathus virens*) display tolerance to the disease. We sought to experimentally determine the effect of corticosterone (CORT), an immunosuppressor, on immune function and malaria infection in wild Amakihi. Based on our field data, which show reduced CORT increase in response to capture and restraint stress in tolerant versus susceptible populations, we hypothesized that variation in circulating CORT influences malaria tolerance. To test this, we studied 40 captive adult males from tolerant and susceptible populations, implanting each with a CORT (n = 20) or sham (n = 20) silastic implant for 4 days and measuring immune function and malaria infection on day 0 (before implant), 2, and 4. CORT levels were higher on day 2 and 4 in CORT than sham birds, with no effect of tolerance status. On day 2, total leukocyte count was elevated in susceptible but not tolerant CORT-implant males compared to sham-implant males, while no differences by tolerance status were detected on day 0 or 4. Hematocrit decreased more during the experimental period in CORT-implant than sham-implant birds with no effect of tolerance status. Our results suggest that immune response may be less influenced by increased CORT in malaria-tolerant than malaria-susceptible birds.

2-3 NARAGON, TH*; BRüCKNER, AK; WIJKER, RS; SESSIONS, AL; PARKER, J; Caltech; *tnaragon@caltech.edu*

Cuticular hydrocarbons and the integration of myrmecophile rove beetles into ant colonies

Cuticular hydrocarbons (CHCs) play a dual role in insects: they prevent against water loss across the cuticle and they are a medium for chemical communication. In eusocial insects the use of CHCs in chemical communication takes on an additional dimension in that the CHCs are used not only for recognition of conspecifics but also for the recognition of members of the same colony. While the complex CHC signature allows ants to identify the majority of nest intruders, a large number of arthropods have nonetheless evolved to live inside of ant colonies via a number of different mechanisms. Of these so called myrmecophiles or ant lovers, the most intimately integrated species often mimic the CHC profile of the host colony, thus reducing, and in some cases entirely avoiding, detection within the colony. Within the colonies of the ant *Liometopum occidentale* two species of myrmecophile rove beetles have evolved to mimic the CHC profile of their host ant. Using a combination of GCMS and stable isotope mass spectrometry we analyzed the CHCs in the two beetle species to identify the mechanism by which the beetles obtained the compounds. In agreement with behavioural observations, we found that the beetle *Sceptobius lativentris* steals its CHCs from *L. occidentale* via a specialized grooming behavior whereas the beetle *Platyusa sonomae* synthesizes a large fraction of its own CHCs. These beetles embody two radically different approaches to chemical mimicry, either via modification of CHC synthesis machinery or through the modification of behavior, and represent a useful system for studying convergence in symbiotic systems.

7-6 NASH, S/B*; RAHMAN, S/M; University of Texas Rio Grande Valley, Brownsville, TX; *sarah.b.nash96@gmail.com*

Short-term heat stress attenuates gonadal functions and induces apoptosis and oxidative stress in the American oyster, Crassostrea virginica: molecular mechanisms and signaling pathways

Global climate change is predicted to intensify thermal stress in marine and coastal organisms, affecting their development, growth, and reproductive functions. In this study, we examined the effects of short-term exposure to elevated temperatures (28 and 32°C for 1-week) on gonadal functions, heat shock protein-70 (HSP70), dinitrophenyl protein (DNP, a biomarker of reactive oxygen species, ROS) and nitrotyrosine protein (NTP, an indicator of reactive nitrogen species, RNS) expressions, protein carbonyl (PC, a measure of ROS) contents, nitrates/nitrites (NOx, a metabolite of nitic oxide), extrapallial fluid (EPF, an important body fluid) conditions, and cellular apoptosis in American oyster (*Crassostrea virginica*, an important marine species). Oysters exposed to higher temperatures significantly decreased the number and diameter of eggs and sperm production, and EPF protein concentrations compared with controls (24°C). In contrast, EPF pH, gonadal HSP70 protein expression were increased after heat exposure, consistent with increased gonadal apoptosis. The enhanced apoptosis in gonads were associated with increased gonadal caspase-3/7activity, PC contents, NOx levels, and NTP and DNP expressions in heat-exposed oysters. Collectively, these results suggest that higher temperatures drastically increase RNS and ROS levels, increasing incidence of apoptosis and subsequently reducing gonadal functions in oysters. To the best of our knowledge, this study reports the first findings on the impacts of elevated temperatures on gonadal functions in oysters.

P2-113 NAUGHTON, LF*; CANNIZZARO, DN; PASK, GM; Bucknell University; *Lfn001@bucknell.edu*

One Big, Smelly Family: Decoding the Olfactory Receptors in the Indian Jumping Ant

Eusocial insects exhibit complex social hierarchies in their colonies, and in order to achieve this high level of coordination, there must be an effective communication system. Insect olfactory receptors (ORs) in the antenna are able to distinguish between a vast array of odorants, and the detection of these minute chemical cues drives insect communication. The Indian jumping ant, *Harpegnathos saltator*, serves as an optimal model for studying social olfaction due to the complexity of behaviors associated with its primitively eusocial caste system. Previous studies have focused on decoding the rapidly evolving 9-exon subfamily of OR genes, but two-thirds of the entire family, which contains genes that are highly conserved across ant species, remains relatively unexplored. This research aims to characterize the pheromonal sensitivity of a selection of highly expressed *H. saltator* OR genes from across this expansive receptor family. In order to determine the response profile of an individual OR gene, we can genetically manipulate the fruit fly genome to express genes of interest and perform electrophysiological techniques to measure neuronal activity in response to various pheromones. This research displays the impressive discriminatory power of insect ORs in the presence of a myriad of chemical stimuli needed for complex communication. In addition, the breadth of stimuli and responses demonstrated in this study contributes to our understanding of the combinatorial code used in the ant olfactory system. These findings can be applied to the future study of social insects with topics including whether certain OR genes are conserved across other species of ants, and whether there exists an olfactory signature along the evolutionary path to complex eusociality.

95-8 NAVARA, KJ*; WROBEL, ER; BENTZ, AB; LORENZ, WW; GARDNER, S; MENDONçA, MT; The University of Georgia, Indiana University, Bloomington, Auburn University; *knavara@gmail.com*

Corticosterone treatment influences expression of gene pathways linked to meiotic segregation in preovulatory follicles of the domestic hen

Decades of work indicate that female birds can control their offspring sex ratios in response to surrounding cues. In laying hens, hormones administered immediately prior to sex chromosome segregation can exert sex ratio skews, indicating that these hormones may act directly on the germinal disc to influence which sex chromosome is retained in the oocyte and which is discarded into an unfertilizable polar body. We aimed to uncover the gene pathways involved in this process by testing whether treatments with testosterone or corticosterone that are known influence sex ratios elicit changes in the expression of genes and/or gene pathways involved in the process of meiotic segregation. We injected laying hens with testosterone, corticosterone, or control oil 5h prior to ovulation and collected germinal discs from the F1 preovulatory follicle in each hen 1.5h after injection. We used RNA-sequencing followed by DESeq2 and gene set enrichment analyses to identify genes and gene pathways that were differentially expressed between germinal discs of control and hormone-treated hens. Corticosterone treatment triggered downregulation of 13 individual genes, enrichment of gene sets related to meiotic spindle organization and chromosome segregation, and additional gene sets that function in ion transport. Testosterone triggered upregulation of one gene, and enrichment of one gene set that functions in nuclear chromosome segregation. This indicates that corticosterone can be a potent regulator of meiotic processes and provides potential gene targets on which corticosterone and/or testosterone may act to influence offspring sex ratios in birds.

P2-60 NAVARA, KJ*; GRADEN, K; MENDONçA, MT; The University of Georgia, Auburn University; *knavara@uga.edu*

More is not always better: Yolk supplementation decreases rate of yolk deposition in Japanese quail, Coturnix japonica

Reproduction comes with a high cost and, for female birds, the production of eggs represents one of the most costly reproductive steps. Generation of egg yolk requires the synthesis and deposition of large amounts of protein and lipid, and is often accompanied by incorporation of additional physiological mediators. While there has been much work examining the relative quantities of yolk components, as well as potential adaptive patterns of their allocation, we still do not have a full understanding of what controls yolk formation and composition. Once ovarian follicles are recruited into the preovulatory hierarchy, yolk is deposited in concentric rings, with one ring deposited per day. Previous studies have shown that there is substantial interspecific and intraspecific variation in the number of rings in yolks, and thus the number of days it took those yolks to grow. We hypothesized that the ability to grow follicles to maturity quickly is limited by the availability of materials to make yolk precursors in the female, either in body reserves or dietary access. To test this, we supplemented the diets of Japanese quail with hard-boiled chicken yolk, and examined the influences of treatment and female body condition on follicle growth rates. Contrary to predictions, females with higher body condition indices produced yolks that grew more slowly, and yolks from supplemented birds grew more slowly than controls. These results indicate that females can modulate the rate of yolk incorporation into developing follicles, and that an energy balance that is too high may not be optimal.

9-6 NAVE, GK*; TALLACKSON, H; PELEG, O; University of Colorado, Boulder; *Gary.Nave@colorado.edu*

The Formation of Honey Bee Swarms

When a European honey bee (*Apis mellifera*) colony outgrows its nest, the colony divides in two, sending a queen and about half the workers in search of a new home. To survive this transition, the outbound group will find a tree branch or other surface and hang together in a swarm while scouts search and decide on a permanent nest location. While this decision-making process of swarms has been well studied, the mechanical aspects of the formation of the swarm on its anchoring surface have not previously been studied. In this work, we will present both experimental and computational work on the formation of honey bee swarms to address the question: How do honey bees decide where to attach to a growing honey bee swarm? To gain insight into this question, we conduct experimental observations of swarm formation and replicate the observed behavior through computational modeling. With the queen confined to a cage, we induce the bees into a swarm under a horizontal surface and allow the bees to locate a new nest site and leave. Because the queen does not travel with them, we record the re-formation of the swarm as the bees return to her. Then, we use agent-based modeling techniques to model swarm formation as an aggregation problem, modeling the decision-making process of where bees join the swarm as it grows. With these modeling techniques, we are able to test various rules for swarm formation and assess their accuracy in reproducing our experimental results. A better understanding of the mechanics and behavior of honey bee swarms will allow for better design of, for example, self-assembling multi-agent robotic systems.

73-2 NAVON, D*; ROGERS, SM; HIGHAM, TE; University of California Riverside, University of Calgary; *dina.navon.3@gmail.com*

Behavioral Variation in Feeding Strikes across Five Populations of Threespine Stickleback (Gasterosteus aculeatus)

Investigating the mechanisms by which natural populations diverge to exploit new ecological resources remains of critical interest to evolutionary biologists. Evolutionary changes in behavior may be integral in initiating adaptive shifts, yet little is known about the microevolutionary changes in behavior that follow the invasion of new habitats. Threespine stickleback offer a unique opportunity to study microevolutionary variation in behavior and biomechanics due to their rapid, repeated invasion of freshwater habitats from a marine ancestor. Here we examine trophic and locomotor kinematics across five populations of threespine stickleback (4 freshwater and 1 marine). We further characterize their responses to both evasive and non-evasive prey, asking whether these populations exhibit significant behavioral plasticity in response to different prey types. We additionally ask whether these kinematics are integrated, and whether patterns of integration are similar among populations. Finally, we examine these traits in lab-raised fish from each population. We ask how these behaviors develop over time in fish as young as 9 days post fertilization through juvenile stages, and whether development differs among populations. Ultimately, we plan to connect this variation in biomechanics and integration to the underlying genetic architecture by performing a series of genetic mapping crosses between our marine and freshwater populations. This work will add to a growing body of literature investigating the genetic basis of behavioral variation, and will serve as a first step to understanding how biomechanical variation and plasticity evolve in a well-known adaptive radiation.

78-7 NAYLOR, ER*; HIGHAM, TE; University of California, Riverside; *emily.naylor@email.ucr.edu*
Toes for any occasion: morphological covariation and ecological signal within the gecko attachment system
Within geckos, elaborately integrated toe pads holding highly branched setae confer dynamic attachment on a variety of substrates. While frictional adhesion is considered key to diversification, penetrating and interlocking claws are ancestral and nearly ubiquitous features within lizards. Geckos exhibit multiple attachment character states through claw and pad loss that may reflect different selective regimes, such as a mixed substrate environment favoring the presence of both features. Recent experiments have only scratched the surface of the pad-claw functional interplay but do show texture-dependence (e.g., claws dominant on rough substrate). That geckos also display multiple pad types and degrees of claw reduction calls for a more holistic approach to understand their association and evolutionary significance. How do these features covary, and does phylogeny and/or habitat use drive these patterns? We dissected and imaged the fourth pedal digit of specimens within Gekkonoidea, from which we scored and measured aspects of the pad and claw. After size and phylogenetic correction, we saw little correlation between trait measurements, but PGLS models indicated that pad type predicted some variables, such as more strongly curved claws in leaf-padded species. PhyANOVAs revealed smaller pads in generalist and terrestrial species relative to scansorialists and longer setae in saxicolous geckos. Smaller pads have been noted in more terrestrial anoles and thus may reflect reduced functional demands, but the relationship between setal length and actual performance has yet to be resolved in padded lizards. This project provides important evolutionary and ecological insights into gecko autopodial diversity and perspective for the evolution of complex functional systems.

P3-115 NAZAR, S*; DEAROLF, JL; THOMETZ, NM; BRYAN, A; REICHMUTH, C; Hendrix College, Conway, AR, Univ. of San Francisco, CA, Alaska Department of Fish and Game, Fairbanks, Univ. of California, Santa Cruz; *nazarss@hendrix.edu*
Fiber-type profile of the locomotor muscle of spotted seals
Spotted seals (*Phoca largha*) can forage in the water column for 1 to 4 minutes and dive to a depth of 4 to 50 meters. Sea ice plays a significant role in the lives of spotted seals, as they depend heavily on it for reproduction and even molting. Climate change and global warming are two of the biggest environmental concerns for spotted seals, as they both directly affect the formation and melting of seasonal sea ice, the habitat for these seals. In order to develop new conservation strategies for spotted seals and to learn more about how climate change is affecting them, it is important to study their unique anatomy and physiology. In this study, we examine the fiber-type profile of a locomotor muscle of spotted seals, the longissimus dorsi (LD). We cut sections of ten spotted seal LD muscles in the cryostat and put them on microscopic slides. We then stained these sections of the LD muscles for their myosin ATPase activities, as well as their reaction to two myosin heavy chain antibodies (A4951-slow, type I myosin, SC71-fast, type IIa myosin). We also captured digital images of the stained slides, categorized fibers based on their dark and light staining, and counted them.. We also measured the diameters of the fibers using ImageJ. The fiber-type profile and fiber diameters of the LD muscle will be compared to those of two other Arctic seals to examine patterns in these features. Therefore, studying the fiber-type profile of the LD will enable us to learn more about the swimming and diving behavior of spotted seals.

P1-4 NEAL, S*; DALY, CMS; KOENIG, KM; Harvard University; *sneal@fas.harvard.edu*
Differentiation and Notch signaling in the Cephalopod Retina
Squid, octopus and cuttlefish have a large and highly complex nervous system that supports a diversity of sophisticated behaviors. The complexity of the cephalopod nervous system evolved independently in molluscs and little is known about its ontogeny. The visual system is an excellent entry into the study of complex nervous systems, and to address fundamental questions in nervous system evolution and development we have established the squid *Doryteuthis pealeii* as a model for cephalopod visual system development. The cephalopod eye is a camera-type eye with a cup shaped retina and a single lens. The cephalopod retina has two morphologically identified cell-types organized into two distinct layers, the photoreceptor cells and the support cells. The cephalopod photoreceptors synapse directly on the optic lobe where signal processing takes place. Previous work showed that the cephalopod retina develops as a pseudostratified neuroepithelium and the photoreceptor cells exit the cell cycle when they differentiate. Cells found in the support cell layer are the only cells that continue to incorporate BrdU after hatching. Our previous work showed that Notch signaling is essential for proper neurogenesis in the retina and that losing Notch signaling leads to premature cell cycle exit. In an effort to better understand neurodifferentiation and organ physiology, we have generated a library of probes for *in situ* hybridization of genes expressed in the eye at hatching. Our goal is to use this "eye atlas" to better assess neurogenic phenotypes. In addition, we have performed an RNA-seq experiment on Notch inhibited and control retinas. We are using this sequencing data and our new cell type markers to better understand the role of Notch signaling during neurogenesis and how these processes contribute to the complexity of the cephalopod visual system.

P1-239 NEBHUT, AN*; SEMRO, MR; SHINKLE, JR; Trinity University, San Antonio, TX; *anebhut@trinity.edu*
The Relevance of Short Wavelength UV-B Radiation in Natural Light Environments
Plants have mechanisms to sense ultraviolet radiation as both a stressor and developmental signal 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 pigment production. UV-B varies seasonally and is absorbed by ozone and therefore varies with altitude and proximity to urban centers, meaning that plants grown in these microclimates may display different UV-stress characteristics. The effect of seasonality and microclimate on plant responses to UV-B radiation was studied at three field sites of varying proximity to urban centers. At each field site, greenhouse-grown native Texas grasses (*Bouteloua curtipendula* and *Chasmanthium latifolium*) were placed for fourteen days under two filters, one which was UV transparent and one which blocked almost all energy at wavelengths shorter than 300 nm. The effects of high energy UV-B radiation on plant function were characterized with UV absorbance spectra taken from leaf pigment extracts, reflectance spectra obtained from whole leaves, and leaf flavonoid content. The location of the grasses had a small and directionally inconsistent effect on each of the characteristics of UV stress, whereas seasonality had a large and consistent impact on the grasses' UV stress responses. As expected, the grasses began with a moderate UV-stress responses, which grew to their peak at the summer solstice before gradually returning to its initial level. Together, these results emphasize plants' ability to sense and respond to minute changes in their light environment.

45-2 NEFF, BD; Western University, London, ON; *bryandneff@gmail.com*

Hormones and Behavior in Sunfish: Celebrating 17 years of Collaboration with Rosemary Knapp

A longstanding focus of my research has been to bridge levels of analysis from mechanism to adaptation. One of the first avenues in this pursuit was to understand the role of androgens in mating and parental care behavior in bluegill sunfish. This interest began when I met Rosemary Knapp in 2002, at the EEEF conference, and our collaboration began. Some of our first work together revealed that circulating androgen levels in parental male bluegill show a consistent pattern during breeding bouts: starting highest when males were mating with females, declining while the males were providing parental care, and then increasing again as parental care came to an end. To understand this pattern, we first examined the value of high androgen levels during mating, and found that males with high levels sired a greater proportion of the offspring in their nest, thereby increasing their fitness. Next, we experimentally manipulated androgen levels during parental care and showed that high androgen levels reduced males' nurturing behavior toward the offspring, providing a potential adaptive explanation for the drop in androgen levels during parental care. Our work, which was sadly cut short, was beginning to examine the interplay between androgens and prolactin, as well as identifying specific genes that underlie parental and mating behavior and their fitness consequences.

77-3 NEGRETE JR, B*; ACKERLY, KL; ESBAUGH, AJ; The University of Texas at Austin Marine Science Institute; *bnegrete@utexas.edu*

The effect of hypoxia induced hemoglobin switching on aerobic performance in red drum, Sciaenops ocellatus

The Gulf of Mexico experiences one of the largest seasonal hypoxic zones in the world, exposing endemic fish to chronically O_2-limited waters. Previous work on red drum – a resident of the coastal waters of the Gulf of Mexico – has demonstrated they can dynamically regulate specific hemoglobin subunits in response to chronic hypoxia exposure, which result in lower blood oxygen binding affinity and a reduced whole animal critical oxygen threshold. Here, we will build upon this prior work by exploring the time course of red blood cell plasticity, and assess the impacts on maximum metabolic rate. Fish were acclimated to 30% air saturation for 1, 4, 8, 14, or 42 days, and red blood cells were collected for gene expression and biochemical profiling. Relative hemoglobin isoform abundance was assessed using real-time PCR and thin-layer isoelectric focusing. Additionally, hematocrit (red blood cell concentration) and NTP concentration were measured. Hb patterns showed up-regulation in Hbα 2 by 50-fold relative to control in response to hypoxia starting at 4 days. Hematocrit showed a difference in treatment at 8-days, with no change over other time points between treatments. Red drum do not show changes in [NTP] in hypoxia, suggesting they regulate Hb-O_2affinity through other changes in the red blood cell such as hematocrit and Hb. Thus, the effects of the observed red blood cell plasticity on whole animal performance were tested by assessing maximum metabolic rate of hypoxia and normoxia acclimated individuals at 50% oxygen saturation for at least 8-days.

133-6 NEUROHR, JM*; KINSEY, ST; University of North Carolina Wilmington; *jmn6284@uncw.edu*

The Impact of Tissue Aerobic Capacity and Life Stage on Oxidative Damage and Protein Turnover in Skeletal Muscle of the Blue Crab, Callinectes sapidus

Reactive oxygen species (ROS) are produced largely by mitochondria in skeletal muscle as a natural by-product of aerobic metabolism and have the potential to elicit oxidative stress. The blue crab, *Callinectes sapidus*, is a high-performance swimming crab, with an ability to undergo anaerobic burst swimming during predator-prey interactions, as well as aerobic endurance swimming during extended daily or seasonal migrations. The locomotor muscles that power these two types of swimming represent extreme ends of the aerobic spectrum. The aerobic (dark) muscles that power endurance swimming have a mitochondrial volume density (MVD) that is *25 times higher* than the anaerobic (light) fibers that power burst swimming. We tested the hypothesis in juvenile and adult crabs that the much higher MVD in dark muscle leads to oxidative damage that may necessitate greater rates of turnover of intracellular components. Juveniles had greater protein carbonylation in both dark and light muscle, and greater lipid peroxidation in dark muscle than in adults. There was no difference in oxidative stress markers between muscle types. Surprisingly, relative protein translation rates were not different between muscle types, and dark muscle in juveniles had a lower translation rate than in adults. Ubiquitin was greater in light muscle of juveniles than in adults while calpain was not different between life stages. Calpain was significantly greater in light relative to dark muscle in adults. These results indicate that the extreme difference in MVD between muscle types does not lead to a proportional difference in oxidative stress or protein turnover, suggesting mechanisms exist to limit net ROS production in dark muscle.

124-6 NEWBREY, JL*; LOVE, Q; NEWBREY, MG; Department of Biology, Columbus State University, Columbus, GA; *newbrey_jennifer@columbusstate.edu*

Differences in Yolk Carotenoid Concentrations of Three Songbird Species Breeding in Nest Boxes in Georgia, USA

We identified and compared yolk carotenoids from the eggs of three species of secondary-cavity-nesting songbirds in west-central Georgia, the Tufted Titmouse (*Baeolophus bicolor*), Brown-headed Nuthatch (*Sitta pusilla*), and Carolina Wren (*Thryothorus ludovicianus*). Carotenoids are biologically-active pigments that act as powerful antioxidants and immunostimulants for both developing embryos and adult birds. Female birds allocate high concentrations of carotenoids to their egg yolks, where the pigments protect developing embryos against damage to lipids, proteins, and DNA. Despite this critical role that yolk carotenoids play in avian reproduction, surprisingly little research has focused on North American songbirds. Therefore, the third-laid egg was collected from 16 nuthatch nests, 7 titmouse nests, and 23 wren nests, for a total of 46 eggs. Yolk carotenoids were extracted and quantified using high performance liquid chromatography. We identified three dietary carotenoids in the eggs of the study species, β-carotene, lutein, and zeaxanthin. Yolk concentrations of β-carotene did not vary across the species, but wrens had the highest concentrations of lutein and total carotenoids, and nuthatches had the lowest concentrations of zeaxanthin. The differences we found in yolk carotenoid concentrations in the three study species are likely linked to differences in diet. Brown-headed Nuthatches consume more seeds than the other two species during egg formation, whereas Tufted Titmice and Carolina Wrens consume more invertebrates. However, further research on dietary sources of carotenoids for these three species is needed to better understand the yolk carotenoid concentration differences we observed.

P1-209 NEWBREY, MG*; WOOLFOLK, FR; MARTíN-ABAD, H; MAISEY, JG; Department of Biology, Columbus State University, Columbus, GA, Universidad Autónoma de Madrid, Madrid, Spain, Paleontology Department, American Museum of Natural History, New York, NY; *newbrey_michael@columbusstate.edu*

Chronological ages of the coelacanths Latimeria chalumnae and Axelrodichthys araripensis by comparing ages from scales and bones

Coelacanth age and growth has been argued for the last 22 years and there are only two published papers on their age and growth. Previously published literature suggests longevities of 20 years old or 40 years old based on ages from scales; an examination of their data suggests very irregular growth. A more recent hypothesis suggests a 100-year lifespan from a 21-year *in situ* study where larger individuals had little to no observable growth. Previous studies also suggest 3 years gestation period based on examination of embryos found in a *Latimeria chalumnae* female. The largest known individuals of *L. chalumnae* grow to 1.8 m TL. Our objective is to determine the number of years it takes to attain maximum size. Previous studies have failed to describe growth cessation marks adequately and there were no other structures to compare assigned ages. We used new criteria to identify growth cessation marks on scales of extant (*Latimeria chalumnae*) and extinct (*Axelrodichthys araripensis*) individuals. New age assignments for *L. chalumnae* resulted in higher individual ages than previously noted in the literature. We also compared chronological ages of scales and bones in *A. araripensis* and found that they agree. Our age assignments suggest a lifespan that exceeds 40 years, and we do not refute the 100 year lifespan hypothesis. The results suggest that coelacanths grow much more slowly than previously reported. This study provides new numerical data that supports the idea of low metabolic rate and slow growth in coelacanths.

17-7 NEWCOMB, JM*; GINGRAS, MA; NELSON, SN; MCGHEE, CB; EASTER, JH; GOODHEART, JA; RAMIREZ, MD; New England College, University of California, Santa Barbara, University of Massachusetts, Amherst; *jnewcomb@nec.edu*

Nudibranch opsins: identification, localization and potential roles in extraocular photoreception and circadian rhythms

R-type (rhabdomeric) opsins are common light-sensitive proteins in invertebrate eyes. R-opsins have been identified in the eyes, brain and skin of numerous molluscs, but not in nudibranchs, which was the goal of this study. We focused on *Berghia stephanieae*, *Hermissenda opalescens* and *Melibe leonina*, the latter two of which have publicly available transcriptomes. From these, we identified multiple types of opsins in both species. Using these sequences, we developed RNA probes for fluorescent *in situ* hybridization (FISH) and found r-opsin mRNA expression in all dermal tissues that we examined. Immunohistochemistry with antibodies to octopus r-opsin corroborated the FISH results and also indicated a similar localization in dermal tissues of *Berghia*. In behavioral experiments to test for extraocular photoreception, *Berghia* and *Melibe* both responded to extraocular stimulation using both white and red light, but not infrared wavelengths. R-opsins were not detected in the brains of *Berghia* and *Hermissenda*, but were expressed in a small number of neurons in the brain of *Melibe* in a similar location to previously identified circadian clock neurons. Double-label FISH experiments confirmed the colocalization of r-opsin with core clock transcripts in the brain. Additional experiments extended this colocalization to dermal tissues. Together, these data suggest that r-opsins are prevalent in dermal tissues of nudibranchs and may play a role in both extraocular photoreception and direct input to central and peripheral circadian clocks.

124-2 NGUYEN, H; HOANG, T; HAWKINS, D; DRECHSLER, J; NILSSON, P; STEINER, B; PERNET, B*; California State University Long Beach; *bruno.pernet@csulb.edu*

Are larvae of the sand dollar Dendraster excentricus food-limited in nearshore waters of southern California?

The feeding larvae of marine invertebrates may often be food-limited in rates of growth and development, a result with important implications for larval ecology and evolution. The generality of this result is uncertain, however, as studies addressing larval food limitation are few, and conflicting results have been reported. We tested for food limitation in larvae of the sand dollar *Dendraster excentricus* in nearshore waters of southern California in six experiments from 2017-19. In each experiment we compared the form and development rates of larvae reared in natural seawater (NS) to those of larvae reared in natural seawater supplemented with *Rhodomonas lens* (NS+); as a control, we also reared larvae in natural seawater diluted 1:1 with filtered seawater (NS-). During our experiments, chlorophyll a levels in NS treatments were fairly high, ranging from 1.48-4.57 $\mu g\ L^{-1}$. Despite this, compared to NS+ larvae, larvae reared in NS consistently had slightly higher postoral arm/midline body length ratios, indicative of a phenotypically plastic response to low food levels, and slightly greater time to 50% metamorphic competence, suggesting subtle food limitation. Larvae reared in NS- were very clearly food-limited: they always had much higher postoral arm/midline body length ratios and much greater time to 50% competence than did larvae in the other two treatments. Our results suggest that even in habitats with relatively high standing stocks of chlorophyll a, larvae may routinely experience food limitation.

75-1 NGUYEN, KD*; VENKADESAN, M; Yale University; *khoi.nguyen@yale.edu*

Construction and Deconstruction of Muscle Work Loops

Muscles are actuators that exert forces to influence animal movement, but are also active, soft materials that exert forces in response to external perturbations. Rheology, the study of deformation of matter, uses sinusoidal perturbations as an important tool in the study of soft matter, and muscle work loops are a generalization of that tool. Although work loops are often quantified in terms of net work performed by the muscle, the complete shape of a work loop is an important part of a muscle's effects on animal movement. Muscle rheology varies with both the neural excitation and the external perturbation it receives; the rheology of interest is thus the entire set of possible loop shapes assumed by a muscle across its physiologically relevant excitation patterns and perturbations. We address here the question of classifying loop shapes so as to compare loops measured across different experimental conditions. We present a work loop construction for muscles with a time-varying excitation using ellipses formed from loss/storage moduli as an illustrative example. Each ellipse corresponds to a constant excitation level, and the construction splices together multiple ellipses to form the muscle's work loop for a time-varying excitation. This motivates a deconstruction of measured loops, if the excitation pattern is known, into ratios of work contributions by elastic, viscous, and ideal forces. All possible loop shapes for muscles undergoing small sinusoidal perturbations are categorized by these ratios. The details differ for other perturbations or if the muscle's rheology is nonlinear, but the viewpoint of muscle work loops obtained under time-varying excitation as spliced basis loops obtained under constant excitation adds a systematic interpretation of loop shapes and muscle rheology.

43-8 NICHOLSON, DJ*; LOGAN, ML; COX, CL; MCMILLAN, WO; GARNER, TWJ; KNELL, RJ; Queen Mary University London, University of Nevada, Reno, Florida International University, Smithsonian Tropical Research Institution, Zoological Society of London; *danielnicholson49@gmail.com*

Population dynamics and morphological change after experimental colonization of a novel environment.

Anthropogenic actions are rapidly redistributing species and allowing novel colonization events. With this colonization comes exposure to new habitats and environments. Rapid changes in the environment can cause a populations mean phenotype to become mismatched with local fitness optima or limit a population's adaptive potential. This mismatch in phenotype can drive directional selection, and while this may lead to higher mean population fitness it also leads to high mortality, affecting population dynamics. Using an experimental island system, we investigated the initial stages of colonization and some of the underlying adaptive mechanisms linked with persistence in a novel environment over three generations in the Panamanian anole (*Anolis apletophallus*). We transplanted hundreds of uniquely-marked adult lizards from a single source population on mainland Panama to four small islands in Lake Gatun (Panama Canal). These islands differ in habitat structure from the mainland. We conducted mark-recapture surveys to assess changes in habitat use, morphology, and population size over three years. After only a single generation, we observed several morphological changes, including a reduction in both head and toe pad size and an increase in limb length across all islands. Several of these changes correspond with changes in habitat use in ways predicted by biomechanical theory. We discuss these results in the context of contemporary evolution and eco-evolutionary dynamics, and what role these factors play in the success of populations that colonize novel environments.

10-5 NIX, RM*; THUESON, K; RABINOWITZ, S; HAVIRD, JC; Baylor University, University of Texas at Austin; *rachel_nix1@baylor.edu*

How do mitochondrial genes with high mutation rates remain functional?

While mitochondrial (mt) genes in bilaterian animals have high mutation rates, mt genomes in most angiosperms evolve slowly. However, in the angiosperm genus *Silene*, some species show mammalian-like ("fast") patterns while closely related species show more typical "slow" rates. This allows us to investigate whether mt function is maintained in "fast" lineages via either: 1) nuclear mutations that compensate for rapidly accumulating, possibly deleterious mt mutations or 2) through strong purifying selection on mt mutations. In this experiment, we compare mt respiration in "fast" species to "slow" species to determine the effect of the many nonsynonymous mt changes that have accumulated in "fast" species. Mt respiration was measured from isolated leaf mitochondria using a new protocol for the Oroboros O2k system. Flux control factors for seven unique respiratory states were calculated to examine the contribution of specific OXPHOS enzymes to respiration (e.g., CI vs. CII). Preliminary results indicate few significant differences in mt function between "fast" and "slow" species. To determine if complementary nuclear changes are responsible for maintaining mt function, respiration was quantified in F2 paternal backcrossed hybrids between two "fast" species, intended to moderately breakup coadapted mitonuclear genotypes. Although germination rates were low in the F2 plants, mt respiration was generally similar to the parental species, with chimeric OXPHOS complexes showing the same or even elevated flux in the hybrids. Together, these results suggest mt purifying selection may be the dominant evolutionary force acting to maintain mt function in "fast" *Silene*. However, nuclear compensation could still play a role. Future research should explore other fast-evolving angiosperm lineages.

75-6 NOEL, A*; NADLER, J; Georgia Tech Research Institute; *alexis.noel@gtri.gatech.edu*

Mimicking the load-holding capabilities of muscle using electrostatic layer jamming

Biological muscles have the ability to quickly stiffen and hold large loads, two highly coveted traits for soft robotic actuators. Various techniques have been used to replicate the load-holding capability of muscle, from shape memory alloys to pneumatics to cable tension-based systems. When considering wearable technology applications, these techniques often fall short in either responsiveness or load limitations. Layer and granular jamming techniques can allow entirely soft robotic systems to conform and stiffen to environments, much like the soft and highly deformable bodies of various invertebrates. Layer jamming involves many sheaths of a thin material being compressed (commonly by vacuum), increasing the frictional resistance between the sheaths and stiffening the material. Layer jamming was recently used for stiffening a sheath for a snake-like continuum robot, with a focus on surgical robotics. In this experimental study, we investigate, develop, and demonstrate a new mechanism where layered sheaths are quickly stiffened through electrostatic pressure. Using layers of conductive and dielectric material, we vary the friction between the moving surfaces by varying applied voltage, thereby having the ability to quickly control bending stiffness, elongation, and other mechanical properties. The results of this project may provide unique force-feedback solutions for areas such as haptic feedback in virtual reality, or provide realistic muscle stiffening for bio-inspired robotics.

10-8 NORDéN, KK*; ELIASON, CM; STODDARD, MC; Princeton University, Princeton, NJ, Field Museum of Natural History, Chicago, IL; *knorden@princeton.edu*

Do diverse feather nanostructures increase the colorfulness of iridescent plumage?

Iridescent bird coloration produces some of the most spectacular color displays in the natural world, yet much of how these colors evolve remains enigmatic. Birds often produce iridescence in their feathers by layering pigment-filled organelles (melanosomes) and keratin in the feather filaments, effectively creating a photonic crystal that reflects only certain colors of light. Typically, melanosomes are solid and cylindrical, but in some iridescent species novel types of melanosomes have evolved, including hollow (air-filled) and flattened morphologies. These derived morphologies have evolved independently multiple times in birds, and likely affect color production. Yet, the interplay between nanostructural diversity and color diversity has never been tested on a large scale. Here, we test the hypothesis that novel melanosome morphologies allow birds to produce a greater diversity of colors. We collected spectral data on 72 iridescent bird species spanning 11 orders and encompassing all types of melanosome morphologies. We combined these empirical data with an optical modelling approach to estimate what colors could theoretically be produced with each morphology, varying a range of optically important parameters. Our results show that birds with derived melanosome morphologies tend to produce brighter and more saturated colors than birds with solid cylindrical melanosomes, which results in a greater possible color diversity. The main evolutionary forces driving the repeated evolution of derived melanosome morphologies might therefore be related to a paired brightness and saturation advantage, compared to the ancestral form.

P1-107 NOTAR, JC*; JOHNSEN, S; Duke University; *julia.notar@duke.edu*
Trends in Spatial Acuity Across the Sea Urchins
Sea urchins lack eyes, yet several species have been shown to have spatial vision via behavioral assay. It has been suggested that their spatial acuity is determined by the density of spines across the body. The spines determine the angle of acceptance of light on an area of their skin, which is generally photosensitive. By combining signals from many areas, the animal may therefore function analogous to a large compound eye. In all published studies to date the acuities predicted by spine density and determined by behavioral assay are similar. In visual ecology, it has been suggested that an animal's visual abilities, including acuity, should match its environmental needs. However, in sea urchins, which lack discrete visual structures (eyes/eye spots), this assumption may not hold. Sea urchins inhabit nearly all marine habitats worldwide, from the intertidal to the deep sea and from the equator to the poles. They are therefore an excellent group in which to examine traits that are suggested to vary by ecology and habitat. If acuity matches environmental needs, we may expect spatial acuity to be high in well-lit habitats with high spatial complexity and low in dim and low spatial-complexity habitats. We performed an extensive survey of species from all 24 extant families of sea urchins (Class Echinoidea). For each species, acuity based on spine density was estimated from photographs from The Echinoid Directory (Natural History Museum, London) and mapped against a published phylogeny and habitat data (including depth range and substrate type). Only species for whom reliable habitat data and high quality photos were available were included. We were therefore able to analyze whether phylogenetic or environmental factors are more likely to constrain the trait (spine density) that most likely determines visual acuity in sea urchins. Results will be discussed.

P2-140 NOURBAKHSH_REY, M*; MARKHAM, MR; The University of Oklahoma; *mrey@ou.edu*
Metabolism Sensing Mechanisms in the Electric Organ Cells of a Weakly Electric Fish
Weakly electric fish use electric organ discharges (EODs) produced by the coordinated action potentials of electric organ cells (electrocytes) to communicate and sense their environments. EOD production in *Eigenmannia virescens* incurs significant metabolic costs. During food restriction, these fish reduce EOD amplitude (EODa) to reduce metabolic costs, an effect mediated by leptin, a peptide hormone with multiple central and peripheral roles in energy homeostasis. We hypothesized that, in addition to central effects, leptin regulates EODa in *E. virescens* by directly regulating electrocytes. We found that electrocytes express a leptin receptor (LepR), supporting this hypothesis. Electrocytes also express ATP-sensitive K^+ channels (K_{ATP}) that in many cell types are targeted by LepRs to couple electrical excitability to metabolic status. We therefore hypothesized that electrocyte LepRs would localize with K_{ATP} channels on the electrocyte's anterior membrane. We expressed a red fluorescence-tagged LepR gene in electrocytes and found that LepRs are primarily expressed on the posterior membrane of electrocytes where voltage-gated Na^+ channels (Na_v) and acetylcholine receptors (AchRs) are located, but more than 1 mm away from the electrocyte's anterior membrane K_{ATP} channels. These findings suggest that leptin is instead modulating electrocyte function by targeting Na_v channels and/or AchRs to modulate their activity and/or membrane expression levels. We also investigated central hormonal networks that might interact with leptin to regulate EODa. Ghrelin hormones play important roles in energy homeostasis and are known to be regulated in part by leptin. In vivo injections of ghrelin increased EODa, suggesting that ghrelin is part of a central endocrine network that regulates EODa.

117-4 NOWICKI, S*; CAVES, EM; SCHWEIKERT, LE; GREEN, PA; TABOADA, C; ZIPPLE, MN; PETERS, S; JOHNSEN, S; Duke University, Durham, NC, University of Exeter, United Kingdom, Florida International University, Miami; *snowicki@duke.edu*
Carotenoid Concentration in Avian Retinal Oil Droplets Correlates with Color Discrimination Across a Perceptual Category Boundary
The ability to discriminate between colors is important across taxa and behavioral contexts. In birds, color discrimination is thought to be enhanced by carotenoid-containing oil droplets found inside photoreceptors. We asked whether variation in the ability of female zebra finches (*Taeniopygia guttata*) to discriminate colors along an orange-red color continuum corresponds to variation in the carotenoid concentration of retinal oil droplets. This color continuum parallels variation in male beak color, a mate assessment signal, and is perceived by both female and male zebra finches in a categorical fashion. We behaviorally tested color discrimination and then used microspectrophotometry to measure cone oil droplet absorbance, a proxy for carotenoid concentration. We found that underlying variation in oil droplet carotenoids corresponds to variation in behaviorally measured color discrimination ability. Oil droplet carotenoid concentration did not affect discrimination ability across the entire orange-red range equally, however. Rather, higher carotenoid concentration was associated only with increased discrimination of colors from different sides of the previously identified color category boundary. These data show that differences in sensory physiology can correlate with individual variation in perception of a signal-relevant color range.

27-2 NUNEZ, SA*; SANGER, TJ; Loyola University Chicago; *snunez3@luc.edu*
The Physiological Basis of Structural Malformations in Thermally Stressed Lizard Embryos
Global warming is driving species beyond their thermal physiological limit. Oviparous species, such as reptiles, may be negatively impacted by climate change as their eggs will be laid and incubated at progressively higher temperatures. *Anolis* lizards subjected to thermal stress during early embryonic development experience decreased survival and increased rates of craniofacial malformation, yet the mechanisms driving these patterns remain unknown. It has been suggested that oxygen restriction sets the thermal range of embryonic development (i.e., oxygen limitation hypothesis). We hypothesized that hypoxic conditions would lower the thermal threshold of *Anolis* embryos while hyperoxic conditions would buffer the effects of thermal stress. We discovered that embryos developing under hypoxia at sublethal temperatures produced craniofacial malformations similar to thermally stressed anole embryos. In contrast, embryos developing under hyperoxic conditions and typically lethal temperatures developed normally. To clarify the potential role of oxidative stress, we measured the activity of the antioxidant enzyme superoxide dismutase (SOD) in anole embryos incubated at varying temperatures. Initial trials show that increased temperature leads to increased SOD activity in the developing head and brain. Additionally, preliminary results indicate a hypoxia marker, Hypoxia inducible factor 1-alpha, is present in the developing brain of thermally stressed anole embryos. Our results suggest that oxygen limitation and oxidative stress may explain how structural malformations arise during embryonic thermal stress, and why survival is negatively impacted at high temperatures. We elucidate a potential mechanism of induced craniofacial defects in thermally stressed lizard embryos.

140-8 O'CONNELL, J; SHAMBLE, P; KOENIG, K*; Standford University, Harvard University; *kmkoenig@fas.harvard.edu*

Comparative Lens Proteomics Across Aves

The proteins in the lens that contribute to transparency and light refraction are crystallins. These proteins have an interesting and complicated evolutionary history with surprising diversity across closely related taxa. Many of these proteins have secondary functions as metabolic enzymes and heat shock proteins. Even more unusual, crystallins α, β and γ are common in vertebrates but individual taxon-specific crystallins have been identified as well. One of the most remarkable examples is the high abundance of lactate dehydrogenase B in the duck lens, designated ε-crystallin, is lacking in the chicken lens. Since this discovery in 1985, progress towards a phylogenetic understanding of lens protein content and evolution has been slow due to the difficulty of performing large-scale protein analysis across species. Recent advances in proteomic methods and the availability of whole-genome sequences now enable our ability to perform broad, cross-species protein content analysis to better understand crystallin protein diversity and lens evolution. Lenses from a phylogenetically diverse sample of bird species were acquired for proteomic analysis. The tissue was analyzed for protein identity and relative abundance using both in-solution and gel-band extraction sample preparations followed by shotgun mass spectrometry. Protein abundances were quantified by normalized spectral counts and integrated ion intensities. Genomic regions surrounding genes identified in the lens proteomics studies were found in the corresponding bird species and comparative sequence analysis was performed. We see significant lens protein content diversity across species as well as differences in relative abundances. These results provide a better phylogenetic understanding of the diversity and unusual regulatory history of crystallin proteins in the bird lens.

S5-4 O'DONNELL, MK*; DEBAN, SM; Brown University, University of South Florida; *mary_kate_odonnell@brown.edu*

The Effect of Water on Salamander Cling Performance at the Critical Roughness

Plethodontid salamanders are capable of extraordinary clinging and climbing performance. This has enabled them to access arboreal, saxicolous, troglodytic, terrestrial, and fossorial habitats to find shelter, access food, and escape predators while traversing substrates in nature that can be rough or smooth, wet or dry. Since these lungless salamanders are dependent on moist environments to ensure sufficient cutaneous respiration, the effect of water on clinging and climbing performance may constrain which habitats they have access to. We previously found that salamanders are capable of high cling performance on both smooth and roughened dry epoxy resin surfaces, depending on their body size, foot morphology, and attachment strategy. Cling performance was weakest on surfaces at a critical intermediate roughness. Salamanders cling to smooth and intermediately roughened surfaces purely through the adhesive strength of their mucus coating. Here, we examined the effect of misted and flowing water on cling performance across a range of substrate roughnesses in 12 species of plethodontid and one ambystomatid salamander. We found that water negatively impacts cling performance on smooth surfaces, but significantly improves cling performance at the critical roughness in some species. On rough substrates where salamanders could engage in gripping, water had no significant effect on cling performance. Study of cling performance and its relationship to surface roughness and wetness may cast light on how the largest family of salamanders in the world have radiated to occupy diverse habitats and inspire synthetic adhesives which function in both dry and wet conditions.

P2-232 O'LEARY, NE*; STARK, AY; Villanova University; *noleary1@villanova.edu*

Adhesive Performance of Tokay Geckos (Gekko gecko) as a Function of Variable Surface Temperature

Geckos use millions of hair-like protrusions on their toe pads (setae) to utilize weak intermolecular van der Waal bond forces and achieve strong adhesion to a variety of substrates. These substrates vary in quality (i.e., moisture, roughness, temperature), namely in the tropics where conditions can be extreme. Tokay geckos (*Gekko gecko*) are native to the tropics, which endure high temperature and humidity. Interestingly, adhesive performance of Tokay geckos is inversely proportional to temperature and directly proportional to humidity (i.e., adhesion increases as humidity increases, but only at low temperature). In humidity the setae, composed of heterogeneous alpha and beta keratinous proteins and associated lipids, soften and become more adhesive. This behavior does not account for temperature and its interaction with humidity. Current literature fails to characterize the isolated effects of temperature and humidity on gecko adhesion, nor does it isolate an important sub-parameter: surface temperature. Geckos are ectotherms, so their body temperature is dictated by ambient temperature. In previous experiments only ambient temperature was varied, potentially complicating adhesion results. The experiments neglect the superheated substrates geckos naturally encounter. To investigate the effect of surface temperature on gecko adhesion we heated glass substrate to a range of temperatures (23 - 55°C) reported as the surface temperature of exposed canopy branches. We predicted that adhesive performance does not vary as a function of surface temperature, supporting the importance of relative humidity in gecko adhesion. The results of our study will help us better understand the adhesive mechanisms responsible for temperature and humidity dependent adhesive performance in geckos.

30-2 O'MARA, MT; AMORIM, F; SCACCO, M; MCCRACKEN, GF; SAFI, K; MATA, V; TOMÉ, R; SWARTZ, SM*; WIKELSKI, M; BEJA, P; REBELO, H; DECHMANN, DKN; Southeastern Louisiana University, Hammond LA, University of Porto, Portugal, Max Planck Institute of Animal Behavior, Radolfzell, Germany and University of Konstanz, University of Tennessee, Knoxville TN, Max Planck Institute of Animal Behavior, Radolfzell, Germany and University of Konstanz, University of Lisbon, Portugal, Brown University, Providence, RI , University of Porto and University of Lisbon, Portugal; *teague.omara@selu.edu*

European Free-tailed Bats Use Wind Regimes to Fly High and Fast

Bats use some of the fastest known vertebrate flight speeds and can forage thousands of meters above the ground, but it is unknown how they manage these high-energy behaviors. We tracked the three-dimensional movement of European free-tailed bats (*Tadarida teniotis*) in northeastern Portugal and developed high resolution wind models to test if bats use the underlying landscape and wind regime to generate high speeds and achieve high flight altitudes. Bats flew at speeds of 5.63 ± 3.66 m/s (maximum 41.24 m/s or 149 km/h) with airspeeds of 4.68 ± 3.79 m/s, (maximum of 37.52 m/s, 135 km/h). Bats largely follow the terrain at 182 ± 206 m above ground level (AGL), but appear to ride uplifting winds to travel hundreds of meters upwards in less than one minute to over 1600 m AGL. Predictive additive models using wind patterns alone are able to predict the location of these high-elevation ascents and explain 91.3% ± 11.1% of the deviance. This suggests that bats exploit the energy in vertical winds generated by the interaction between wind and topographic slope to minimize energetic expenditure, similar to diurnal birds, and likely follow a path of least resistance to high-elevation hunting grounds. Free-tailed bats generate some of the fastest powered flight speeds among vertebrates, forage at exceptional altitudes, and continue to challenge our understanding of flight in the wild.

119-7 OAKLEY, TH*; HENSLEY, NM; ELLIS, EA; GOODHEART, JA; VARNEY, RM; GERRISH, GA; TORRES, E; UCSB, U Alabama, UW-Madison, CSULA; *oakley@lifesci.ucsb.edu*

From Chaos Came Beauty: The Origin of a Novel Bioluminescence Gene with Ecosystem Impacts

Bioluminescence is ecologically impactful through its use in communication, including courtship signals whose origins may increase rates of speciation. Therefore, learning how genes for bioluminescence originate is critical for understanding how genetic changes influence ecological communities. One origin of bioluminescence occurred in cypridinid ostracods (Crustacea), some of which employ complex bioluminescent courtship displays that differ among dozens of species. Cypridinid bioluminescence involves a novel enzyme (c-luciferase) with two deeply conserved sequences, both Von Willebrand Factor D (VWD) domains. We characterized the history of VWD to inform the origin of this novel gene. We analyzed VWDs in animal genomes, finding them as parts of many different genes with distinct domain architectures. We next included VWDs from ostracod transcriptomes and a draft genome, and discovered c-luciferase originated through novel fusion of distantly related VWD domains. Unexpectedly, we found VWDs proliferated in ostracods before the origin of bioluminescence. Many of these genes contain highly repetitive elements, suggesting a chaotic evolutionary history. Although we still have much to learn about the function of genes related to c-luciferase, this mode of gene origin may be similar to Innovation Amplification Duplication (IAD), but with different timing. Our results illustrate how contingent, unpredictable genomic histories contribute to new genes and ecologically impactful, sometimes beautiful, phenotypes.

P2-124 OBERMAN, W*; KONDRASHOV, P; MAISANO, J; YOUNG, BA; Kirksville College of Osteopathic Medicine, University of Texas at Austin; *byoung@atsu.edu*

Meningeal Structure in Reptiles

The existing literature on the meninges in reptiles has an abundance of contradictory claims and nomenclatural revisions. In part this stems from the literature containing mainly single-species studies that were performed under either a developmental or mammalian perspective. There is still disagreement about the number of meningeal layers in reptiles, and the relative degree of vascularity associated with the individual layers. To explore this subject we examined post-embryonic specimens of four reptilian taxa: American alligator (*Alligator mississippiensis*), western diamondback rattlesnake (*Crotalus atrox*), Chinese pond turtle (*Mauremys reevesii*), and water monitor lizard (*Varanus salvator*). Specimens from each species were examined using three different techniques: paraffin histology, freeze fracturing prior to scanning electron microscopy, and high-resolution X-ray micro-CT analysis. The analysis centered on four anatomical regions: 1) the cervical spinal cord, 2) longitudinal (parasagittal) sections through the foramen magnum, 3) the structure of the tela choroidea over the 4th ventricle, and 4) the cerebral cortex. In all four species three meningeal layers, of varying distinctiveness, could be identified; these were identified as pia mater, arachnoid mater, and dura mater. In all four species there was considerable variation in the relative position of the arachnoid mater, meaning that the sizes of the subdural and subarachnoid spaces were variable. In general, the meninges of the examined reptiles are similar to those of the more studied mammals with three clear distinctions: there are no prominent septa or trabeculae; the meninges, and more specifically the dura mater, do not exhibit a marked transition at the foramen magnum; and the meninges over the 4th ventricle are more continuous or "closed" than in mammals.

P3-100 OCHS, RA*; CHAMBERLAIN, JD; Southern Arkansas University; *raochs7784@muleriders.saumag.edu*

The Reproductive Effects of Supplemental Nutrition in an Income-breeding Snake

Maternal fitness of animals is tightly correlated with allocation of maternal resources to gametes and resulting offspring. Understanding how animals physiologically achieve this allocation process and what are its limitations may provide insights into the evolution of life-histories. In order to reproduce, animals must obtain anabolic nutrients (lipid and protein) from their environment. The quality of prey consumed dictates the raw materials a mother will have available to allocate to production of her offspring. However, prey quality in terms of lipid and protein likely varies environmentally. Allocation of maternal resources is therefore likely to vary as prey quality varies. To add an additional layer of complexity, maternal protein and lipid are allocated at dissimilar proportions due to differences in how they are utilized by developing offspring. Thus, it is unclear how variation in prey quality will vary maternal allocation to offspring. To address this question, we supplemented the diets of captive brown house snakes (*Boaedon fuliginosus*) with either protein, lipid, or both and measured eggs and offspring produced from these mothers. We measured egg size, clutch size, clutch mass, hatchling mass, and hatchling length of all clutches and compared these values to clutches produced from females on control diets. While we are currently still measuring clutches, we estimated treatment effects by comparing residuals from regressions of female size and each clutch/hatchling characteristic. Here we will present our preliminary data from this experiment.

46-4 OEL, AP*; LAMANNA, F; HERVAS-SOTOMAYOR, F; KAESSMANN, H; ARENDT, D; EMBL Heidelberg, Germany, ZMBH, University of Heidelberg, Germany; *phillip.oel@embl.de*

Evolution of retinal cell types in the sea lamprey, Petromyzon marinus

The advent of single cell RNAseq has enabled the transcriptomic comparison of cell types within and between species. By characterizing the cell type diversity of phylogenetically diverse animals, we can identify how and when key innovations in cell types have occurred in various lineages. Here, we present progress in documenting the diversity of photoreceptor cell types in the sea lamprey *Petromyzon marinus*, a basal branching jawless vertebrate. We dissociated retinas and brains of larval and adult lamprey, generating ~15,000 retinal cell transcriptomes for each stage with Chromium 10X technology, clustered them with Seurat in R, and validated markers for key cell type clusters with *in situ* staining methods. The adult lamprey retina showed overt cell type conservation with jawed vertebrates, although canonical markers of retinal ganglion cells and amacrine cells labeled both populations variably, suggesting that these cell types are not yet fully distinct in jawless fishes. Additionally, the photoreceptors and bipolar cells expressed deep brain opsins highly, suggestive of nonvisual photoreceptive roles. In stark contrast, the histologically simple retinas of the larval lamprey lacked most markers for bipolar cells, suggesting that larvae lack this cell type. Additionally, the larval photoreceptors were devoid of visual opsins, expressing only deep brain opsins, suggesting that larval retinal photoreceptors first differentiate as ambient light sensors resembling pineal and deep brain photoreceptors. Together, our data support the photoreceptor origin of bipolar cells, and the evolution of retinal, pineal, and deep brain photoreceptors by division of labor.

19-2 OHDERA, AH*; SHARP, V; WATSON, K; STEINWORTH, B; DIAZ-ALMEYDA, E; POOLE, AZ; FITT, W; MARTINDALE, MQ; MEDINA, M; Pennsylvania State University, University of Florida, New College of Florida, Berry College, University of Georgia; *aohdera@caltech.edu*

Alterations in transcriptional and developmental regulation: Evolutionary implication of symbiosis in Cassiopea xamachana

While symbiosis can lead to genetic and morphological changes in the both the host and symbiont, few examples exist in which host developmental transition becomes tightly linked to the symbiosis. Similar to corals, the upside-down jellyfish *Cassiopea xamachana* establishes a symbiotic partnership with members of the dinoflagellate family Symbiodiniaceae. While both host and symbiont benefit from the interaction to fulfill their nutritional requirements, the jellyfish relies on the symbiont in order to complete its lifecycle. In *Cassiopea*, the polyp to medusa transition (strobilation) is triggered by the colonization of the host. In order to understand the mechanisms that lead to strobilation in *Cassiopea*, we used Illumina sequencing to profile the transcriptome of polyps post-colonization and during strobilation. We found genes previously shown to be up-regulated in non-symbiotic jellyfish prior to strobilation were not differentially expressed. A closer examination of these genes showed that while expression levels remain unaltered, in situ hybridization patterns revealed their involvement in *Cassiopea* strobilation is likely maintained. Further assessment of differentially expressed genes of both host and symbiont revealed additional genes that are involved triggering strobilation. These findings shed light on how symbiosis can lead to evolutionary changes in host gene expression and developmental history.

29-1 OLBERDING, JP*; ILTON, M; CROSBY, AJ; AZIZI, E; University of California, Irvine, Harvey Mudd College, University of Massachusetts, Amherst; *olberdij@uci.edu*

Limits and Losses: the Power of Recoiling Biological Springs

Many organisms use springs to actuate extremely fast movements because they can bypass the power limits of other actuators, like muscles. Measurement of muscle-mass-specific power exceeding muscle limits is a common way to identify systems actuated by springs; however, this measurement says nothing about the power of the spring itself. Here we explore the power limits of biological springs and their potential to determine the upper limits of performance in movements actuated by spring recoil. Because a spring applies force to accelerate a mass, we can predict that recoil velocity and power scale as mass$^{-0.5}$ and maximum power is reached when the spring moves only its own mass. However, a spring oscillating at high frequencies releases less energy during recoil than is stored during stretching and this loss is greater at higher frequencies. This leads to the prediction that a spring moving a very light mass will recoil with high velocity, yet much of the stored elastic energy will be lost. Therefore, for any spring there is a specific load mass that balances power output with energy loss. Using a novel experimental approach, we have measured the power of elastic tissues isolated from multiple vertebrate species recoiling with displacements <1 mm and durations <1 ms to move a range of load masses. These measurements confirm the mass-dependent trade-off: recoil power is greater at smaller masses, but energy loss is minimized at larger masses. This result suggests that biological springs must be tuned for the loads they are moving to balance energy and power. Additional experiments will explore the connection between the power/load relationship of a recoiling elastic tissue and material properties, such as resilience and loss modulus.

91-5 OLENSKI, M/S*; BILBREY, C; DIRIENZO, N; DORNHAUS, A; University of Arizona, University of Arizona, School of Information, University of Arizona, Department of Ecology and Evolutionary Biology; *molenski@email.arizona.edu*

The Effect of Neurotransmitters on Life History Strategy: How do Increased Dopamine Levels Influence Aggression in Black Widow Spiders?

Our research is focused on the effects of dopamine on the behavior and individual life history strategies of Black Widow spiders (Latrodectus hesperus). We wanted to perform this experiment to further understand the effects of dopamine in different nervous systems than our own and to better see how the chemical affects individual behavior. The effects of dopamine on the behavior of certain species is well understood, from humans to certain species of insects, but little work has been done on the effects of dopamine on spiders. We compared spiders injected with a solution consisting of .03M dopamine with ones injected with a saline control and a negative control of no injection. Following injections, we then placed spiders on their webs and used a vibratory stimulus on the web to measure individual aggression level. We found that dopamine did not affect individual aggressive behavior, but dopamine injections did decrease the weight of webs. Our results thus suggest that in black widow spiders, individual aggression levels may not be regulated by dopamine; however, our results also suggest that life history strategy, which in spiders is reflected by investment in web building, may be influenced by dopamine.

54-4 OLIVEIRA, DR*; FOSTER, SA; FITZPATRICK, SW; Clark University, Worcester, MA, Michigan State University, East Lansing, MI; *DOliveira@clarku.edu*

Integrating Phenotypes and Genomes in a Fine-Scale Study of Lake-Stream Divergent Rainbow Darters

Populations inhabiting different environments often display phenotypic and genetic differentiation associated with local conditions. Many well-known examples of local adaptation exist from freshwater fish populations occupying varying environments, such as lake versus stream ecotypes. Identifying the adaptive potential of freshwater fish populations is critical, given anthropogenic habitat modification and climate change. However, population-level differentiation has rarely been documented in darters, one of the most species-rich clades of fish in North America. This study assessed fine-scale phenotypic and genetic variation in *Etheostoma caeruleum* (rainbow darters), including a unique lake population. We collected individual data for several phenotypes, including thermal tolerance, morphology, boldness, and locomotion. We characterized neutral and potentially adaptive variation using a modified RADseq protocol. Initial analyses indicate population differentiation for thermal tolerance matching habitat temperature, suggesting local adaptation. We also found a significant pattern wherein populations harbouring more genetic variation have higher thermal tolerance. Furthermore, we found significant lake-stream morphological divergence associated with mouth position, supporting ecotypic differentiation. Despite the small geographic scale, we find evidence of fine-scale genetic structure and recent admixture not owing to stream connectivity. We are currently exploring further ecotype divergent phenotypes and putatively adaptive outlier loci associated with the lake population of rainbow darters.

32-5 OLIVER, KD*; MARTIN, TE; WOLF, BO; University of New Mexico, University of Montana; *kristenoliver@unm.edu*

Air Temperature Limits Metabolic Scope in Mid-elevation Tropical Birds

As global air temperatures continue to rise due to climate change, the effects of temperature on the breeding performance of birds is of increasing interest. If the ability to dissipate heat generated by activities such as foraging and feeding nestlings is diminished in future climates then reproductive success may decrease. With this question in mind, we surveyed a tropical mid-elevation (1500-1900m) bird community in Mount Kinabalu National Park in Borneo, Malaysia where air temperatures range from 15-21^{o}C. We used a hop-flutter flight wheel and flow-through respirometry to measure resting metabolic rate, exercise metabolic rates, evaporative water loss, and body temperature in 24 species of birds ranging in size from 6g to 140g in dry air over a range of air temperatures (16^{o}C - 30^{o}C). Under dry conditions, metabolic scope (peak metabolic rate – resting metabolic rate) and exercise performance were highly diminished at $T_{air} > 28^{o}$C suggesting that warmer temperatures may importantly limit activity and potentially breeding performance under future climates.

123-4 OLROYD, SL*; SIDOR, CA; University of Washington, Seattle, University of Washington and Burke Museum, Seattle; *savano@uw.edu*

Allometry and porosity of the novel sound reception structure of chameleons

Chameleons lack a tympanum, but two chameleon species have co-opted their pterygoid plate to serve as a receptor for airborne sound via a connection between this plate and the extracolumella. We hypothesize that the pterygoid plate of these "hearing" chameleons has adaptations that would improve its sound reception function. We expected that the pterygoid plate would exhibit more negative allometry in "hearing" chameleons than in "non-hearing" ones, as negative allometry is common in sensory structures. We also hypothesized that the porosity of the plate would be lower in "hearing" chameleons, reducing the structure's acoustic impedance. We measured basal skull length and pterygoid plate area in chameleon skulls and fitted the measurements to an allometric growth curve. We also µ-CT scanned dry skulls and used CT-An to measure porosity of the plate. We used dissections to identify a connection between the pterygoid plate and extracolumella in four additional species, indicating that this hearing method has evolved at least three times independently. Our preliminary allometry results show that the pterygoid plate has more positive allometry in "hearing" species. This could indicate that chameleons never reach a body size that would allow their plate to be large enough to optimally capture the frequencies they need to hear. Equally surprising was the preliminary result that "hearing" chameleons have a plate with about half the porosity of "non-hearing" ones. This could serve to give the structure a higher resonant frequency in "hearing" species. Overall, our results do suggest that "hearing" chameleons have subtle modifications in their pterygoid plate compared to other species. We intend to explore the acoustic consequences of these modifications through modeling.

97-3 OLSEN, AM*; HERNÁNDEZ, LP; BRAINERD, EL; Brown University, Providence, RI, George Washington University, Washington, DC; *aaron_olsen@brown.edu*

A 13-bar linkage model of the channel catfish skull and the degrees of freedom needed to suction feed

To manipulate their external environment, animals must use the degrees of freedom (DoFs) afforded by their musculoskeletal system to control the DoFs of external objects. For example, grasping a food item with the hand and moving it to the mouth typically requires six DoFs to control the translation and rotation of the food. Suction feeding fishes encounter a similar problem but rather than grasp food items directly, they use a complex linkage of over 10 skeletal elements to manipulate the fluid surrounding the food to capture and transport it to the pharyngeal jaws or esophagus. Do a similar number of degrees of freedom underlie both motor tasks? Previous studies using two-dimensional four-bar linkages suggest fish use just one to three DoFs. However, the skull has over 10 potential DoFs of motion. To answer this question, we created a 13-bar cranial linkage model of the channel catfish first and second jaw arches and validated the model using in vivo data collected using XROMM (X-ray reconstruction of moving morphology). We find that the skull allows at least 14 DoFs of substantial motions (those that affect fluid flow). However, we only observed motion along five of these DoFs. These results show that the manipulation of fluid during suction feeding, though in some ways more complex than grasping a single food item, uses a similar number of DoFs of motion, suggesting analogous strategies in controlling the motion of external objects across terrestrial and fluid domains. Funding: NSF 1612230, 1655756.

85-4 OLSON, RA*; CURTIS, HE; WILLIAMS, SH; Ohio University, Ohio University Heritage College of Osteopathic Medicine; *ro603313@ohio.edu*

To chew or not to chew: a comparison of the 3D kinematics of feeding and drinking in pigs

Feeding has been the primary focus of most 3D kinematic studies of cranial function in mammals. Drinking, on the other hand, has received less interest perhaps due to the emphasis on soft tissue movements responsible for liquid transport through the oral cavity. Nevertheless, the opening and closing of the jaw, or gape cycle, is a fundamental component of both feeding and drinking, and thus can be used as a common basis for comparison between the two behaviors. The objective of this study is to compare the dynamics of the gape cycle, characterized by the durations and amplitudes of 3D jaw movements, and relate jaw movements to tongue movements during drinking and feeding in pigs. We hypothesize that the gape cycles will be similar during both behaviors, but that chewing will exhibit higher levels of variability due to the interactions of the teeth and tongue with food. Data were collected from 3-month old pigs feeding on apples or drinking apple juice. The juice was ingested by a sucking mechanism combined with pumping movements of the tongue. Chewing cycles had an extended slow-close phase, reflecting the tooth-food-tooth contact necessary for preparing a bolus while sucking cycles had an extended slow-open phase, which corresponds to tongue protrusion into the fluid. Compared to chewing, sucking showed low amplitudes for all degrees of freedom used (jaw protraction, yaw, and opening). Sucking cycles were shorter than chewing cycles ($p<0.001$), but had a much higher coefficient of variation (9.47 vs 25.3), suggesting that sucking is not as rhythmic as mammalian chewing. These results provide a context in which to analyze regional tongue movements and deformations relative to the gape cycle.

34-6 ONTANO, AZ*; BENAVIDES, L; HARVEY, M; GIRIBET, G; SHARMA, P; University of Wisconsin, Harvard University, Western Australian Museum; *ontano@wisc.edu*

Disentangling Arachnid Systematics Through Rare Genomic Events

The evolutionary relationships among the orders of Arachnida has proven challenging despite the availability of a vast amount of genetic data. The placement of pseudoscorpions remains uncertain due to a phylogenetic artefact, long branch attraction, which leads to statistically inconsistent relationships among the arachnid orders. Analyses including a broad sampling of pseudoscorpion taxa spanning each of superfamily support the placement of pseudoscorpions as the sister group to scorpions. The sequential removal of basally branching lineages from analyses artificial increases the branch length of the order's basal branch, leading to support for the placement of pseudoscorpions as sister to the parasitiform ticks and mites due to long branch attraction. Alternative classes of phylogenetic data are a potential solution for reconstructing relationships where sequence data have not achieved topological stability. Rare genomic events serve as a data class to determine the relationship between pseudoscorpions and the rest of Arachnida. We investigated the signature of shared duplicated genes as phylogenetic characters as indication for a relation between pseudoscorpions with the arachnopulmonates (spiders, scorpions, and their allies), which are inferred to have undergone an ancient whole genome duplication. We sequenced the first developmental transcriptome of the pseudoscorpion *Conicochernes crassus* to investigate the incidence of duplicated genes shared by the arachnopulmonates. Our transcriptomic data show that pseudoscorpions retain many duplicated genes across a variety of disparate gene families. Analysis of gene trees recovered topologies consistent with a single shared genome duplication with arachnopulmonates, suggesting a close relationship with the pseudoscorpions.

84-5 ORBACH, DN*; BRENNAN, PLR; HEDRICK, BP; KEENER, W; WEBBER, M; MESNICK, SL; Texas A&M University- Corpus Christi, TX, Mount Holyoke College, MA, University of Oxford, UK, Golden Gate Cetacean Research, CA, Southwest Fisheries Science Center, CA; *dara.orbach@tamucc.edu*

Unique Coevolution of Genital Asymmetry and Lateralized Mating Behavior in A Mammal

Consistent lateralized mating behaviors have only been reported in one species of mammals. Male harbor porpoises (*Phocoena phocoena*) sexually approach females exclusively on the female's left side while hooking their lengthy penis around the female into her vaginal opening. We assessed the morphological symmetry and shape of post-mortem reproductive tracts of male and female harbor porpoises to understand the evolution of this unusual lateralized behavior. Two-dimensional geometric morphometrics of the vagina and three-dimensional models of the vaginal lumen and inflated penis tip were used to characterize and quantify genital shapes and assess the influences of asymmetry on overall genital shape. In 2D, there was substantial individual variation in vaginal shape that was not correlated with total body length. The vaginas exhibited significant fluctuation and directional asymmetry, suggesting the asymmetry is functional. The vaginal lumens were highly asymmetric, which was driven by complex 3D spirals and vaginal folds with deep recesses. These vaginal folds appear to physically obstruct the penis and curtail the depth of penetration. The asymmetric shapes of the penis tip of free-swimming harbor porpoises, excised penis tip, and vaginal lumen were remarkably similar. We suggest that the left-sided sexual approach of males enables the penis to deeply penetrate the vagina. We demonstrate that the reproductive anatomy of males and females and their lateral mating behavior have coevolved in harbor porpoises.

P1-58 ORCUTT, JD*; RITCHEY, TE; VIETRI, CB; Gonzaga University, Spokane, WA; *orcutt@gonzaga.edu*

Otospermophilus mckayensis and the Evolution of Burrowing in Oligo-Miocene Squirrels

The Cenozoic spread of grasslands drove morphological, physiological, and behavioral transitions in many mammal taxa, perhaps the most profound of which was the evolution of burrowing in rodents. While several rodent families underwent this transition, sciurids are of particular interest not only due to the diversity of ground squirrels, but to the range of locomotion within the Sciuridae. While the vast saga of squirrel evolution is well documented in the fossil record, this record consists largely of craniodental remains. Postcrania are more informative about locomotion, but are often found isolated from teeth and skulls, making them impossible to assign to species. An exception to this rule was uncovered in 2017 from McKay Reservoir, a Miocene locality in northeast Oregon. The specimen is referable to *Otospermophilus mckayensis* and includes a skull and jaws as well as most of the anterior portion of the skeleton. We calculated functional indices based on measurements of the forearm of *O. mckayensis* as well as extant taxa and less complete specimens of Oligo-Miocene squirrels. A discriminant function analysis of these data had a high success rate when placing modern taxa into locomotor categories, but the fossil taxa cannot be classified as arboreal, terrestrial, fossorial, or gliding with a high degree of confidence. We also compared individual indices between species and found that while many were nearly identical to those seen in modern ground squirrels, others differed significantly. Ongoing analyses will test whether this indicates mosaic evolution of the ground squirrel limb and what implications this might have for behavior and locomotion of the earliest squirrels to take to the soil.

121-2 ORR, SE*; BUCHWALTER, DB; North Carolina State University; *seorr@ncsu.edu*

It's All About the Fluxes: Temperature Influences Ion Transport and Toxicity in Aquatic Insects

Many freshwater ecosystems are becoming saltier and/or warmer, but our understanding of how these factors interact and affect the physiology and life history outcomes of most aquatic species remain unknown. We hypothesize that temperature modulates ion transport rates. Since ion transport is energetically expensive, increases in salinity and/or temperature may influence ion flux rates and ultimately, organismal performance. Radiotracer ($^{22}Na^+$, $^{35}SO_4^{-2}$, and $^{45}Ca^{2+}$) experiments with lab-reared mayflies (*N. triangulifer*) and other field-collected insects showed that increasing temperature generally increased ion transport rates. For example, increasing temperature from 15°C to 25°C, increased $^{22}Na^+$ uptake rates by two-fold ($p < 0.0001$) and $^{35}SO_4^{-2}$ uptake rates by four-fold ($p < 0.0001$) in *Hydropsyche* sp.. Smaller changes in $^{22}Na^+$ and $^{35}SO_4^{-2}$ uptake rates were observed in *Isonychia* sp. and *Maccaffertium* sp., suggesting species-specific differences in the thermal sensitivity of ion transport. We further explored the influence of SO_4 challenge on mRNA expression of two SO_4 transporter genes (putatively Na-dependent and Na-independent SO_4 transporters in the SO_4 permease family). Expression of the Na-dependent SO_4 transporter was unaffected, whereas the expression of the Na-independent SO_4 transporter was increased 4.5-fold at the highest salinity (1300 mg/L SO_4) ($p < 0.05$), suggesting an efflux function. Finally, we demonstrated that the toxicity of SO_4 was influenced by temperature profoundly in a 96-hour bioassay. Under the saltiest conditions (1500 mg/L SO_4), mayfly survival was 78% at 15°C, but only 44% at 25°C ($p < 0.0036$). Conceivably, the energetic cost of osmoregulation in warmer, saltier environments may cause significant major ion toxicity in certain species of freshwater insects.

S4-13 ORR, TJ; New Mexico State University; *TeriOrr@nmsu.edu*
Round Table Discussion for Reproduction: the Female Perspective from an Integrative and Comparative Framework
To conclude our symposium on female reproduction from a comparative and integrative perspective we invite our participants as well as all SICB attendees to join in a roundtable discussion. The symposium itself focused on female reproduction from diverse avenues and we hope to collect a snapshot of perspectives that reflect this diversity. Several key questions will be addressed including: What are the key gaps in our knowledge regarding female reproduction? Where might ignoring the female perspective result in misguided conclusions? How can we bridge these gaps? What terminology is biased or otherwise antiquated and promotes misleading assumptions, ex: fertilization, egg? What alternatives can we provide, ex: conception, ovum? What are the issues with any alternatives? What are the next big questions in biology as they relate to the female perspective? Symposium organizers and participants will be encouraged to bring forth questions that have been posed throughout our sessions. Our goal is to make strides in refining terminology as well as outlining gaps in our knowledge that are of broad interest to integrative biologists.

S4-12 ORR, TJ*; HAYSSEN, V; New Mexico State University, Las Cruces, Smith College, Northampton; *TeriOrr@nmsu.edu*
Where now? Future directions in reproductive biology framed by the female perspective
Female reproduction is key for the success of sexually reproducing species. However, not only have females been understudied in many regards, but data have commonly been interpreted in the context of now-outdated social mores. As a summary to our symposium, we highlight gaps in our knowledge about female reproductive biology and provide a jumping-off point for discussing future research areas with a focus on a process: sperm storage, a morphological trait: genital evolution and life history theory: reproductive timing. We also discuss the promise of emerging methods such as micro-CT scanning, high-throughput sequencing, proteomics, CRISPR-Cas9 and viral vector technology, and big-data analyses for yielding insights into previously cryptic processes and features. For example, in mice DNA sequencing via ChIP-Seq is already unveiling how epigenetic interactions lead to sex differences in brain development- and holds promise for future work. Similarly, we discuss how new areas such as microbiome research are debunking dogmas such as the notion of the ‘sterile womb.' In light of NSF's Rules of Life Idea projects we highlight how female reproductive biology is well suited to studies that are ‘Predicting Rules of Life.' Studies of female reproductive biology will enable scholars to: 1) traverse levels of biological organization from the ovum, to reproductive proteins, vaginal and uterine morphologies, physiology, mating behaviors, whole-organism performance, ecology, and population structure; 2) discover generalizable rules such as the nature of trade-offs females navigate to reproduce when both sufficient energy and mates are available; and 3) predict the impacts of changes in biological systems such as in the reliability of changing environmental cues used to time reproduction.

P1-148 ORR, TJ*; YAMADA, KYH; NELSON, MD; MATOCQ, MD; NIELSEN, DP; SHAPRIO, MD; DEARING, MD; New Mexico State University, Auburn University, University of Utah, University of Nevada, Reno, University of Utah; *teri.orr@utah.edu*
Diet switching in mammalian herbivores: dietary specialization and toxin tolerance in two woodrat species
Herbivores face many dietary challenges including those presented by the toxins that are produced as defense mechanisms by many plants. To understand the evolution of toxin tolerance in herbivores, we are investigating two species of woodrats, *Neotoma lepida* and *Neotoma bryanti*, and their hybrids. Both species experienced a shift in their diet about 18,000 years ago, as creosote bush (*Larrea tridentata*) expanded its geographic range and replaced the ancestral diet of juniper (*Juniperus spp.*). Creosote bush contains numerous toxic compounds that differ from the compounds found in juniper and require different detoxification mechanisms. We conducted feeding trials with woodrats from 2 species and their hybrids from 13 geographic locations to determine the maximum tolerable dose (MTD) of creosote resin. Some populations are creosote feeders, whereas others feed on the ancestral diet of cactus and juniper. We found that MTDs vary between species, where the MTD of *N. lepida* is approximately 1.5 times higher than that of *N. bryanti*. Hybrids showed intermediate tolerances. This pattern was reflected across all the populations, including sites where both species and their hybrids are found. We found that the presence of creosote explains some of the variation in MTD. Furthermore, MTD is negatively correlated with distance from the origin of creosote invasion suggesting that evolutionary history (duration of exposure) with creosote has allowed for greater adaptation to this diet.

S4-1 ORR, TJ*; HAYSSEN, V; New Mexico State University, Las Cruc, Smith College, Northampton, MA; *vhayssen@smith.edu*
Introduction
This symposium is about reproductive biology from the female perspective, but what do we mean by the female perspective? Most obviously, since we have chosen female speakers, one meaning is that the female perspective is the view of female scientists. Our diverse speakers are from a range of academic ranks (post-docs to chaired professors) and study a range of animal taxa from insects to mammals. More importantly, we want to examine reproductive biology from the perspective of female organisms themselves. What happens when we examine social behavior, physiology, or ecology strictly from the viewpoint of females? In many cases the female-centric perspective will alter our prior interpretations. For example, with DNA fingerprinting, differences between genetic and behavioral mating systems became obvious. We realized that assessing parentage (the ultimate basis of categorizing mating systems) using male-mating strategies resulted in flawed conclusions; in fact, sperm selection leading to conception is more important than mating per se. This is an example of how behavioral ecology might change its interpretations if we examine systems from the female perspective. Another example comes from studies of whole-organism performance –whereby jumping, running, and swimming have been measured in males with a deliberate removal of females and the major facet of their physiology, i.e. reproduction. However, female biology may actually set the limits of performance given the extra weight and changes in body shape required for reproduction. For instance, new insights into metabolic ceilings arose from examining energy consumption during lactation. These changes in how we understand behavior and physiology are relevant across diverse taxa. Our speakers will continue the exploration of ways in which our framework shifts when we use a female perspective.

87-5 ORTEGA-JIMENEZ, VM*; SANFORD, CP; Kennesaw State University, Kennesaw, GA; *ornithopterus@gmail.com*

Beyond the Kármán Gait: Knifefish swimming responses to complex wakes shed by a free oscillating cylinder

Tropical fish such as knifefish are commonly challenged by unsteady flows associated with natural and artificial structures. A classical example, broadly used in animal locomotion research, is the Kármán vortex street: a regular pattern of counter-rotating eddies downstream produced by a rigid body. However, natural structures in rivers (e.g., plants, submerged logs, rocks) are relatively loose, and tend to oscillate due to a phenomenon called vortex-induced vibration. These vibrations result in a more complex pattern of vortex shedding that can have pronounced effects on fish locomotion. We investigated the 3D kinematics and swimming behavior of the black ghost knifefish (*Apteronotus albifrons*, N=7) in response to the complex wake of a free oscillating cylinder, a fixed cylinder and laminar flow. Flow conditions were characterized using PIV. We found that knifefish maintain position with minimal movements in the recirculation zone of a fixed cylinder, using their ribbon and pectoral fins to occasionally regain stability. In contrast, for the oscillating treatment individuals actively swim using their ribbon and pectoral fins, as well as body bending to maintain position behind the moving cylinder. We observed that in some individuals, the body oscillated in or out-of-phase depending on downstream location. A model knifefish (reconstructed using photogrammetry and 3D printed) was placed at different downstream distances from an oscillating cylinder to verify passive movements. The fish model located just downstream from the cylinder oscillated out of phase with the moving cylinder, but oscillated in phase when placed one-cylinder diameter downstream. Thus, vortex-induced vibrations in bluff bodies create an unsteady flow environment that is more challenging for animals, than Kármán vortex streets.

P3-90 ORTIZ, J*; DEBIASSE, MB; RYAN, JF; Whitney Laboratory for Marine Bioscience, University of Florida and Iowa State University, Ames, IA, Whitney Laboratory for Marine Bioscience, University of Florida; *ortiz1@iastate.edu*

Evolutionary history of an ancient innexin gene cluster in ctenophores

Innexin proteins facilitate cell-cell communication by forming gap junctions or non-junctional hemichannels. These channels have a range of important cell physiological roles. To date, the complement of innexin genes in ctenophores (comb jellies) has not been characterized in any detail. In this study, we have identified and phylogenetically characterized the full complement of innexins in the genomes of three ctenophores: *Mnemiopsis leidyi*, *Pleurobrachia bachei*, and *Beroe ovata*. We identified nine innexin genes in *P. bachei* and twelve in both *M. leidyi* and *B. ovata*. The last common ancestor was determined to have at least twelve innexins with a cluster of three. We show evidence from single-cell RNA-Seq and developmental time-course RNA-Seq that expression within this cluster is co-regulated. Using MEME and TOMTOM we identified highly conserved non-coding motifs upstream of these clustered genes. We predict that these motifs are regulatory elements important for the gene co-regulation that we observe and have contributed to the maintenance of this cluster over hundreds of millions of years. Lastly, we show that one innexin in the *M. leidyi* cluster is expressed exclusively in colloblasts, adhesive cells used to capture prey. This colloblast-specific innexin that is present in the transcriptomes of other ctenophores has been lost in both *B. ovata* (which lacks colloblasts) and *P. bachei* (which has colloblasts). Our results provide insight into gene regulation, ancient gene clustering, and the potential for cell-cell communication via gap junctions in ctenophores.

P2-238 ORTIZ, T.E*; CHANDLER, C; SUNY Oswego; *tortiz2@oswego.edu*

Prevalence of Microsporidia and Wolbachia infection in the amphipod Gammarus fasciatus

Microsporidia and *Wolbachia* are two different kinds of endosymbionts that can be found in various arthropod hosts, and can cause severe reproductive changes and affect population ratios. *Wolbachia* is a rather common endosymbiotic bacterium, while microsporidia are fungal endosymbionts, but both affect their hosts in various ways that overlap. These endosymbionts can affect reproductive success, sex ratios, and cause male killing or feminzination. While prior work has focused more on terrestrial species, there is interest in studying aquatic isopods and amphipods. The focus of our research was the potential effects microsporidia and *Wolbachia* can have on local aquatic isopods and amphipods. Using PCR, aquatic isopod and amphipod specimens were obtained from the Rice Creek Field Station in Oswego, New York, which were then observed to determine species and sex. No sex ratio bias or evidence of *Wolbachia* infection was found in the aquatic isopod, *Caecidotea racovitzai*. In the amphipod species, *Gammarus fasciatus*, we observed a moderately female-biased sex ratio, and found some evidence of infection by microsporidia. We are currently testing additional samples, and planning another field collection to compare possible seasonal effects, and we hope that further work will help us to understand the prevalence of these types of endosymbionts in aquatic systems.

98-7 ORTON, RW*; SCHIELD, DR; NIKOLAKIS, ZL; PERRY, BW; DEMUTH, JP; MACKESSY, SP; SMITH, CF; MEIK, JM; CASTOE, TA; University of Texas at Arlington, University of Northern Colorado, Tarleton State University; *richard.orton@uta.edu*

The landscape of diversity and divergence across genomes highlights links between genome structure and evolution in the formation of genomic islands

A central goal of evolutionary biology is understanding how genetic differentiation is accumulated and structured across genomes during lineage divergence. Recent advances in the interrogation of genome-wide patterns of variation in divergent lineages have revealed heterogenous landscapes of diversity and differentiation that are marked by genomic ‘islands' of high population differentiation set against a genomic background of low population differentiation. Although genomic ‘islands' are generally expected to show greater resistance to introgression, the relative contributions of various evolutionary processes to the formation of genomic ‘islands' are poorly known. Here, we sampled genomic variation using RADseq sampling from three pairs of rattlesnake lineages, and interpreted these data using a chromosome-level reference genome for the Prairie Rattlesnake (*Crotalus viridis*) to compare patterns of variation, population genetic structure, and differentiation among genomic regions. Because macro-, micro-, and sex chromosomes differ in rates of recombination, we assessed each chromosome class individually. We then tested correlations between nucleotide diversity (pi), relative differentiation (Fst), and absolute differentiation (dxy) in order to infer the evolutionary processes underpinning lineage divergence. Our results illustrate the insight gained through interpreting population genetic variation using chromosomal genome assemblies, and provide links between genomic islands and the forces that contribute to their formation and persistence.

99-1 OSGOOD, A.C; SUTTON, G; ST.PIERRE, R; COX, S.M*; Mount Holyoke College, University of Bristol, Carnegie Mellon University, Penn State; *zanne@psu.edu*

More evidence against a force-velocity trade-off in dynamic lever systems

Levers impose a force-velocity trade-off. In static conditions, a larger moment arm increases a muscle's force capacity while a smaller moment arm enhances velocity at the end of the lever. However, muscle force is influenced by contractile velocity and fiber length. Additionally, the rate at which the muscle contracts is influenced by the inertial properties of the mass it accelerates. We hypothesize that these dynamic effects constrain the functional output of a muscle-lever system. We predict that there is an optimal moment arm for either force or velocity for any given muscle-lever configuration. Here we test this hypothesis by building and systematically modifying a simple lever system in OpenSim. The model consists of a mass on the end of a lever that pivots around a pin joint, driven by a Millard2012EquilibriumMuscle muscle with a non-compliant tendon. The muscle's moment arm was defined by the radius of a cylinder around which it wraps. We generated 3600 modifications of this model with different muscles with varying optimal fiber lengths, moment arms and starting normalized muscle lengths. For each model we simulated the motion that results from 100% muscle activation and extracted the maximum velocity of the driven mass as well as the total impulse applied to the mass from the onset of movement until the time of maximum velocity. In contrast to the common notion of a tradeoff between force and velocity in a lever system, we found that there was, instead, an optimal moment arm which maximized both velocity and total impulse. From this we conclude that in a dynamic lever system where muscle activation is held constant, there is no tradeoff between force and velocity.

36-4 OSMANSKI, AB*; JOHNSON, M; GONGORA, J; DENSMORE III , LD; RAY, DA; Texas Tech University, Dept of Biological Sciences, Lubbock, TX, University of Sydney, Sydney School of Veterinary Science, Sydney, Australia; *austin.osmanski@ttu.edu*

Genomic Signatures of Selection Detection Across the Order Crocodylia

Crocodylians are of considerable biological importance as the largest extant reptile and prevail as necessary components of healthy aquatic ecosystems worldwide. Understanding the evolutionary relationships among crocodylians is of vital importance for their conservation especially since many of the charismatic species within this order are listed as threatened or endangered by the ICUN Red List. Therefore, to better understand these organisms at a genomic level, we generated light-to-medium coverage Illumina data for 18 species of crocodylian and curated a comparative structural variant dataset while constructing reference-guided assemblies. Using the box-turtle genome along with multiple bird genomes as outgroups, we produced an array of shared single-copy orthologous genes among all species for selection detection. Putative genes under positive selection were identified and a Bonferroni correction was applied to increase conservativity. These data will improve our understanding of selection among crocodylians and provide a template for future investigation into their genomes.

5-1 OTHAYOTH, R*; THOMS, G; LI, C; Johns Hopkins University; *ratan@jhu.edu*

Animals and robots transition from more challenging to easier locomotor modes to traverse obstacles

Animals transition between multiple locomotor modes when traversing obstacles in complex terrain. However, the physics of such locomotor transitions are not well understood. Previous studies in our group of grass-like beam obstacle traversal observed that the discoid cockroach often pitches up when initially interacting with the beams (pitch mode). To traverse, the animal then either continues pushing down the beams with sustained pitching, i.e., continue to use the pitch mode, or transitions to roll mode by rolling the body into the gap between the beams. Curiously, whether the animal continues to use the pitch mode or transitions to the roll mode depends strongly on the stiffness of the beam obstacles. Here, we tested a robophysical model traversing beam obstacles with different stiffness and developed a potential energy landscape to understand these animal observations. We found that the system states were always strongly attracted to local minima basins on the potential energy landscape. Regardless of beam stiffness, the system was always more likely to transition from more challenging (higher minima) to easier locomotor modes (lower minima) on the landscape. At lower beam stiffness, the pitch local minimum was lower than the roll local minimum, i.e., the pitch mode was easier. Thus, pitch-to-roll transition did not occur. As beam stiffness increased, the pitch local minimum became higher than the roll local minimum, making the roll mode easier. Thus, the system was more likely to transition to the roll mode. These results from robophysical experiments were consistent with our animal observations. Our study revealed the physical principles governing the direction of locomotor transitions in complex terrain and is a step in establishing energy landscapes for locomotor transitions.

91-4 OTTER, K*; KATZ, P S; University of Massachusetts Amherst; *kotter@umass.edu*

Hunger state modulates the decision of a nudibranch to pursue or evade hazardous prey

Predators constantly make decisions about whether to pursue or evade prey, especially when their prey has the capacity to injure them. The nudibranch mollusc, *Berghia stephanieae* provides a special opportunity to study the neuroethology of predator pursuit and avoidance. Like many nudibranchs, it is a specialist predator, feeding exclusively on the sea anemone, *Exaiptasia pallida*. However, unlike other nudibranchs, it and its prey can be reared in the lab in large numbers facilitating experimentation on behavioral choice. When feeding, *Berghia* is repeatedly stung by the *Exaiptasia's* nematocysts and must decide whether to approach and feed or turn and evade. We characterized the feeding behavior and the probabilities of response to contact with the *Exaiptasia* in starved and sated animals to elucidate the neural mechanisms underlying the approach-avoidance decision making in this animal. The *Exaiptasia* can sting *Berghia* with its tentacles or with its acontia, structures with a higher concentration of nematocysts that are extruded as a threat response. The hunger state of the *Berghia* modulated their decision-making; hungry animals endured more stinging than sated animals. In response to contact with *Exaiptasia* tentacles, starved *Berghia* had a significantly higher probability of engaging with their prey than sated individuals, furthermore after contacting the *Exaiptasia* acontia, starved *Berghia* also had a significantly lower probability of an evasion response than sated animals. Moreover, starved animals spent a smaller proportion of time exploring the arena and more time feeding than sated animals. Thus, the choice of whether to pursue or evade is modulated by the animal's internal state; it seems that they make riskier choices when hungry. Future work will examine potential neural mechanisms for this cost benefit decision making.

105-4 OUFIERO, CE; Towson U; *coufiero@towson.edu*
Morphological evolution of the praying mantis (Mantodea) raptorial foreleg in relation to body size and depth perception
Mantises (Mantodea) are a group of 2600+ ecologically diverse species that all use raptorial forelegs for prey capture and processing. The mantis foreleg is comprised of the coxa, trochanter/femur, and tibia. During a feeding strike, extension of the coxa and trochanter/femur places the femoral and tibial spines in place for prey capture, which occurs when the tibia is flexed, trapping the prey in the spines. Variation in lengths of each segment may affect the mechanical advantage of the foreleg and influence feeding performance. While research on terrestrial, vertebrate locomotion has shown that variation in limb proportions have adaptively evolved across environments, much less is known about adaptive diversification of invertebrate feeding appendages. Furthermore, as feeding performance is influenced by the sensory system, few studies have examined the coevolution of sensory-motor structures. Using 97 species of mantises I examined foreleg diversification with a combination of methods, including ternary plots for morphospace visualization, phylogenetically informed allomteric relationships, and comparison of evolutionary rates of diversification. Furthermore, using head width as a proxy for depth perception, I examined the correlated evolution of foreleg diversity with depth perception. The results show that among the three segments of the foreleg, the tibia is the smallest, most diverse, and has the highest rate of evolution after body size corrections. Furthermore, while all foreleg segments were related to head width, head width explained the most variation in tibial length. The results suggest a potential adaptive functional role of the length of tibia related to the velocity or force produced in this second class mechanical lever. Furthermore, results from this study support distinct ecomorphs of mantises, as several independent evolutions to grass mimicry evolve similar morphologies.

P2-101 OWEN, P*; AGYEI, D; JILANI, C; JOSHI, D; MILLER, A; ODAKA, Y; TRAN, M; WILSON, K; University of Cincinnati; *patrick.owen@uc.edu*
Food Choices of Rusty Crayfish (Faxonius rusticus) Maintained on Fiber-rich and Protein-rich Diets Relative to Changes in Their Gut Microbiomes
The Rusty Crayfish (*Faxonius rusticus*) is native to the Ohio River Basin in North America but has become an invasive species in other regions. Rusty Crayfish are dietary generalists and opportunists, feeding on both cellulose-rich and protein-rich food items that are seasonally available to them. As part of a larger study examining how different types of diets (cellulose-rich vs. protein-rich) influenced the gut microbiomes of Rusty Crayfish captured from native parts of their range, we examined how diet-induced changes in microbial diversity might be related to dietary preference at the end of the study period. The first behavioral experiment involved placing crayfish in food-choice arenas where they could orient toward and follow chemical cues emitted from the two food types enclosed in perforated plastic tubes. The second behavioral experiment was performed in home containers, and the crayfish were able to directly choose one of the two food types and, in contrast to the first experiment, consume it. In terms of the initial contacts with food items, in both experiments crayfish did not significantly choose one food type over another. However, in the first experiment, crayfish that had been maintained on a cellulose-rich diet made more total contacts with tubes containing cellulose-rich food. These crayfish also showed greater increases in cellulose-digesting bacteria in their guts during the housing period compared with crayfish fed on the protein-rich diet.

P1-25 OYEKWE, O.L*; WAITS, D.S; HALANYCH, K.M; Auburn University; *olo0002@auburn.edu*
LTR retrotransposons in the non-model marine invertebrate Lamellibrachia luymesi (Annelida)
In vertebrates and plants, transposon-derived content can exceed half of the whole genome. Comparatively, data on transposons is mostly limited to model organisms, and thus Lophotrochozoa, the major bilaterian clade with the greatest diversity of body plans, is poorly sampled for transposons. Here, we focus on the genome of an invertebrate to gain knowledge of transposons in marine setting. Specifically, we are searching the genome of the hydrocarbon seep-dwelling tube worm Lamellibrachia luymesi (which hosts a horizontally transmitted gamma-proteobacterial endosymbiont) for Long Terminal Repeat retrotransposons (LTR retrotransposon). We made use of "LTR harvest" and "LTR digest" software packages, amongst other bioinformatics tools, to aid automatic annotation of LTR's in genome. LTR harvest finds repetitive structures of the LTR and LTR digest allows annotation of internal features and protein domains of putative LTR retrotransposons using local alignment and Hidden Markov Model based algorithm to detect retrotransposon. The identified elements were clustered and classified into families based on the 80-80-80 similarity rule. Our preliminary results suggest that Lamellibrachia luymesi hosts several known LTR retrotransposon families with putative GYPSY elements being one of the most common. We plan to further classify transposable elements in this non-model marine invertebrate and then extend our comparative analyses to other lophotrochozoan taxa.

4-3 OZALP, MK*; MILLER, LA; STRICKLAND, C; UNC, Chapel Hill, NC, UT, Knoxville, TN; *mkoz@live.unc.edu*
PLANKTON DISPERSION THROUGH VEGETATIVE SEABED WITHIN COMPLEX FLOW ENVIRONMENTS
The movement of plankton is often dictated by local flow patterns, particularly during storms and in environments with strong flows. Reefs, macrophyte beds, and other immersed structures can provide shelter against washout and drastically alter the distributions of plankton as these structures alter and slow the flows through them. Advection diffusion and agent-based models are often used to describe the movement of plankton within marine and freshwater environments and across multiple scales. Experimental validation of such models of plankton movement within complex flow environments is challenging, however. In this study, we experimentally investigate plankton dispersion through various, rigid macrophyte models in complex flow environment at the scale of tens of centimeters. We use *Artemia* spp., or brine shrimp, as a model organism given their availability and ease of culturing. Experiments were conducted within a flow tank with simplified physical models of macrophytes. These simplified models were 3D-printed arrays of cylinders of varying heights and densities. *Artemia* nauplii were injected within these arrays and their distributions over time were recorded with multiple video recorders. The detailed three-dimensional flow fields were quantified using computational fluid dynamics and validated experimentally with 2D particle image velocimetry. Complementary agent-based simulations of the movement of brine shrimp through these structures were also performed. The results show that increasing density and the height of the macrophyte bed drastically increases the average time it takes the plankton to be swept downstream. It was also observed that some brine shrimp can entirely avoid being swept away in the presence of macrophyte model. This phenomenon was observed only in the close vicinity after the model and only at the bottom of the flow tank, where the effect of the boundary layer is significant. Moreover, more brine shrimp stayed attached with the increased density and height and the zone of attachment extended, as well. However, no shrimps could avoid being swept away in the model. Agent-based models of brine shrimp that move with random motion and are advected with the flow show similar trends.

96-8 OZKAN-AYDIN, Y*; GOLDMAN, D I; BHAMLA, M S; Georgia Institute of Technology; *yaydin6@gatech.edu*

Collective Behavior of Worm Blobs

Aggregate formation and clustering are common behaviors observed across taxa and can facilitate the survival of the collective (Allee, 1978). Here we study the aggregation of blackworms (*Lumbriculus variegatus*) into large ensembles of entangled, living "blobs" composed of thousands of worms knotted together. To understand the mechanism and advantages of aggregation in these worm blobs, we systematically expose them to different environmental stresses including evaporation, light, temperature and starvation. The diameter of the worm blob can be controlled by both light stimulus history and light intensity. At low light intensity the blob dilates; conversely, increasing the light intensity contracts the blob and leads to more entangled and tightly packed state. This behavior also affects the collective movement under thermal stress. Under high light intensity (>1500 Lux) we find that a 5 g (600 hundreds) worm blob placed under a linear temperature gradient between 15 to 50°C stay as a blob and move collectively to the cold side at speeds of 0.35 ± 0.001 cm/min. In contrast, if the light intensity is reduced to 400 lux, the worm blob dissipates and individual worms crawl to the cold side with a speed of 0.38± 0.01 cm/min. We find that the number of surviving worms increases as they move as a blob. Finally, we show that this worm blob can also navigate structured environments (mazes) to survive from starving. Individual worms search the maze and the worm blob finds the shortest path to the food source. We hypothesis that the exchange of information between individuals and the perception of nutrient concentration released from a food source determines the direction of migration.

P2-227 OZKAN-AYDIN, Y*; LIU, B; GOLDMAN, D I; HAMMOND III, F L; Georgia Institute of Techology; *yaydin6@gatech.edu*

Lateral Undulation Aids Soft Earthworm Robot Anchoring and Locomotion in Heterogeneous Environments

Earthworms are characterized by soft, highly flexible and extensible bodies that are capable of locomoting in most terrestrial environments (Trueman1975). Most studies of earthworm movement have focused on the use of retrograde peristaltic gaits. However, worms can also generate axial body bends during locomotion (Gray1968). Such lateral undulation dynamics can aid locomotor function via hooking/anchoring, modify travel orientation, and even generate snake-like undulatory locomotion in environments where peristaltic locomotion results in poor performance. We posit that lateral undulation can play an important role in the creation of soft robotic devices capable of traversing a variety of environments. To understand how the mechanism should move through complex and heterogeneous environments, we built a four-segment pneumatically-driven soft worm-like robot. From our animal experiments, we observed that within confined and heterogeneous environments, the worm uses tip bending to search the environment and to anchor its body. We tested this strategy in our robot both in a confined environment (in an acrylic tube D = 4.3cm) and in a regular lattice (an array of evenly spaced pegs). We started the robot from the same initial position and measured the forward displacement per gait cycle (ΔX). The robot performed better for both cases when it used tip bending (in the tube ΔX =0.11± 0.005 BL/cycle, in the lattice ΔX = 0.06± 0.003 BL/cycle) compared the runs without tip bending (in the tube ΔX =0.05± 0.003 BL/cycle, in the lattice ΔX = 0.012± 0.002BL/cycle). These results show that this simple open-loop, undulatory locomotion strategy can be considered a beneficial method for exploring environments where there is uncertainty about the structure of the terrain.

52-1 PADDA, SS*; JOHNSON, DJ; GLASS, JR; STAHLSCHMIDT, ZR; U Pacific, Ariz State U; *s_singh40@u.pacific.edu*

Alter Investment or Conserve? Assessing animal strategies to limit costs from concurrent weather extremes

Climate change models predict an increase in the co-occurrence of heat waves and water limitation (e.g., drought). Both of these stressors can independently impact an animal's resource (energy or water) balance, which is tightly linked to survival and reproduction. Yet, the interactive (e.g., additive or synergistic) costs of heat wave and water limitation to animals is poorly understood. Animals experiencing heat wave and/or water limitation may employ two general strategies to limit costs to resource balance. Stressed animals may use a resource conservation strategy via shifts in physiology (e.g., reducing metabolic rate to conserve energy or altering integument to reduce water loss) or behavior (e.g., reducing behavioral activity to limit energy use and water loss). Second, stressed animals may alter their resource investment strategies whereby resources are divested from one trait to maintain investment into another trait. We used a factorial design on fasted wing-dimorphic crickets (*Gryllus lineaticeps*) to examine the independent and interactive costs of a field-parameterized heat wave and water limitation. We determined survival, energy balance and loss (body mass and metabolic rate, respectively), water balance and loss (total water content and evaporative water loss rate, respectively), behavioral activity, and investment into reproduction (gonad mass), locomotion (flight muscle), and immune function (total phenoloxidase activity). Together, our results will clarify the costs of multiple stressors to several levels of biological organization (from life history to behavior and physiology), and reveal complexities underlying general strategies employed during resource-related stress.

P1-104 PADILLA, GM*; WOODS, CE; TODD, KL; Westminster College; *gmp0816@westminstercollege.edu*

Electrophysiological Responses of Hirudo verbana to Different Intensities of Ultraviolet Radiation

The leech *Hirudo verbana* sees the world through two different sets of eye cups: cephalic and sensillar. Cephalic eye cups are located on the anterior sucker, whereas sensillar eye cups are situated along the leech body. Recent studies show that shining ultraviolet radiation (UVR) on the different eye cups elicits different escape behaviors. These behaviors have yet to be characterized at a cellular level. We recorded electrical activity from the leech nerve cord to see how cephalic eye cups are encoding visual information. We also modulated light brightness to determine how leeches distinguish different UVR intensities. Lastly, to further understand the anatomical pathway of cephalic eyes and how they transmit visual information, we attempted to identify the neural pathway from the cephalic eyes to the leech headbrain. This data will be paired with behavioral assays, as well as electrophysiological recordings from sensillar eyes. We hypothesized that intensities will be encoded as follows: higher UVR intensity yields more action potentials, and each type of eye will encode UVR through a different action potential pattern. These differences may underlie the two escape behaviors. Our raw data recordings indicate that there is a difference in the firing pattern for different intensities of UVR shined on the cephalic eye cups. This work will lend insights on how *H. verbana* detects where light is coming from, and how the organism processes different intensities of aversive stimuli.

114-5 PAEZ, L*; MELO, K; IJSPEERT, AJ; EPFL;
laura.paez@epfl.ch

The advantage of gait of mosquito larvae over undulatory swimming

Although the elongated morphology of mosquito larvae shares similarities with several other aquatic organisms, many of which swim under comparable hydrodynamic conditions using undulatory gaits, their locomotion consists of unsteady sideways strokes of the paddle-like end of their articulated body. This pulls back a large volume payload (the insect thorax) located at the other end of their body. We hypothesize that such a gait may help transport larger payloads at certain hydrodynamic regimes, as compared to undulatory swimming gaits. We analyzed the kinematics of larvae motion using videos, to break down their gait into different instances of thrust generation. Previous studies explain the drag-based thrust generated solely by the paddle motion. However, these studies overlook other important inertial thrust contributions. We identified translations of the center of mass due to changes of the body configuration across the stroke time, as well as body rotations due to angular momentum conservation, that enhance the paddling action by conveniently reorienting the body at each stroke. To this end, we created a model that faithfully captures the kinematics of the larvae gait in a form of a large amplitude, small wavelength traveling wave along the body, giving us the possibility to track the center of mass motion using different body segment mass properties. This opens questions about the role of discrete articulated segments present on the larvae's body, compared to the continuous body in undulatory swimmers, the role of a passive/active paddle in comparison to tail fins, and how the payload payload impacts the gait's cost of transport to favour unsteady gaits over undulatory ones. To make such comparisons, we complemented our model with a physical robot to experimentally test and validate our observations on living larvae.

21-8 PAGGEOT, LX*; GOSLINER, TM; California Academy of Sciences; *lpaggeot@calacademy.org*

Stinger Thieves: Nematocyst Acquisition Process in Aeolid Nudibranchs

Nudibranchs encompass over three thousand species around the world, and still counting. One subgroup of nudibranchs is called aeolids: a specialized group of nudibranchs that are capable of stealing nematocysts from their cnidarian prey and using them as part of their own defensive mechanism. Nematocysts are also known as "explosive cells", a variety of special organelles that are present in cnidarians. The relationship between the nematocysts in nudibranchs and their cnidarian prey remains unclear due to the variation and diversity within nematocysts. Earlier studies also show a discrepancy in the results, warranting a project looking at different species of aeolid nudibranchs and their cnidarian prey. My project focuses on comparing nematocyst content in multiple aeolids and cnidarians along the Californian coast to examine specificity of nematocyst selection and retention within Nudibranchia. Preliminary results show that different aeolid nudibranchs vary in the diversity of nematocysts they retain, and these only represent a subset of nematocysts found in their prey.

70-3 PALAVALLI-NETTIMI, R*; THEOBALD, JC; Florida International University, Miami, FL; *rpalaval@fiu.edu*

Light intensity and eye size dependent spatio-temporal visual abilities in Drosophila melanogaster

The fruit fly *Drosophila melanogaster* is sensitive to light and prefers certain light intensities. But lab-reared flies are often tested for vision in bright light conditions to obtain the best response. Similarly, scarce feeding during the late larval stage, which is common in nature, can lead to smaller flies contributing to a wide range of body and eye sizes which are not observed in lab colonies fed ad libitum. Flying with smaller eyes and under dimmer light conditions is challenging due to reduced signal-to-noise ratio affecting visual behaviors. To better understand the visual capabilities of flies in nature, it is thus important to study flies of different eye sizes and under different light intensities. In this study, we use a virtual reality flight arena and moving sinusoidal gratings to test how spatial acuity, temporal acuity and contrast threshold are affected at different light intensities in female flies that vary in eye size. We also investigate vision in often neglected male fruit flies under different light intensities and compare them to that of females. We show that as light intensity drops from 50.1 lx to 0.3 lx, it leads to reduced spatial acuity (females: from 0.1 to 0.06 cycles per degree, CPD, males: 0.1 to 0.04 CPD) and temporal acuity (females: from 50 Hz to 10 Hz, males: 25 Hz to 10 Hz), and higher contrast detection threshold (females: from 10% to 29%, males: 19% to 48%). We find no major sex-specific differences in visual abilities after accounting for eye size variation. While vision in both small (eye area 0.1 to 0.17 mm^2) and large flies (0.17 to 0.23 mm^2) reduce at 0.3 lx compared to 50.1 lx, small flies suffered more (spatial acuity: 0.03 vs 0.06 CPD, contrast threshold: 76% vs 57%, temporal acuity: 5 Hz vs 10 Hz). These results have implications to many visual behaviors in flies.

40-7 PALECEK-MCCLUNG, AM*; BLOB, RW; Clemson University; *apalece@g.clemson.edu*

Wading through water: The influence of water depth on the locomotion of the Chilean Flamingo (Phoenicopterus chilensis)

One of the factors impacting the diversity of locomotor modes in animals is the habitat in which movements are performed. Environments like water and land impose different physical demands and, as a result, many species that operate in both environments use a distinct mode of locomotion in each; for example, swimming in water versus walking on land. However, many species that move between land and water may continue to use a terrestrial mode of locomotion in aquatic environments. If animals are not entirely submerged, such behaviors are termed wading, and are present in a variety of taxa including amphibians, reptiles, mammals, and birds. As animals move through water of increasing depth, species with long legs may be able to lift their feet above the water surface to reduce drag that could slow their performance. However, there may also be a critical depth, above which it becomes awkward to raise the foot above the surface, and kinematics again resemble terrestrial patterns of movement. To test these predictions, head, body, and limb kinematics of the long-legged Chilean flamingo (*Phoenicopterus chilensis*) were measured as birds walked through increasing depths of water in a zoo enclosure. A variety of kinematic changes occurred across environmental conditions. As flamingos moved through deeper water, they showed a combination of slower movements with mass concentrated closer to the body that may help to increase stability as hindlimb angular excursions became more exaggerated. Although a critical depth at which wading kinematics began to resemble those used in terrestrial habitats was not identified over the range of depths tested, our results show that wading birds can implement a range of kinematic strategies to enable successful movement through different water depths.

51-4 PALERMO, NA*; SIDDIQUI, SG; THEOBALD, JC; Florida International University; *npale005@fiu.edu*
Drosophila melanogaster uses its regional attention to maxamize spatial information during flight.
Fruit flies rely heavily on their visual field to stabilize flight. The images projected onto their retinas are only as useful as the amount of information they provide. The spatial information capacity of the eye (H) is a measure of how many unique images can be drawn onto the eye and therefore describes the usefulness of images presented onto it. H depends on endogenous factors of the eye but also on the image source. Dim, low contrast, or fast-moving images all result in lower H. Flies recover this lost H via neural pooling but here we explored how attention shifting can also recover H. We found that flies actively shift attention to predictably slower moving regions as light levels decrease. We also found that the eye is passively designed to respond stronger frontally under low contrast conditions where images would likely be moving slower. Both these attentional strategies would maximize H under sub optimal flight conditions.

P2-183 PAMFILIE, AM*; GARNER, AM; NIEWIAROWSKI, PH; The University of Akron; *amp183@zips.uakron.edu*
Watch Your Step: A Comparison of Digital Morphology Across Ecomorphs in Anolis Lizards
Anolis lizards have been heavily studied ecologically for their morphological niche partitioning. These lizards are known to exhibit ecomorphological trends, where several distantly related species convergently evolved to resemble each other due to similar microhabitat conditions. However, fewer studies have examined the digital features of these lizards in relation to their ecology. Anoles, like geckos, possess adhesive subdigital pads and claws on their digits that allow them to adhere and cling to a variety of substrates. Adhesive pads have been intensely studied for their multifunctionality and unique fibrillar structure. Claws, on the other hand, have been studied more frequently in an ecological context. Claw morphology has been related to habitat in other genera of lizards, such as *Varanus* and *Liolaemus*. While some relationships between digital morphology and habitat have been demonstrated for *Anolis*, these correlations have generally not included claw morphological characters. This study will investigate trends in digital morphology and their relationships to microhabitat and substrate use. Trends are expected to resemble those in other lizards, such as curved, short claws and large toe pads in arboreal species and uncurved, long claws and small toe pads in more terrestrial species. Studies thus far on the functional ecology of adhesive toe pads have been lacking in geckos and anoles. Examining the toe pad in the context it evolved may inform both the relevant characteristics and appropriate applications of synthetic fibrillar adhesives. Furthermore, a similar approach to studying claw morphology may help explain the functional relationship of the claws to the toe pads and to interactions with the substrate.

P2-203 PANESSITI, CE*; RICKARDS, G; RULL, M; KONOW, N; UMass Lowell, Andover High; *Caitlin_Panessiti@student.uml.edu*
Does the contribution of elastic recoil vary with temperature and between strike and chewing behaviors in axolotl feeding?
In feeding systems, jaw opening and closing may involve both muscle contractions and the stretch and recoil action of elastic structures including tendons and ligaments. The contribution of these elements may vary, both with changes in behavior and temperature. Muscles are less capable at extreme temperatures due to enzymes being less functional, which follows the Q10 principle. However, the action of elastic systems is supposedly temperature insensitive. The goals of this study were to use temperature manipulations during axolotl feeding to determine if feeding behaviors involve elastic recoil, and also to determine whether or not the contribution of elastic structures varies among behaviors, specifically strikes and chews. High-speed recordings were taken of seven axolotls feeding on crickets at low (6°C), intermediate (14°C), and high (23°C) temperature. We extracted gape opening and closing speeds for each behavior and temperature treatment. We found that gape opening speed for strikes increases with temperature, but the closing speed for strikes is unaffected by temperature. These data indicate that gape opening during strikes is largely muscle controlled, whereas gape closing during strikes is elastic recoil driven. During chewing, both gape opening and closing speed decreases as temperature increases. We cannot fully explain this result, but hypothesize that at low temperatures, the muscles involved are nearly incapacitated, leaving only elastic recoil to drive the behavior. As the animal warms, the muscles can function, and actually slow the entire process down. These data add to a surprisingly small body of evidence of elastic recoil action in vertebrate feeding systems.

P2-146 PARRY, HA*; YAP, KN; GLADDEN, LB; HILL, GE; HOOD, WR; KAVAZIS, AN; Auburn University, Auburn, AL; *hap0017@auburn.edu*
MitoMobile Validation: Taking a Molecular Physiology Lab to the Field
Mitochondria have been of great interest to ecologists and physiologists because their function has large impacts on the evolution of species and the performance of individual organisms. Measurements of mitochondrial function within the skeletal muscle and liver tissues of an animal provide valuable insight into how an animal is responding to natural challenges or experimental interventions. Laboratory settings are often unable to replicate the natural environment of animals and the responses of those animals to natural events. Additionally, the ability to catch a wild animal and bring it into the lab for measures of mitochondrial respiration causes additional stress on the animal, and therefore the measurements may no longer be a "true" representation of mitochondrial respiration. To address these challenges, we converted a recreational vehicle into a mobile physiology laboratory (MitoMobile) in order to bring the molecular physiology lab to the field. To establish the utility of the MitoMobile, the methods of mitochondrial isolation and functional measures must be validated. To complete this, mitochondrial isolations with deer mice, house mice, and house finches will be completed in the MitoMobile and in a standard wet physiology lab (n=16 per species). Two technicians will complete mitochondrial isolations on skeletal muscle and liver at each location (n=8 per species) before switching locations (n=8 per species) and performing the methods again. This methodology will provide validation of each location and each technician. Data on coefficients of variation, maximal respiration (state 3), basal respiration (state 4), and the respiratory control ratio (RCR) will be presented.

45-5 PARTRIDGE, CG*; MACMANES, MD; KNAPP, R; NEFF, BD; Grand Valley State University, University of New Hampshire, University of Oklahoma, University of Western Ontario; *partridc@gvsu.edu*

Brain transcriptional profiles of alternative reproductive tactics in bluegill sunfish

Bluegill sunfish are a classic system for studying male alternative reproductive tactics (ARTs). In this species, there are two life histories: parental and cuckolder, encompassing three reproductive tactics, parental, satellite, and sneaker. The parental life history is fixed, whereas within the cuckolder life history individuals appear to transition from the sneaker to the satellite tactic as they grow. We used RNAseq to identify differentially expressed transcripts in the brain of male ARTs and females during spawning. Sneaker males had higher levels of gene differentiation compared to the other two male tactics. Specifically, sneakers males exhibited high expression in ionotropic glutamate receptor genes, which may be important for working spatial memory while cuckolding parental males. We found expression differences in several candidate genes previously identified in other species with ARTs, suggesting some conserved pathways influencing these behaviors.

16-3 PASK, GM; Bucknell University; *g.pask@bucknell.edu*

Working to Learn: Applying Labor-Based Assessment to Scientific Writing and Laboratory Courses

There is a growing concern in higher education that students are focusing too much on grades and too little on their own learning and growth. Not only does grading for accuracy inadequately reflect a career in science, but it can disadvantage students with different backgrounds who may be unfamiliar with how to "play the game" of the education system. Across several disciplines in higher education, assigning grades to students based on their effort has shifted the focus to learning and self-improvement as well as created a more equitable and inclusive classroom. I've incorporated several aspects of labor-based assessment into my upper-level scientific writing course, where students routinely engage in a variety of writing assignments that are graded on completion instead of conforming to my own rubric. Students have appreciated the freedom to take risks in their writing without being penalized by point reductions and enjoyed having more ownership over their writing. In my laboratory course, students work toward achieving specific goals throughout the semester that prioritize technical mastery, experimental design, data analysis, and a peer learning environment. In evaluations and self-reflections, students found this goal-oriented approach to be very effective in their development as scientists, and it mirrored the types of experiences they hoped for in joining research labs. For both classroom and laboratory contexts, I present labor-based assessment as an approach to encourage self-motivated learning in all students regardless of their educational background.

PLEN-1 PATEK, S.N.; Duke University; *snp2@duke.edu*

Plenary Lecutre - Impact and discovery: extreme movement in an interdisciplinary and political world

Organisms moving at the outer known extremes of speeds and accelerations reveal new phenomena that push the boundaries of knowledge in numerous fields. The very first ultra-high speed images of mantis shrimp (stomatopod) raptorial strikes revealed imploding cavitation bubbles that emit heat equivalent to the surface of the sun. This discovery sparked research into the pathways and durations of energy transformation – from loading springs to cavitation implosion – that span the order of magnitude difference between one second and one year. The extraordinary cascade of energy flow and control in mantis shrimp strikes aligns with their evolutionary diversification to capture fish and crush snails, as well as their ritualized behaviors to ensure non-lethal fights. These biomechanical, behavioral, and evolutionary insights have stimulated a vibrant interdisciplinary field of materials and robotics. The dynamism of these systems has also attracted considerable attention from the public, press, and politicians. This talk will address the intersection of biological discovery with interdisciplinary and accessible research, and foster general discussion about the impacts and adventures of discovery science.

P3-94 PAULAT, NS*; MANTHEY, JD; PLATT II, RN; RAY, DA; Texas Tech University, Lubbock, Texas Biomedical Research Institute, San Antonio; *nicole.paulat@ttu.edu*

Transposon Activity and Mutational Impacts in Myotis

Transposable elements (TEs) are DNA sequences that mobilize through copy-and-paste or cut-and-paste mechanisms, expanding within a host genome. *Myotis* is one genus within vespertilionid bats which has experienced an unorthodox TE history. For example, their genomes are unique among mammals in containing many active DNA transposons, which continue to shape their genomic landscapes. Recent data suggests that, in addition to the indel mutations normally associated with TE activity, these genetic elements may also contribute to higher mutation rates via low-fidelity DNA repair mechanisms. DNA transposons preferentially insert near genes, and so transposon activity may be correlated with mutation rate increases in regulatory regions and coding sequences. Retrotransposons likely have a similar, but lesser mutational impact, as the elements insert via single-stranded nicks, and do not excise themselves. An analysis of transposon polymorphisms in eleven *Myotis* species, identified by Mobile Element Locator Tool (MELT), will reveal the extent of mutations in nearby genes that are associated with DNA repair after transposon insertions and excisions. These increased mutation rates could correlate to differences in orthologous genes between closely related *Myotis* species and contribute to our understanding of this exceptionally diverse clade.

18-6 PAYETTE, WI*; RICHTER, MM; HODINKA, BL; PULLUM, KB; ASHLEY, NT; Western Kentucky University, Simon Fraser University, University of Pennsylvania;
wesley.payette468@topper.wku.edu

Effect of sleep on loss on parental care in Arctic-breeding songbirds

Sleep loss is well known to impair cognitive function, immunological responses, and general well-being in humans. However, sleep requirements in mammals and birds may vary dramatically, especially with changes in environment. In circumpolar regions with continuous light, sleep requirements may be little, particularly in breeding birds. The effects of sleep loss on several fitness parameters were examined in two species of Arctic-breeding passerine birds: Lapland longspurs (*Calcarius lapponicus*) and snow buntings (*Plectrophenax nivalis*). Adult males were implanted during the nestling phase (4 days post-hatch) with osmotic pumps containing an anti-narcolepsy drug, modafinil, to induce sleep loss for 72 h. We measured nestling weights on day 2 and day 7 following hatching. In addition, we conducted 1 h observations of nestling feeding rates on day 6 post-hatch. Recent data show that adults undergo a 4-5 h quiescent period between 0000h and 0500h. We predicted that further inhibition of sleep may temporarily increase feeding rates, but eventually lead to decreased parental care and slower nestling development from birds needing to sleep after pharmacological inhibition. Alternatively, as high-arctic species are adapted to continuous light throughout their breeding season, mechanisms may exist that allow them to function normally despite loss of sleep.

P2-105 PENDLETON, LP*; CORNELIUS, JM; CHAPPLE, TC; WIKELSKI, M; HAHN, TP; HUNT, KE; Eastern Michigan University, University of Oregon, Max Planck Institute of Animal Behavior, Germany, University of California, Davis, Northern Arizona University; *lpendlet@emich.edu*

Food Availability and Its Effects on Spatial Habitat Use in Breeding and Nonbreeding Red Crossbills (Loxia curvirostra)

Animal movement plays a significant role in the development and fitness of species, population dynamics and the stability of resources within ecosystems. The ability of an animal to secure resources requires energy spent searching and is reflected in their movement and breeding patterns. This study aims to investigate the relationship between food availability and movement patterns of breeding and nonbreeding red crossbills (*Loxia curvirostra*). We captured 40 birds using live decoy lures and mist nets through the summer and winter of 2009 and 2010 and through the summer and winter of 2016 and 2017, which represented low food years and high food years, respectively. Birds were fitted with a continuous-tone radio transmitter, released and subsequently tracked for 48 hours. GPS coordinates were recorded and later used to generate Brownian Bridge Movement Models (BBMMs) to analyze spatial habitat use across seasons. Total linear distance traveled and total area of activity will be used as two quantitative measures of general activity. We discuss activity patterns and habitat use in the context of foraging theories, food availability, season and red crossbill foraging ecology.

137-5 PEPPER, H E*; PARTIN, A M; JENKINS, M S; ROWLAND, J F; BURGHARDT, G M; University of Tennessee, Knoxville;
hpepper@vols.utk.edu

Responses of Juvenile Eastern Garter Snakes (Thamnophis sirtalis) to Own, Littermate, and Control Chemicals

Chemical cues and signals are essential components of numerous behaviors among squamate reptiles, especially snakes. Tongue flicking allows transfer of chemical cues to the vomeronasal organ and the accessory olfactory bulb. Past studies have suggested that several species of snakes can discriminate chemicals deposited by themselves, conspecifics, or clean controls. Is this a measure of self-recognition? Most studies have used visual recognition, using a mirror. However, animals relying on different types of cues may use non-visual means of self-recognition. Prior snake studies, while suggestive, lacked controls, such as for diet and genetics, and video recording. We carried out a study on 24 juvenile eastern garter snakes, Thamnophis sirtalis, with an even sex ratio, from a single litter. We manipulated substrate chemicals in test arenas using clean or previously occupied cage liners and measured the frequency of tongue flicking and general activity. Each snake was tested under four conditions: one's own substrate, substrate of a same sex littermate fed the same or different diet (fish or worm), or a control clean substrate. Trials lasted 30 minutes, were video-recorded, divided into three 10-minute segments, and both tongue flick and activity counts tallied for each segment. We found that tongue flick and movement rates were consistently lower in the own chemical vs the control condition, replicating prior findings. We also found sex and diet differences with regard to tongue flick rates to own vs conspecific chemicals of snakes fed identical diets. These appear to be the first data showing sex differences pre-reproductively.

P2-171 PERCIVAL, C*; PULLEY, K; TAPSAK, S; TSCHEULIN, T; PENTANIDOU, T; GONZALEZ, V; ABRAMSON, C; HRANITZ, J; BARTHELL, J; Pomona College, University of Texas at El Paso, Bloomsburg University, University of the Aegean, University of Kansas, Oklahoma State University, Bloomsburg University, University of Central Oklahoma;
crpa2017@mymail.pomona.edu

The effect of social context, acclimation, and feeding status on critical thermal maximum of honey bees

The temperature at which an organism can no longer escape death (CTmax) has been proposed as a measure of a species' thermal tolerance. As climates shift it becomes important to understand how organisms will be affected. Insects' status as indicators of environmental change makes them valuable tools for predicting the effects of climate change. Our research focused on the Greek honeybee (Apis mellifera cecropia) and how its ability to resist high temperatures changed in response to several variables: social context, acclimation, and feeding status. Our results demonstrate that our social context and acclimation protocols did not affect CTmax in honeybees. Feeding status had a significant effect on CTmax ($H=488.5$, $p=<0.001$), with unfed bees spasming faster and at lower temperatures (40°C). This suggests that feeding status is an important component of a honeybee's ability to resist high temperatures. Grouping bees and allowing bees to cool partway through trials did not appear to affect CTmax.

P1-194 PEREDO, C.M*; MARSHALL, C.D; University of Michigan, Ann Arbor, Texas A&M University, Galveston; *cmperedo@umich.edu*

Orientation of the orbit predicts feeding ecology in marine mammals

Marine mammals represent textbook examples of macroevolutionary change to facilitate their transition to life in the water. Carnivorous marine mammals, such as cetaceans and pinnipeds, have dramatically altered their feeding strategies relative to their terrestrial ancestors. Both clades independently lose mastication, a hallmark of mammalian feeding, and there are numerous examples of individual lineages within each clade independently converging on specific feeding modes (i.e. suction feeding, filter feeding, raptorial feeding). However, understanding the breadth of morphological changes associated with these shifts in feeding strategy has proved elusive, largely because feeding ecology cannot be observed for fossils. Here, we examine the relationship between the orientation of the orbit, measured as a deflection from the sagittal plane, and distinct feeding strategies in modern marine mammals with known feeding ecologies. In the extant walrus, *Odobenus rosmarus*,extreme lateral deflection of the orbits correlates with the evolutionary transition from raptorial to benthic suction feeding in this lineage. Similar patterns are observed in certain cetacean lineages that more exclusively rely on benthic suction feeding, suggesting that raptorial feeding selects for anteriorly oriented orbits. This suggests that the morphology of sensory systems, such as the orientation of the orbit, may be informative for predicting the feeding ecology of fossil marine mammals.

73-4 PEREVOLOTSKY, T*; GENIN, A; HOLZMAN, R; Tel Aviv University, Hebrew University of Jerusalem; *taltal.pere@gmail.com*

Work That Body: Thrust generated by the fins and body contributes to the feeding success of herbivorous reef fish

Herbivorous fish feed by biting, tearing or scraping algal material off the substrate. Due to their neutral buoyancy, fish feeding off hard surfaces may experience a recoil force pushing them backwards as they bite their food. To successfully detach prey items from hard substrates, fish need to constantly generate thrust in order to maintain contact with the substrate and pull the prey away. However, studies on adaptations for herbivory in fishes have hitherto focused on the jaws and teeth, neglecting the role of thrust-generating mechanisms. We hypothesize that these fish coordinate body and fin movements with mouth kinematics to facilitate algal removal. We used an underwater video system composed of two synchronized high-speed cameras, to observe the feeding kinematics of two *Zebrasoma* species *in situ*, in the coral reef. The system provided accurate 3D kinematics of the fish's mouth, fins and body, while a synchronized load cell recorded the forces exerted by the fish while feeding from a feeding plate. We found that bites were characterized by stereotypic and coordinated movements of the mouth, head and fins. Fish opened their mouth when approaching the feeding plate, reaching peak gape and often starting to close the mouth before initiating contact with the plate. Sideways head flicks accompanied almost all the bites. Upon mouth closing on the algae, fish swung their head laterally while moving their pectoral fins forward. This coordinated movement exerted a pulling force that was used to tear the algae from the substrate. Our results show that thrust generating mechanisms play a crucial role in the feeding success of herbivorous fish and suggest that adaptations for hard surface feeding expand beyond teeth and jaws.

79-3 PEREZ, JH*; TOLLA, E; DUNN, IC; MEDDLE, SL; STEVENSON, TJ; University of Glasgow, Roslin Institute, University of Edinburgh, Roslin Institute, University of Edinburgh; *Jonathan.Perez@glasgow.ac.uk*

Neuropsin and VA-opsin both facilitate photoinduction of avian seasonal breeding

Avian seasonal breeding has long been tied to the seasonal change in photoperiod in a number of temperate zone species. Unlike mammals, detection of light cues has been shown to occur independent of both the eyes and pineal glands via extra-retinal photoreceptive opsins located in the medial basal hypothalamus. To date, the precise identity of the specific opsin types and populations responsible for the photoinduction of seasonal breeding remains unresolved. Based on brain localization and light spectra profiles two potential candidates have emerged for the detection of light cues with respect to breeding; Neuropsin (Opn5) and Vertebrate Ancient Opsin (VA-opsin). Utilizing recent developments in viral vector technology we have silenced Opn5 and VA-opsin expression independently and together in the medial basal hypothalamus of Japanese Quail (*Coturnix japonica*) prior to photostimulation by long days (18L:6D). Body weight and cloacal gland volume was measured weekly for 4 weeks following photostimulation, a period sufficient for un-manipulated animals to reach reproductive condition. We found that RNA inhibition of Opn5 or Both showed an increase in mass gain rate when compared to VA only and control individuals. All three silencing treatments (Opn5, VA, Both) displayed reduced rates of cloacal gland growth (K) compared to control birds suggesting opsin silencing decreased the rate of hypothalamus-pituitary- gonadal (HPG) axis activation. Our data suggest that both Opn5 and VA-opsin play a key role in the activation of the reproductive axis in response to photostimulation and seasonal mass gain may be controlled via partially independent pathways from the HPG axis. Research was funded by the Leverhulme Trust and BBSRC (BB/P013759/1).

36-5 PERRY, BW*; SCHIELD, DR; MACKESSY, SP; CASTOE, TA; University of Texas Arlington, Arlington, TX, University of Northern Colorado, Greeley, CO; *blair.perry@uta.edu*

Mechanisms Driving Venom Gene Regulation in Rattlesnakes Revealed Through Integrative Analyses of Genome Structure and Function.

The evolution of novel organ systems necessitates the evolution of regulatory architecture to facilitate the function of the new organ. Understanding the processes by which this architecture evolves can provide broad insight into the evolution of phenotypic and physiological novelty and demonstrate previously unknown genomic features important for gene regulation. However, most organ systems are exceptionally complex and are driven by the coordinated regulation of thousands of genes located throughout the genome, making detailed interrogation of regulatory mechanisms exceedingly challenging. The snake venom gland represents an ideal system in which interrogate hypotheses about the evolution of novel regulatory architecture as it exhibits precise and high-magnitude regulation of a comparatively small set of principal genes, evolved relatively recently, and is physiologically distinct from other snake organ tissues. Here, we leverage the snake venom gland system and multiple integrative genomic analyses including Hi-C sequencing to investigate the evolution of venom gene regulatory machinery and provide new perspectives on the interplay between the evolution of regulatory sequences and the three-dimensional regulation of genome architecture in driving novel patterns of gene expression. Specifically, we identify transcription factors and regulatory pathways that have likely been co-opted from non-venom tissues and rewired to regulate venom gene expression, in conjunction with new insight into the role of three-dimensional organization and interaction of chromosomes during venom gene regulation.

9-5 PETERS, JM*; PETERSEN, KH; Cornell University;
jcbptrs@gmail.com

Honeybee swarms use a flow-mediated pheromone signaling scheme to coordinate aggregation

Reproductive honeybee swarms form when thousands of workers fly from the nest with a queen, land on a nearby surface and aggregate around the queen to form a bivouac or cluster. The queen emits a volatile pheromone to attract the workers, but its dispersal is initially diffusion-limited. When a worker locates the queen it orients its head towards her, exposes the Nasonov scent gland on its abdomen and fans a jet of pheromone-laden air away from the queen with its wings. Other workers align with this airflow and propagate it. In this way, thousands of workers align with a collectively induced airstream which emanates from the queen's position. Workers toggle between "scent-fanning" and "scent-tracking" as they navigate upstream toward the queen. To better understand how individual behaviors scale up to generate this emergent aggregation scheme, we filmed the aggregation behavior of small artificial honeybee swarms and tracked the position, orientation and behavioral state of individual bees over time. Our preliminary results suggest that this phenomenon has two phases: (1) a rapid transition from disorder to order triggered by flow-mediated signal propagation and (2) a slow progression toward the queen which is structured by the emergent flow-pheromone field initialized in phase 1. This is an extraordinary example of how groups of individual organisms can sense and actuate their environment locally to achieve global coordination.

P2-234.5 PETERS, K*; LANGDON, T/R; LENT, D; HANSEN, A/K; California State University Fresno;
kaylin_peters@mail.fresnostate.edu

Fabricating biomechanics activities to increase K-16 students' interest in STEM

This study aims to combine engineering, and more specifically fabrication, into biology education outreach. Following a design-based research methodology (Barab & Squire, 2004), we are iteratively developing K-12 educational materials to target core ideas in life science as described in The Next Generation Science Standards. In our first iteration, we designed and fabricated various skulls and mandibles using a MakerBot Replicator+ for use as outreach materials with middle school students who visited our university on a school field trip. Students were able to handle the fabricated materials (as opposed to just looking at real skulls) to correctly identify organisms as herbivores or carnivores based on the structure and function of the teeth and jaw bones. In our second iteration, we are focusing on high school students and incorporating physics concepts through biomechanics to help them fabricate their own herbivore or carnivore jaw. For educational facilities that do not have access to a fabricator, affordable methods will also be available. By using these hands-on activities, teachers will be able to integrate various sciences together and increase the students' conceptual understanding and interest in Science, Technology, Engineering, and Mathematics (STEM).

P2-9 PETERSON, BN*; YEO, AC; ALLEN, JD; William & Mary, William & Mary ; *bnpeterson@email.wm.edu*

Attack of the Clones: Examining the Factors that Influence Cloning in Echinoderm

Larval cloning has been observed in a variety of species of marine invertebrates, but is perhaps best known in echinoderms. Larvae have been noted to clone through a variety of processes and under many different conditions, but the inductive cues for cloning are largely unknown. Prior work suggests that both increases in food availability and the presence of predator cues could be contributing factors to larval cloning. In this project, we examined the effects of food, temperature, and salinity on the frequency of cloning in the larvae of *Pisaster ochraceus*. We also tested the impacts of predator cues from larval crabs and planktivorous fish on the frequency of cloning in larval *P. ochraceus*, *Dendraster excentricus*, *Strongylocentrotus purpuratus*, and *Evasterias troschelii*. Food, temperature, and predator cues had little effect on the frequency of cloning in any species. While there were few effects of predator cues on larval cloning, larvae exposed to crab megalopae were smaller in size than those of the control or fish treatment groups. Additionally, in *P. ochraceus* there was a salinity effect detected, where larvae exposed to lower salinity levels exhibited more frequent cloning. In addition, the clones of *P. ochraceus* were tracked to determine regeneration time and mortality of different clone types. These results contrast with other studies that have demonstrated an impact of both food availability and predator cues on larval cloning and suggest that other environmental factors, such as salinity, may play a role in inducing cloning in some species. The ultimate effects of larval cloning on recruitment of individuals into a population are largely unknown for any species, but in the future, we plan to test the consequences of cloning on survival and recruitment of larvae and juveniles.

P1-43 PETERSON, CR*; BOLNICK, DI; University of Texas at Austin, University of Connecticut;
Christopher.R.Peterson@gmail.com

Phenotypic Variation in Invasion and Community Assembly

Human activity has vastly accelerated the rate of novel community assembly through invasive species, habitat alteration, and climate change. As these processes often involve rapid adaptation to new conditions, incorporating evolution into a theoretical understanding of community formation is vital. The strength of species-level interactions that help determine assembly outcomes can be mediated by individual trait variation. We used eco-evolutionary models to examine the effect of intraspecific phenotypic variation on invasion success in a variety of community modules. Our preliminary results suggest that populations when invading a community to which they are maladapted or one which is dominated by predation selection pressures; conversely, lower variance populations are more successful when the greatest selection pressure is resource acquisition.

73-3 PETERSON, AN*; MCHENRY, MJ; Univ. of California, Irvine; *anpeter1@uci.edu*

Slow and steady wins the prey: The persistent predation strategy of the red lionfish (Pterois volitans)

The red lionfish (*Pterois volitans*) is a notoriously voracious predator and invasive species in the western Atlantic ocean. In contrast to its reputation, lionfish are plodding swimmers with no obvious advantages in predatory behavior. We performed behavioral experiments to determine the pursuit strategy of red lionfish as they pursued green chromis (*Chromis viridis*). Lionfish were able to capture prey with a high success rate on the first strike attempt (81%, n = 16), even though the median swimming speed of green chromis was 2-fold greater than the lionfish. Lionfish were persistent predators that employed a pure pursuit strategy by attempting to maintain a zero bearing. The swimming speeds of both fish decreased over time. The relatively slow approach by the lionfish may serve to prevent evoking evasive swimming by the prey. The prey decelerated significantly in the milliseconds before a successful strike occurred. Prey fast-start behaviors were rarely initiated prior to a strike (19%, n = 16) and were ineffective for survival. The simultaneous decrease in prey speed and rapid forward acceleration of the lionfish during suction feeding may increase the accuracy of the strike. In summary, lionfish persistently pursue their prey (up to 1 hour) and strike on the rare occurrences when the prey is moving slowing and within close proximity. Therefore, red lionfish appear to compensate for their slow locomotion with a predatory strategy that is characterized by persistence and opportunism.

62-3 PFEIFFENBERGER, JA*; TYTELL, ED; Tufts University, Medford, MA; *Janne.Pfeiffenberger@Tufts.edu*

Active muscular changes in the effective mechanical properties of fish bodies

Fish generate propulsive forces by bending their bodies back and forth using their muscles. During this motion, their bodies interact mechanically with the fluid around the fish. Therefore, the mechanical properties of their bodies are important for determining how effectively these muscle forces can be converted into whole-body propulsive forces. In this study, we measured the whole-body visco-elastic mechanical properties of pithed bluegill sunfish, *Lepomis machrochirus*. We used an oscillatory bending apparatus in which the tail of the fish was connected to a servomotor, while the other end was attached to a six-axis force transducer. Electrodes were inserted into the red muscle bands on the left and right side of the fish. The bodies were then bent back and forth at 3 Hz and an amplitude of 5 degrees while we altered muscle activation phases (-30%, <u>-15%</u>, and 0%) and duty cycles (20%, <u>30%</u>, and 40%). Muscle activations were performed based on previous observations (<u>underlined</u>) made by Schwalbe et al. (2019). We aim to answer the following questions: 1) how do whole-body visco-elastic properties change between active and passive bending cycles?, and 2) do naturally observed muscle activation phases and duty cycles result in higher body stiffness? We found that body torques, local flexural stiffness, and local damping were highest at 0% phase, and were lowest at -30% phase. Passive stiffness and damping tended to be lower than active measurements. Surprisingly, changes in duty cycle did not result in any changes to the visco-elastic properties measured in this study.

P1-7 PHELPS, AN*; LUC, HM; GROSS, JB; University of Cincinnati; *phelpsas@ucmail.uc.edu*

Comparative developmental expression of neural crest genes in the blind Mexican cavefish, Astyanax mexicanus

The neural crest is a transient embryonic tissue giving rise to diverse cell types including melanocytes, peripheral and enteric cells, neurons and glia, smooth muscle cells, cartilage, and bone. Several genes are associated with neural crest migration, specification and differentiation. Here, we examined two morphotypes of *Astyanax mexicanus*: blind morphs living in caves throughout NE Mexico, and surface morphs drawn from rivers and streams in the same region. Cave morphs demonstrate important phenotypic alterations, including pigment regression, eye loss, and craniofacial asymmetry. We sought to understand if differences in neural crest gene expression and laterality may impact craniofacial differences. Towards this end, we evaluated key marker genes over early development, associated with migration (*ets1*, *fgfr1*), specification (*fgf8*, *msx*, and *twist2a*), and differentiation (*sox10*, *tfap2a*, *snai2*, and *pax7*) of the neural crest. Using whole-mount *in situ* hybridization, we assayed stage-matched individuals at 24, 36 and 72 hours post-fertilization. We discovered substantial expression differences both across development, and the right and left sides of the developing head of cavefish. These early alterations to neural crest gene expression may be associated with asymmetric alterations and bony fragmentation in adult cavefish. We believe these changes may prefigure cranial and directional asymmetries that arise later in the life history of the blind Mexican cavefish, which may explain lateral preferences in swimming patterns.

S2-7 PHELPS, SM; PHELPS, Steven; University of Texas at Austin; *sphelps@utexas.edu*

Genetic and epigenetic influences on alternative tactics in the mostly monogamous prairie vole

Social behavior is among the most complex and variable of phenotypes. Optimal behaviors often depend on the strategies prevalent in a given population. In the case of the prairie vole, Microtus ochrogaster, a male transitions between a single and pair-bonded mating strategy when he is able to monopolize a female. The neuropeptide vasopressin plays a major role in the formation of such bonds, and the resulting strategies require coordination of brain regions involved in attachment, aggression, and memory. The expression of the vasopressin 1a receptor (V1aR) in the retrosplenial cortex (RSC), a brain region critical to memory, differs profoundly among prairie voles. Among males, RSC-V1aR predicts patterns of space use and sexual fidelity. We identified two alleles that drive differences in RSC-V1aR: a high allele that is favored in the context of intra-pair paternity, and a low allele that is favoring during extra-pair paternity. The alleles differ in several single-nucleotide polymorphisms located within a putative enhancer. The low-expressing allele contains significantly more CpG sites within this enhancer. Manipulations of developmental environments reveal that the low allele is more sensitive to both methylation and demethylation. Together the data suggest that the high allele shapes socio-spatial memory to promote mate-guarding, and is largely insensitive to developmental environment; the low allele, in contrast, seems to promote scarmble competition, but allows epigenetic modification of gene expression and behavior. We hypothesize that this represents an example of neuroendocrine reaction norms mediated by the abundance of CpG sites within a regulatory sequence.

50-6 PHILLIPS, JR*; HEWES, AE; SCHWENK, K; University of Connecticut, Storrs, CT; *jackson.phillips@uconn.edu*

Novel Air-breathing Modes in Anuran Tadpoles

The biomechanics of air-breathing in anuran tadpoles is virtually unstudied. Our previous work showed that surface tension prevents small tadpoles from breaching the surface to breathe. They overcome this constraint using a novel form of air-breathing, termed ‘bubble-sucking'. When bubble-sucking, a tadpole attaches its mouth to the under-surface of the water, expands its buccal cavity and pulls the surface into the mouth to create a bubble, which is then pinched off and compressed into the lungs. Tadpoles typically transition to breach breathing when large enough. In this study, we examined air-breathing mechanics in *Hyla versicolor* tadpoles over ontogeny using a combination of high-speed videography, paraffin histology, and statistical modeling. We found that *H. versicolor* differs from other species by never breach-breathing, even after growing large enough to do so. Rather, tadpoles transition from typical single bubble-sucks to ‘double bubble-sucks', which entail an initial bubble-suck, during which the lungs are emptied and the bubble expelled, followed by a second bubble-suck, in which a second bubble is compressed into the lungs. Air remaining in the buccal cavity is released from the mouth. Unlike single bubble-sucks, double bubble-sucks prevent the mixing of fresh and used air, increasing the efficiency of air-breathing. The shift from single bubble-sucking to double bubble-sucking occurs at approximately 6 mm body length. At this same body length we found a parallel transition in lung morphology, shifting from a low to high degree of vascularization. These results suggest that single bubble-sucks in *H. versicolor* are non-respiratory, possibly serving developmental or hydrostatic functions, whereas double bubble-sucks provide a derived, efficient mechanism of gas exchange in *H. versicolor*.

22-1 PHIPPS, N*; STEIN, LR; HOKE, K; Colorado State University, University of Oklahoma; *Nathan.Phipps@colostate.edu*

Genetic Background and Sexual Experience Jointly Determine Courtship Strategy

Animal mating behavior is influenced by both genetic background and lifetime experience. We sought to investigate how genetic adaptations to environmental stressors interact with events within an organism's lifetime to alter behavior. Reproductively isolated populations of Trinidadian guppies (Poecilia reticulata) occur in environments with either high or low predation rates. Evolutionary history with predators influences many phenotypes, including male courtship strategy. We observed male guppies from high predation, low predation, and intercross populations in their first encounter with a female. After 24 hours, we repeated the mating encounter to observe differences in mating strategy. We recorded occurrences of a variety of courtship behaviors in these encounters to determine how the effect of sexual experience on courtship strategy is influenced by population predation history. Our results describe the extent to which heritable factors contribute to learning in guppies. Follow-up experiments will investigate specific genetic loci which may influence mating behavior.

P2-36 PICCIANI, N*; MUSSER, JM; OEL, AP; GARM, AL; ARENDT, D; OAKLEY, TH; University of California, Santa Barbara, European Molecular Biology Laboratory, University of Copenhagen; *natasha.picciani@lifesci.ucsb.edu*

Organ Complexity and Cell History: a Case of Eye Evolution in Cnidaria

Acquiring eyes consists in a major evolutionary transition since it requires the assembly of several functionally integrated components, and strongly impacts the lifestyle of an organism. While eyes evolved many times in bilaterian animals with elaborate nervous systems, image-forming and simpler eyes also exist in cnidarians, which are ancient non-bilaterians with neural nets and regions with condensed neurons to process information. How often eyes of varying complexity, including image-forming eyes, arose in animals with such simple neural circuitry remained obscure. With large-scale phylogenies of Cnidaria and their photosensitive proteins, we show that cnidarian eyes originated at least eight times, with complex, lensed-eyes having a history separate from other eye types. Our results show eyes evolved repeatedly from ancestral photoreceptor cells in non-bilaterian animals with simple nervous systems, co-opting existing precursors, similar to what occurred in Bilateria. Now, we are leveraging single cell analysis tools to measure gene expression across photoreceptor cells from jellyfish with eyes that originated separately to understand their evolutionary history and interplay with eye origins.

P2-3 PIERCE, ER*; GELLER, JB; Moss Landing Marine Laboratories, Moss Landing; *epierce@mlml.calstate.edu*

Molluscan Waste is not a Load of Crap: Comparing Environmental DNA Accumulation and Degradation Rates from Mussels, Limpets, and Abalone

Water in the marine environment is filled with particles and compounds including pigments, cells, waste products, and free nucleic acids. DNA released from organisms into surrounding waters are referred to as environmental DNA (eDNA). eDNA can stay present in water for weeks. Modern sequencing technology can be used on eDNA to characterize complex, mixed species assemblages from a small water sample. Few studies have looked into the details of eDNA such as variation in accumulation and its persistence for different species. This study seeks to use manipulative experiments to quantify the accumulation and degradation of eDNA in three mollusc species: the intertidal limpet (*Lottia digitalis*), the red abalone (*Haliotis rufescens*), and the California blue mussel (*Mytilus californianus*). Overall goals of the study include (1) to understand how much eDNA these molluscs exude, (2) which organismal compartments generate eDNA, and (3) to characterize the rate of degradation under different temperature, UV, and bacterial conditions for the three species. The results of this research will enhance the utility of eDNA as a monitoring tool by characterizing its accumulation, detectability, and degradation within a system. The endangered owl limpet *L. gigantea*, black abalone *H. cracherodii*, and white abalone *H. sorenseni* are relatives of organisms in the present study; molecular techniques along with eDNA could be an inexpensive, rapid monitoring tool to track these organisms if the eDNA remains detectable in the system for long enough.

P1-138 PIMIENTA, MC*; RUIZ, CA; KOPTUR, S; Florida International University, Miami, FL; *mpimi007@fiu.edu*
Do Diurnal Floral Visitors Increase the Fruit-set of a Sphingophilous Plant?: The Case of the Rough-leaf Velvetseed (Rubiaceae)
A large number of flowering plants rely on insects for sexual reproduction: without their pollinators, many angiosperms could go extinct. In southern Florida, the rough-leaf velvetseed, *Guettarda scabra* L. (Vent.), exists only in remnants of the imperiled pine rockland and hardwood hammock habitats, and depends on insects for its reproduction. This species exhibits all the floral traits typical for attracting nocturnal hawkmoths (Sphingidae), but is also visited by diurnal visitors, since floral reward is available during day time as well. We studied the relative contribution of diurnal and nocturnal pollinators to female reproductive success by selectively exposing the plants to these groups. We also determined the identity of these visitors by direct observation during the blooming period of three consecutive flowering seasons. Plant fruit-set mediated by nocturnal pollinators was significantly higher than by diurnal visitors, although the daytime visitors were apparently more frequent. Our results suggest that even though the flowers of *G. scabra* are visited by different pollen vectors, nocturnal pollinators are required for successful sexual reproduction in this species, suggesting a rather specialized pollination system.

121-1 PIPES, BL*; NISHIGUCHI, MK; New Mexico State University; *nish@nmsu.edu*
mCherry-pHLuorin Tagging Illuminates the Role of Light Organ pH Modulation in the Vibrio fischeri-Euprymna scolopes Symbiosis
The bioluminescent marine bacterium *Vibrio fischeri* has been used to study mechanisms of environmental specificity in mutualistic associations with animal hosts. *V. fischeri* colonizes the light organ of sepiolid squids (Cephalopoda: Sepiolidae) and produces luciferase-based light which provides ventral counter-shading camouflage for the squid. Low pH levels may cyclically develop within the colonized light organ as a result of diurnal *V. fischeri* growth. Adaptation to such stressful conditions may provide *V. fischeri* a competitive advantage in colonizing the light organ. To investigate this phenomenon, we are developing novel methods of directly assaying pH within the colonized light organ of the Hawaiian bobtail squid, *Euprymna scolopes*. Previously developed *V. fischeri* strains containing a pH responsive ratiometric GFP derivative (pHLuorin) have shown promise as a fluorescent pH biosensor enabling the determination of both cytoplasmic and extracellular pH *in vitro*, but have constrained utility for assaying pH within the light organ due to the necessity of using uncommon fluorescence microscopy excitation/emission filter sets. To negate this limitation, new strains have been developed using a ratiometric mCherry-pHLuorin fusion protein in lieu of the standard pHluorin protein. These can be used to assay pH via fluorescence spectrometry, microscopy, and flow cytometry using standard red/green filter sets, while providing equivalent levels of sensitivity. The use of these novel biosensors in the lumen of the light organ will allow us to determine the extent of cyclic pH fluctuations as a determining factor in establishing successful colonization by *V. fischeri* in sepiolid squids.

95-1 PLAKKE, MS*; MESLIN, C; ARIKAWA, K; CLARK, NL; MOREHOUSE, NI; University of Kansas, INRA, SOKENDAI, University of Utah, University of Cincinnati; *mplakke@ku.edu*
A recent, lineage-specific, co-option event within the female reproductive tract of the Cabbage White butterfly, Pieris rapae L.
While reproductive traits are known to be some of nature's most rapidly evolving traits, investigations of this rapid evolution have traditionally focused on male reproductive traits. Females have been commonly viewed as passive participants in sexual reproduction, despite increasing evidence that female genitalia and proteins evolve at rates comparable to those documented in males. To better understand the rapid evolution of female reproductive traits, and how such rapid evolution may contribute to reproductive isolation, we studied evolutionary divergence in female reproductive traits of the Cabbage White butterfly, *Pieris rapae*. In butterflies and moths, females possess a unique reproductive organ, called the bursa copulatrix, which functions to digest the male spermatophore. Crosses between recently isolated subspecies indicate a potential reproductive barrier involving reduced spermatophore digestion rates in hetero-subspecific crosses. These results imply that traits involved in spermatophore digestion may have diverged between these two subspecies. Expression analyses of male and female proteins involved in bursa-spermatophore interactions indicate that proteins specific to the spermatophore remain constant in expression between the subspecies. In contrast, the female proteases that digest the spermatophore differ dramatically in their expression. Additionally, we observed a unique co-option event in one subspecies, where a protease normally expressed during the larval stage was also expressed in the bursa. Taken together, these results indicate that female reproductive traits may, in some species, be more evolutionarily dynamic than male traits. Our work thus motivates more careful study of female reproductive traits and their role in the rapid evolution of reproductive barriers.

P3-25 PLAKKE, MS*; BLUMENSTIEL, JP; WALTERS, JR; University of Kansas; *mplakke@ku.edu*
Patterns of small non-coding RNA expression across dimorphic sperm
The primary function of sperm has long been assumed to be solely for the transference of genetic material to the next generation. However, not all sperm are able to fertilize eggs, yet somehow are maintained during spermatogenesis. Numerous taxa have been documented as predictably transferring non-fertilizing sperm to females during copulation. The most striking example of non-fertilizing sperm comes from Lepidoptera, the butterflies and moths. Males produce two distinct morphs of sperm: the nucleated, fertilizing sperm (eupyrene), and an anucleated, non-fertilizing sperm (apyrene). Despite the fact that apyrene sperm are incapable of fertilizing a female's eggs, they are not only consistently produced and transferred to females, but also appear to play a vital role in the success of eupyrene sperm. We hypothesized that the apyrene sperm may support the function of eupyrene sperm through a difference in expression of small, non-coding RNA (sncRNA). Transfer of sncRNA have been documented in vertebrate sperm cells, including mammals and birds. Further, the sncRNA have been implicated in several vital transgenerational processes, such as epigenetic inheritance patterns and proper embryo development. No work to date has explored sncRNA in lepidopteran sperm and the dual nature of sperm morphs provides an exciting new frontier in reproductive biology. Using monarch butterflies, *Danaus plexippus*, we explored the differences and similarities in expression levels for sncRNA in both eupyrene and apyrene sperm. Our results are discussed in the context of sperm cell specialization and reproductive trait evolution.

P2-97 PLUM, F*; LABONTE, D; Imperial College London; *fabian.plum18@imperial.ac.uk*

Large-scale analysis of ant foraging dynamics enabled by Deep Convolutional Neural Networks

Herbivorous leafcutter ants display an extreme polymorphism which is tied closely to task specialisation. However, studying such size-specific division of labour is a meticulous and error-prone task, as individual workers either have to be removed for weighing, or their weight has to be estimated from experience. To overcome these limitations, we developed a computer vision and machine learning-based tool which automatically detects and tracks variable numbers of ants within crowded areas such as foraging trails and sites, and simultaneously predicts their size and weight with high accuracy. This system consists of three independently trained deep convolutional neural networks. The first network robustly identifies individuals in crowded areas; it is a YoloV3 detector implemented in darknet, trained on a custom dataset to detect ants in various lighting conditions and degrees of occlusion. The second network is a newly developed modular buffer-and-recover tracking network which matches detections across frames, preventing identity switches with an accuracy of 99.2 %. The resulting tracks are then processed by a final deep convolutional regression network which estimates the weight of each individual. In contrast to previous implementations which were limited to a fixed number of individuals filmed in a well-defined environment, our marker-less detection system can cope with a time-variable number of individuals and does therefore not only significantly reduce the interference required for obtaining data, but also brings with it the potential to be used in the field. We demonstrate the potential of our tool by analysing differences in the worker size-frequency distribution of ants foraging on leaves of different mechanical properties, indicating tougher food sources being preferentially foraged on by larger workers.

P2-220 PO, T*; HEYDARI, S; KANSO, E; MCHENRY, MJ; UC Irvine; *mmchenry@uci.edu*

The neuromechanics of locomotion in sea stars (Protoreaster nodosus)

Sea stars walk through the coordinated action of hundreds of tube feet despite lacking a central nervous system. We investigated the neuromechanics of walking in sea stars through a combination of experimentation and mathematical modeling. We devised software to automatically track the motion of the tube feet from video recordings. Kinematic measurements of *Protoreaster nodosus* showed that the tube feet moved with a power stroke in the opposite direction of walking, with no significant differences between arms. We found that the coordination among the tube feet was the highest when sea stars transitioned into the faster bouncing gait. Our mathematical model considered the mechanics of the body and tube feet and assumed that each foot operates independently with a chain of reflexes. Simulations successfully replicated both slow crawling and bouncing gaits. These results suggest that the tube feet synchronize by using local proprioception at the tube feet rather than global neuronal signals.

S1-3 POLITO, MJ*; MICHELSON, CI; MCMAHON, KW; Louisiana State University, University of Rhode Island; *mpolito@lsu.edu*

Advances in the use of biogeochemical markers to track the diets and movement of Antarctic marine predators

Quantifying the diets, foraging ecology, and at-sea distribution of wide-ranging marine predators is critical to understanding their ecological responses to recent environmental change and predicting species responses in the future. However, logistical, financial, and ethical constraints can often limit researchers' ability to directly measure these key life history characteristics in Antarctic marine predators. The analysis of intrinsic biogeochemical markers, such as stable isotopes, fatty-acids, DNA, and bioaccumulating contaminants, represent powerful techniques that provide proxies of the diets and movements of marine predators when they cannot be directly observed. These methods are based on the principle that consumers "are what and where they eat" with conservative transfer of biomarker compounds from the base of the food web to consumers across the food web. This presentation will briefly review recent advances in the use of biogeochemical markers in studies of Antarctic predator ecology. It will also highlight two case studies. The first study uses compound-specific stable isotope analysis of feather amino acids to evaluate the diets and migration patterns of penguins from the genus Pygoscelis during the winter months when they are away from their breeding colonies. The second study uses this same technique to examine the trophic responses of sympatric chinstrap (P. antarctica) and gentoo (P. papua) penguins from the Antarctic Peninsula to nearly 100 years of shared environmental change. These studies highlight the potential that intrinsic biogeochemical markers have in complementing traditional diet and tracking methods to significantly expand the spatial and temporal scope of Antarctic marine predator studies.

S10-7 POLLY, P.D.; Indiana University; *pdpolly@indiana.edu*

The landscape of adaptive landscapes: trade-offs between performance surfaces in space and time

An important component of fitness is the performance of a functional trait in its local environment. But environments vary spatially and temporally, and so too will the performance of the trait. The adaptive landscape of any given functional trait thus changes as an individual encounters different environments in its daily movements, as a local population experiences environmental change over time, as gene flow in a metapopulation crosses environmental gradients, or as descendant species colonize environments that are different from those occupied by their ancestors. Shifts in trait optima across these environmental boundaries creates a selectional trade-off that in some contexts favors a compromise trait value and in others changes the rate and direction of selection on the trait. Here I present a recently developed approach for modeling the effect of such trade-offs on the evolution of multivariate phenotypes. It uses geometric morphometrics to construct a continuous phenotypic space that defines the axes of the adaptive landscape. Differences in performance of phenotypes across that space are assessed using computational tools like finite element analysis (FEA) and computational fluid dynamics (CFD) or experimental strategies to estimate an adaptive landscape for each environmental situation. Using a combination of computer simulations and new data I show how maximum likelihood can be used to estimate the balance of environments that is most consistent with any given realized phenotype. I also show how this approach can be used in to predict the net phenotypic change expected from a shift in environment.

27-1 POMERANTZ, AF*; KISHI, Y; PINNA, C; ELIAS, M; PATEL, NH; University of California Berkeley, California Institute of Technology, Museum National d'Histoire Naturelle, Museum National d'Histoire Naturelle, Marine Biological Laboratory; *pomerantz_aaron@berkeley.edu*

Making it Clear: Evolution and Development of Wing Transparency in Lepidoptera

The wings of butterflies and moths (Lepidoptera) are typically covered with thousands of flat, overlapping scale cells that endow the wings with colorful patterns and make them predominantly impenetrable to light. Yet numerous species of Lepidoptera have evolved transparent wings that allow light to pass through. Transparency requires low absorption and reflection, as well as low scattering of light, and these constraints are often difficult to fulfill for terrestrial organisms. This is particularly due to the large difference between the refractive indices of living tissues (n=1.5) and air (n=1) resulting in significant surface reflections. As a solution, some Lepidoptera have evolved modified scales so that the underlying wing membrane is exposed, and in some cases added elaborate nanostructures on the surface that gradually change the index of refraction and, as a result, give the wing anti-reflective properties. Here we set out to explore the evolutionary history, morphological diversity, and development of wing transparency in Lepidoptera, and find that clearwing traits arose numerous times independently. To probe features of clearwing development, we apply confocal and transmission electron microscopy to generate a description of scale cytoskeletal organization in the glasswing butterfly, Greta oto. Finally, we compile optical and scanning electron microscopy of clearwing scale types and surface nanostructures, highlighting a range of novel and structurally diverse solutions to achieve anti-reflection properties. These findings give us additional insight into the evolution and development of naturally organized micro/nanostructures and may provide bioinspiration for design and engineering of new anti-reflective materials.

68-2 POOLE, AZ*; BAILEY, GF; Berry College; *apoole@berry.edu*

GTPases of Immunity Associate Proteins (GIMAP) gene expression in response to induction of apoptosis and autophagy in the sea anemone Exaiptasia pallida

Coral reefs, one of the world's most productive and diverse ecosystems, are currently threatened by a variety of stressors that result in increased prevalence of both bleaching and disease. Therefore, understanding the molecular mechanisms involved in these responses is critical to mitigate future damage to the reefs. One group of genes that are potentially involved in cnidarian immunity and symbiosis are GTPases of Immunity Associated proteins (GIMAPs). In vertebrates, this family of proteins is involved in regulating the fate of developing lymphocytes and interacts with proteins involved in apoptosis and autophagy. Since both apoptosis and autophagy are processes previously shown to be involved in cnidarian symbiosis, the goal of this research was to determine the role of cnidarian GIMAPs in these cellular processes using the sea anemone *Exaiptasia pallida*. To do so, GIMAP genes were characterized in the *E. pallida* genome and changes in GIMAP gene expression were measured using qPCR in response to chemical induction of apoptosis and autophagy. The experiment was conducted in both symbiotic and aposymbiotic anemones to account for the effect of the presence of symbionts. The results revealed four GIMAP-like genes in the *E. pallida* genome, which are referred to as *Ep_GIMAPs*. Induction of apoptosis resulted in a general downregulation of *Ep_GIMAPs* in both symbiotic and aposymbiotic animals indicating these proteins may be involved in pathways that promote cell survival or inhibit apoptosis. Overall, these results increase our knowledge of the role of GIMAPs in a basal metazoan.

S5-10 POPPINGA, S*; SPECK, T; Botanic Garden, University of Freiburg, Freiburg im Breisgau, Germany; *simon.poppinga@biologie.uni-freiburg.de*

Abstraction of Slow and Fast Plant Movement Principles for the Technical Transfer into Biomimetic Motile Structures

Plants can move organs or organ parts (e.g. trap leaves, flower petals, seed capsules, roots) with a variety of actuation principles. In strong contrast to most animal motion principles, the motility in plants is achieved with the complete absence of nerves, muscles and real, i.e. localized, hinges. The motion timescales and modes of deformation at work are very diverse and have recently become a source of inspiration for the development of bioinspired compliant mechanisms, which are of great interest for various fields, e.g. micro-electromechanics, microfluidics, soft robotics, medical applications and architecture. We concisely summarize the procedures in such biomimetic approaches with the help of several examples from our own research and development projects. The work processes presented include basic biomechanical and functional-morphological investigations of fast and slow plant movements, the abstraction of working principles, simulations and the transfer into novel materials systems and products. A focus is laid on systems, which are directly triggered and powered by changes of environmental conditions (e.g. temperature, humidity). With the help of such autonomous and self-sufficient actuators, reduced electrical consumption and maintenance are envisaged, which are important aspects for future technologies.

P3-119 PORRAS, ND*; CULVERHOUSE, EK; TATE, KB; Texas Lutheran University ; *Nporras@tlu.edu*

The Metabolic and Cardiovascular Response of Central Texas Pulmonate Snails to Acute and Chronic Warming Events

We explored the response of two physiological parameters, metabolic rate (VO_2) and heart rate (HR), in two species of pulmonate snails in response to acute and chronic temperature elevations. Land snails, Asian tramp snail (*Bradybaena similaris*, BS) and Milk snail (*Otala lactea*, OL) were collected from central Texas and acclimated to laboratory conditions. Snails were chronically exposed to either low (22&degC) or high (30&degC) ambient temperatures for a minimum of two weeks. Following the two week acclimation, VO_2 and HR were measured in both *B. similaris* and *O. lactea* in the low temperature (22&degC; BS-22 and OL-22) and elevated temperature (30&degC; BS-30 and OL-30). We measured HR and VO_2 in response to acute exposure to the acclimated and reciprocal temperatures. We predicted that snails exposed to acute and chronic elevated temperature would display depression of metabolic rate and heart rate. We observed metabolic depression in BS-22 when measured at 30&degC, while HR increased 26%. HR in BS-30 increased 24% when measured in 30&degC compared to measurements collected at 22&degC. VO_2 of OL-30 measured at 30&degC was 24% lower than OL-22 measured at 22&degC. HR of OL-22 and OL-30 was unaffected by acute temperature changes, however there was a reduction in HR in OL-30 measured at both temperatures compared to OL-22. In our study we found that the pulmonate snails collected from central Texas did not respond to changes in environmental temperature in the similar manner. While we did confirm the impact of temperature on VO_2, in both acute and chronic exposures, HR responses were variable in response to acute and chronic changes in temperature, with *B. similaris* responding to acute changes in temperature, while *O. lactea* responses were primarily due to prolonged exposure.

P2-20 PORTER, NA*; JOST, JA; Bradley University ; *nporter@mail.bradley.edu*

Seasonal Variation in Oxidative Stress for Zebra Mussels Exposed to an Acute Thermal Challenge

Since being introduced to the US, the invasive zebra mussel, *Dreissena polymorpha*, has spread rapidly and caused extensive damage by harming native species, altering water quality, and biofouling hard surfaces. 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. The aims of this study were to determine (1) whether zebra mussels experience oxidative stress during acute thermal challenges, (2) if this response is greater due to hot or cold temperatures, and (3) if seasonal acclimation affects the response. Mussels were collected in both summer and fall and exposed to either a decrease to 10°C or increase to 30°C and held for 24 hours. Tissue was collected at various timepoints to determine superoxide dismutase (SOD) activity, total antioxidant capacity (TAC), and thiobarbituric acid reactive substances (TBARS). No significant differences were seen in the levels of TBARS. However, SOD activity was higher in fall-acclimated mussels and in mussels exposed to cold temperatures. TAC was also higher in mussels exposed to cold temperatures, suggesting that cold exposure elicits oxidative stress in zebra mussels. Ongoing analysis include quantitative real-time PCR to measure the levels of SOD and catalase as well as western blotting to measure a suite of thermal stress markers.

42-3 POS, KM*; KOLMANN, MA; GAO, T; HERNANDEZ, LP; GIDMARK, NJ; George Washington University, Washington DC, University of Chicago, Chicago, IL, Knox College, Galesburg, IL ; *kmpos@gwu.edu*

Morphological evolution within minnows exhibits decoupling of form & function during periods of climate change in North America

Independent lineages often evolve similar morphologies in response to similar functional demands; however, there are diverse clades where such convergence is underappreciated due to perceived phenotypic homogeneity. Many fishes, including leuciscids (Cypriniformes), are equipped with a secondary set of jaws (gill arch elements in the pharynx) that have become the primary site for prey processing. The shape of these pharyngeal jaws presumably relates to their function in feeding (i.e., robust teeth for crushing hard prey), and in minnows there are significant correlations between diet and anatomy. Using comparative macroevolutionary methods with a published phylogeny, we tested how pharyngeal phenotypes are shaped by evolutionary integration, phylogenetic signal, and diet. We used geometric morphometric methods to explore overall shape diversity, and measured functionally-relevant traits relating to feeding performance from micro-computed tomography scans of 165 species. Our geometric morphometric dataset provides us with a measure of shape change independent of functional connotations, whereas our linear morphometrics measure function directly. Our results suggest widespread anatomical and dietary convergence: clades largely overlap in morphospace and similar patterns of shape change correlate with shifts to similar diets. However, the overall shape of the pharyngeal jaws and their functional diversity do not always evolve in parallel through time; rather, changes in jaw shape and function can evolve independently. These instances of form-function decoupling are concomitant with periods of widespread climate change in North America and ecomorphological shifts in feeding zone (benthic to pelagic).

13-2 POWERS, MJ*; WEAVER, RJ; HEINE, KB; HILL, GE; Auburn University, University of Texas at Austin; *mjp0044@tigermail.auburn.edu*

First clutch size is a reliable proxy for reproductive success in a marine copepod

In experimental studies, researchers are often unable to track individuals through a natural lifetime and must rely on proxies of lifetime reproductive success. The number of offspring produced at first reproduction is readily measured and has been used as a proxy for lifetime reproductive output in studies using copepods, including the species *Tigriopus californicus*. However, the accuracy of such a proxy has been questioned and to date no validation of this approach to estimating lifetime reproductive success has been undertaken. In this study, we undertook such a validation of using the number of first-clutch offspring as a proxy for lifetime reproduction by observing the reproductive output of female *T. californicus* for the entirety of their reproductive life spans. We measured several life history traits including egg gestation duration, the number of offspring produced per clutch, the total number of clutches, offspring survival, offspring development, offspring size, and female lifespan. We found that the size of the first clutch was positively correlated with many of these measures of reproductive fitness, even after controlling for difference in female lifespan. Additionally, we analyzed variation in life history traits over the entire life span of *T. californicus* females and found that reproductive output generally declined, suggesting senescence in these small crustaceans.

82-6 POWERS, DR*; LAPSANSKY, AB; SHANNON, ES; TOBALSKE, BW; George Fox University, University of Montana; *dpowers@georgefox.edu*

Body-Temperature Management by Hovering and Perching Hummingbirds in Cold and Warm Temperatures

Hummingbirds generate large amounts of heat during hovering. When ambient temperatures (T_a) are cool this extra heat could be used as a source of endogenous heat to maintain body temperature. However, when T_a is warm this extra heat must be dissipated to avoid hyperthermia. Our previous work suggests that hummingbirds have difficulty dissipating heat while hovering in warm T_a likely requiring them to behaviorally thermoregulate after perching. In this study we used infrared thermography and standard video recordings to examine differences in heat retention/dissipation strategies between hovering and perching calliope hummingbirds (*Selasphorus calliope*, ~2.5 g) at 5, 22, and 32 °C. Based on earlier anecdotal observations we predicted that perching birds would rapidly radiate heat from the flight muscles after hovering. However, this was not supported by our data. Instead across all T_a values regulation of heat delivery to the bill, feet, and eye heat dissipation area (HDA) appeared key in controlling heat transfer during both hovering and perching. At 5 °C no heat was actively delivered to either the bill or feet when hovering or perching allowing for effective heat retention. At 32 °C the bill and feet appeared actively warmed with surface temperatures (T_s) sometimes >40 °C during hovering. T_s variation of the eye HDA was less than for the bill and feet but exhibited slightly higher T_s during hovering when heat transfer across general body surfaces is limited. While calliope hummingbirds can effectively cool while perching higher T_s of bill, feet, and eye HDA exhibited during hovering result in thermal gradients of 8-10 °C promoting dissipation of some of the heat produced during hovering even when T_a is warm.

P2-4 POWERS, MM*; ELLISON, C; MADRID, M; RODRÍGUEZ, L; MASLAKOVA, S; University of Iowa, Oregon Institute of Marine Biology, University of Oregon, Smithsonian Tropical Research Institute, Panama City, Panama, Smithsonian Tropical Research Institute, Panama City, Panama; *megan-m-powers@uiowa.edu*

Nemertean diversity in Colón, Panama assessed by DNA-barcoding

Most marine biodiversity remains undescribed. DNA barcoding is an important tool for the assessment of biodiversity and the identification of species in taxa with few easily assessed and preservable morphological characters and many cryptic lineages, like ribbon worms (Nemertea). Nemerteans play important ecological roles as top predators, and some have economic significance as egg predators of commercially harvested crustaceans or biomedical potential as toxin producers. The objective of this study was to assess nemertean species diversity in a previously unsampled part of the Caribbean coast of Panama by DNA-barcoding of the mitochondrial gene cytochrome c oxidase subunit 1 (CO1). This contributes to the larger goal of assessing nemertean diversity in the Caribbean Sea. Using universal and nemertean-specific primers, we were able to obtain good quality sequences from 92/97 (94.8%) specimens collected from Colón, Panama during six collecting trips in 2018. Sequences were sorted into operational taxonomic units (OTUs) using a 4% p-distance cut off. Six sequences belonged to other phyla of marine invertebrates (Arthropoda, Annelida) and likely represent contamination from gut contents. The 86 nemertean sequences represented 37 OTUs (putative species), and 13 of those belong to previously unsequenced (i.e. likely newly discovered) species bringing the total number of nemertean species in the Caribbean Sea to 191. This is in stark contrast with the 36 described nemertean species currently reported from the Caribbean. The large proportion of new species (35.1%) discovered at the new site suggests that the nemerteans of the Caribbean remain undersampled.

2-2 POWERS, SD*; THOMPSON, LM; PARRY, D; GRAYSON, KL; AGOSTA, SJ; Virginia Commonwealth University, Clemson University, State University of New York; *powerssd3@vcu.edu*

Climate-related variation in metabolic rate across the geographic range of an invasive ectotherm

Our current understanding of how physiological traits respond to divergent climates as species expand their geographic ranges is still limited. Invasive species currently undergoing range expansion provide unique opportunities to study how physiological traits may evolve in relation to climate as populations spread into different and possibly novel climates. In our study, we quantified variation in thermal physiology along the latitudinal range of the gypsy moth (*Lymantria dispar*) in North America. Specifically, we measured resting metabolic rates (RMR) of larvae from 14 wild populations across the invasion front, which span 11.5°C of latitude. For each population, RMR was assayed at three ecologically-relevant temperatures (15°C, 25°C, and 30°C). From these data, we estimated a least square mean, temperature-corrected RMR for each population and tested for differences as a function of latitude and local climate variables. This analysis revealed a significant positive relationship between RMR and latitude and a significant negative relationship between RMR and a suite of climate variables. Further analysis using multi-model inference revealed annual min. temperature to be the most significant predictor of population-specific RMR. Overall, the patterns were consistent with predictions made by the Metabolic Cold Adaptation hypothesis, with elevated RMR in colder climates. This study demonstrates the evolutionary potential of thermal physiology to evolve rapidly in response to changing climates. However, as the gypsy moth invasion reached warmer southern climates the invasion front has retracted possibly because this evolutionary potential has reached its limits in the south.

57-4 PRADHAN, DS*; GROBER, MS; WHITE, KJ; Idaho State University, Pocatello, ID, Georgia State University, Atlanta, GA; *praddeva@isu.edu*

Onset and maintenance of male-typical parenting behavior during protogynous sex change

In species that change sex based on social cues, behavioral sex change is rapid and precedes gonadal rearrangement. The precise time course of both rapid and long-term behavioral changes could be highly variable and based largely on group dynamics. In this study, we attempted to better describe the initiation and maintenance of male-typical parenting behavior during protogynous sex change in *Lythrypnus dalli*, a bidirectional hermaphrodite. These fish live in groups consisting of a dominant male and multiple subordinate females. Male-typical behavior consists of nest defense, courtship jerk swims, and parenting displays involving fanning and rubbing behaviors regardless of egg presence in the nest. We studied these fish under four social contexts. First, in stable social groups consisting of a large male and size mis-matched females, males spent >99% time inside the nest and displayed high rates of parenting, while females spent ~38% time inside the nest, but did not parent. Second, we manipulated the male such that he was in the social group, but did not enter the nest. In this case, the dominant female entered the nest and cannibalized the eggs within the first 30 min, but concurrently displayed parenting and had elevated levels of brain 11-ketotestosterone. Third, we removed the male completely, which triggered a period of hierarchical instability, during which the most dominant female initiated aggression, territoriality, and short bouts of parenting. Fourth, in all female groups, at 5 d, transitioning fish spent ~34% of time inside the nest and exhibited lower parenting rates, while at 10 d, fish spent >70% time in the nest and similar rates of parenting compared to males from stable groups. Future studies will investigate whether similar hormonal mechanisms regulate parenting in males and during protogynous sex change.

111-2 PRAKASH, V.N*; BULL, M.S; PRAKASH, M.; Stanford University; *vprakash@stanford.edu*

Motility induced fractures reveal a ductile to brittle crossover in the epithelial tissues of Trichoplax adhaerens

Animal tissues are continuously subjected to dynamic force loading while they crawl, walk, run or swim. While epithelial tissues provide an important barrier function in animals, they are subjected to extreme strains during everyday activities such as breathing and feeding. However, failure or inability to withstand to these extreme strains can result in epithelial fractures, and associated diseases. Understanding tissue mechanics and adaptive response in dynamic force landscapes remains an important frontier. Motivated by understanding tissue properties at the limits of their integrity, here we carry out a multi-modal study of a simple yet highly dynamic organism, the *Trichoplax adhaerens*. We report the discovery of abrupt, bulk epithelial tissue fractures induced by the organism's own motility. Coupled with rapid healing, this discovery accounts for dramatic shape changes and physiological asexual division in this early-divergent metazoan. We generalize our understanding of this phenomena by codifying it in a heuristic model focusing on the debonding/bonding criterion in a soft-active-living material. Using a suite of quantitative experimental and numerical techniques, we demonstrate a force-driven ductile to brittle material transition governing the morpho-dynamics of tissues pushed to the edge of rupture.

P3-146 PRAKASH, V.N*; BULL, M.S; PRAKASH, M; Stanford University; *vprakash@stanford.edu*
Tissue fracture dynamics govern plastic shape changes in a simple animal
Epithelial tissues usually provide support to organs and embryos, but during development, epithelial tissues can also exhibit a dynamic fluid-like behavior. During morphogenesis, epithelial tissues undergo both elastic and plastic shape changes. These shape changes are often accompanied by local cell rearrangement mechanisms such as intercalation, 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 extreme plastic shape changes in a simple, early divergent animal – *Trichoplax adhaerens*. These animals continuously glide on substrates using ciliary traction to generate mechanical forces and induce internal strain in the tissue. The epithelium is surprisingly able to sustain local physiological fracture holes which can either enlarge or heal, resulting in plastic shape change and cell rearrangement. We employ novel bead-based tagging, live microscopy, and computational analysis to quantitatively demonstrate motility-induced tissue fractures in these animals. We also reveal how tissue dynamics plays a critical role in the life cycle of these animals during their asexual reproduction process.

P3-86 PREISING, GA*; FABER-HAMMOND, J; RENN, SCP; Reed College; *gabe.preising@gmail.com*
aCGH Detects Copy Number Variation with Similar Resolution to PacBio Sequencing Approaches
We aim to address the genomic consequences of adaptive radiation as well as the rapid and repeated speciation in a lineage resulting in extensive ecological diversity. African cichlids present an exciting radiation exhibiting morphological and behavioral diversity. Prior work in the Renn lab employed array-based comparative heterologous genomic hybridization (aCGH) to reveal a large amount of inter- and intra-specific copy number variation events (CNVEs). While next-generation sequencing allows for the sequencing and comparison of a large number of species, the popular short-read sequencing technologies are prone to collapsing reads in repetitive genomic regions, resulting in artificially low CNVE counts. Using the recently published PacBio genome assemblies derived from long-read sequence data for two African cichlid species, *Oreochromis niloticus* and *Metriaclima zebra*, we demonstrate that the CNVEs detected by our low-cost aCGH, are better retained by long-read assemblies and more accurately represent true copy number variation. We used BLAST to align our microarray probes to both the Illumina and PacBio genome assemblies for both species and calculated the degree to which the Illumina genome assemblies collapse CNVEs detected using aCGH hybridization ratios. These results support aCGH as a relatively cheap approach to quantify and localize copy number variation.

P2-102 PRETENDS EAGLE, TJ*; RODRIGUEZ, SD; GONZALEZ, V; ABRAMSON, CI; North Dakota State University, Saint Philip's College, University of Kansas, Oklahoma State University; *troy.pretendseagle@ndsu.edu*
Ants Build Defensively Against Ant Traps in the Field
The study of pesticides and other agrochemicals on insect behavior is an important and active area of research. During a recent trip to Lesvos, Greece we took the opportunity to determine if ants (Camponotus sp.) will build a defensive wall around a pesticide under natural conditions. We placed a three-well circular ant trap (active ingredient: sodium cacodylate) with a single reservoir of poison connecting the wells together, but separate tabs preventing feeding from the three well openings. We placed this in the path of an ant colony, and documented for 16 days i.e. morning and evening (3 days undisturbed, 3 days unopened, 4 days one tab, 4 days second tab). We turned new tabs to face ant activity. Then another ant trap is placed with all wells closed. In the control period we only saw minimal addition of dirt to the surrounding area. Once the traps were open it took 1-2 days to see significant building around the trap. The exploratory ant trap had a pile of plant material placed along the side of the ant trap that bordered the main ant trail. Other traps saw the placement of dirt in the wells. Other wells saw no building ant activity at all. The colonies from the exploratory site and site #1 both clearly exhibited building activity against the ant trap. Site #4 had no building activity. Sites #2 and #3 both only plugged the wells with dirt. We also noticed colony entrances at sites #2 and #3 both moved about a foot away from their original placement. This would be critical information for dealing with the Red Fire Ant which costs billions of dollars in management & damages. Another experiment must be done to view this behavior more thoroughly. This research was supported by NSF REU grant 1560389 and NSF PIRE grant 1545803 and performed at Skala Kalloni Greece.

P2-103 PRETENDS EAGLE, TJ*; DE JESUS-SOTO, MG; RODRIGUEZ, SD; FLETCHER, SJ; PENTANIDOU, T; TSCHEULIN, T; BARTHELL, J; GIRAY, T; ABRAMSON, CI; North Dakota State University, University of Puerto Rico, Saint Philips College, South East Oklahoma State University, University of the Aegean, University of Central Oklahoma, Oklahoma State University; *troy.pretendseagle@ndsu.edu*
The Effect Of Extended Training Cap Pushing Response, Extinction In Honey Bees (Apis Mellifera)
This experiment provides data on a conditioning procedure for free flying honey bees. We look at the effect of extended training on extinction of the cap pushing response. Twenty-eight bees were captured from a 10 % sucrose solution artificial feeder and trained to platform with a well of 50% sucrose solution. Bees are trained to push a cap to reveal the hidden food source. They were randomly divided into one of two groups consisting of 14 bees each. The two groups were differentiated based on the number of training trials, with one group receiving 6 trials and the other 12 trials before each group received a 10-minute extinction session in which the food well was switched to tap water. The dependent variable was the number of target landings, the number of cap touches, and the number of cap pushes. Both groups displayed similar outcomes in average cumulative data. They both landed on the platform the most; touched the cap second most, and pushed the cap the least. Moreover, the majority of bees trained with twelve trials, stopped returning to the target during extinction much faster than the bees who received the six training trials. This research was supported by NSF REU grant 1560389 and NSF PIRE grant 1545803 and performed at Skala Kalloni Greece.

P3-223 PRICE, SA*; LAROUCHE, O; FRIEDMAN, ST; CORN, KA; WAINWRIGHT, PC; MARTINEZ, CM; Clemson University, University of California, Davis, University of California, Davis; *sprice6@clemson.edu*

A practical guide to implementing a quantitative specimen-based classroom undergraduate research experience

The measurement and analysis of phenotypes is often a rate-limiting step for many integrative organismal studies but engaging undergraduate researchers can help overcome this challenge. We present a practical guide to implementing a quantitative specimen-based Classroom Undergraduate Research Experience (CURE) that trains students to collect phenotypic data and mentors them through the entire scientific process using the data they help to collect. Direct access to specimens is not necessary to implement this undergraduate research experience, as recent efforts to digitize museum collections along with online image archives allow data extraction to take place in any classroom. The processes of science are covered in four equal sections: 1) Data collection training 2) Hypothesis development 3) Analytical methods 4) Interpretation, evaluation and presentation. We focus on hypothesis development and quantitative skills, as they are essential for modern biological discovery but are rarely emphasized in traditional lecture-based classes. We provide suggestions for how to guide students through hypothesis development by first engaging them with the scientific literature and then going through multiple rounds of hypothesis writing, critiquing and further development. We also provide tips for teaching basic programming concepts, data visualization, analytical reasoning and data interpretation using the R software environment for statistical computing. We have run this experience, focusing on collecting and analyzing body shape data across fishes, at two institutions with a total of 39 students. It has so far resulted in 14 research talks and 4 posters presented by students at local symposia, with 2 scientific papers in preparation.

49-4 PRICE, ER*; JARA, RF; University of North Texas; *edwin.price@unt.edu*

A 'Dispersal Syndrome' Approach for Relating High Paracellular Absorption in Birds and Bats to Plant Ecology

Birds and bats rely heavily on paracellular nutrient absorption, unlike non-flying mammals, which rely principally on transporter-mediated transcellular absorption. This characteristic should make birds and bats less susceptible to the physiological effects of naturally occurring plant toxins that inhibit intestinal glucose transporters, such as SGLT1. Previously, E.R.P and colleagues proposed that this could allow plants to favor flying seed dispersers, thus encouraging long-distance dispersal. While this is difficult to test, a more tractable approach takes advantage of the 'dispersal syndrome' concept. Historically, a mammal/bird dichotomy has been suggested for dispersal syndromes in forest ecosystems. Here we propose a flyer/nonflyer dichotomy, thus grouping bats with birds. Further, we propose that plant secondary metabolites be included as a key trait in this syndrome.

P3-3 PRICE, ER*; MAGER, EM; University of North Texas; *edwin.price@unt.edu*

The Effects of Oil and PAH Exposure on Swim Bladder Development and Function

Polycyclic aromatic hydrocarbons (PAHs) are the major toxic component of petrochemicals. PAH exposure causes a syndrome of abnormalities, many of which are downstream sequelae of diminished cardiac function. Failure to inflate the swim bladder is a common developmental outcome of PAH exposure, and has been linked to heart defects, but may occur by other mechanisms as well. Here, we review multiple mechanisms by which oil may affect swim bladder inflation or function. A lack of circulation due to diminished cardiac function causes failed development and non-inflation. However, EC_{50} data indicate that swim bladder non-inflation can be a more sensitive outcome than diminished cardiac function, especially for some particular PAH. Because initial inflation occurs by surface gulping in physostomes and many physoclists, inflation failure can also occur due to the presence of a surface film or the inability to complete swim-up behavior and reach the surface. Non-inflation could also result from failed maintenance of swim bladder volume following initial air gulping, due to damage to the rete mirabile. Functional studies of swim bladder function in adults following PAH exposure are lacking. Thus, there are many potential mechanisms of swim bladder failure in response to oil or PAH exposure, and some could lead to sub-lethal chronic effects.

P3-181 PRICE, S*; SCHUMER, M; WANG, S; CUMMINGS, M; University of Texas at Austin, Stanford University, University of British Columbia; *sarah.price@utexas.edu*

Transcriptomic signatures of 'choosy' vs 'indecisive' social preferences in a sailfin molly (Poecilia latipinna)

To identify underlying mechanisms of social and mating preferences, transcriptomic expression in the brain can be isolated within minutes of the preference behaviors. These transcriptomic profiles help elucidate previously-unexplored genetic pathways expressed during these behaviors. Using an established model for mating preference and social preference behaviors, 16 females from the Poeciliidae species, the sailfin molly (*Poecilia latipinna*), were profiled for their preference behavior and brain transcriptomes using RNA-seq. During the 30 minute behavioral assay, females were placed into one of two groups: (n=8) given the choice of a large male and small male ('mate choice') or a choice between a large and small female (n=8; 'social preference'). Twelve of the 16 female fish spent the majority of the 'association time' near the large conspecific (n=6 towards the large male; n=6 towards large female). Of all 16 females, half exhibited 'choosy' preference behavior, which was arbitrarily defined as fish spending over 65% of the 'association time' with one conspecific. The remaining half exhibited 'indecisive' behavior, i.e., spending less than 65% of the time with either conspecific. The RNA-seq transcriptomes from each female (n=16) will be analyzed by comparing differential expression between the two groups ('mate-choice' vs 'social preference'). Additionally, we can determine if transcriptomic signatures differ between 'choosy' and 'indecisive' individuals.

32-4 PRINZING, TS*; BIGMAN, BS; SKELTON, Z; WEGNER, NC; DULVY, NK; Simon Fraser University, Burnaby BC, Scripps Institution of Oceanography, La Jolla CA, NOAA Southwest Fisheries Science, Center La Jolla CA, Simon Fraser University Burnaby, BC; *tprinzin@sfu.ca*

Paired Estimates of Metabolic Rate and Gill Surface Area in the Horn Shark (Heterodontus francisci)

Metabolic rate underpins life history traits such as reproduction and growth rate and in turn, the maximum population growth rate of a species. However, our understanding of the metabolic basis for life histories and population dynamics is hindered by the challenge of using laboratory respirometers to estimate metabolic rate, resulting in relatively few estimates of metabolic rate for larger, aquatic organisms. An alternate approach is to seek morphological proxies for metabolic rate, such as respiratory surface area. Metabolic rate is highly correlated with respiratory surface area, yet there are exceedingly few paired estimates to allow a direct comparison of these traits in the same individuals. Here, we estimated resting and maximum metabolic rates in addition to gill surface area in a coastal elasmobranch, the Horn Shark (*Heterodontus francisci*), across a broad size range. We found that resting metabolic rate and body mass scaled with a slope of one, while the slope of maximum metabolic rate and body mass was significantly greater than one. These results are consistent with those of similar species and suggest that the aerobic capacity of this species increases through ontogeny. We will also discuss the scaling of gill surface area with body mass and with resting and maximum metabolic rates. By estimating these traits together in the same individuals, our work elucidates the allometric scaling of gill surface area in relation to both resting and maximum metabolic rates while minimizing the confounding factor of intra-individual variation. Overall, the results of this study may be used to inform life histories and conservation efforts of vulnerable, data-poor species.

P1-135 PROFETTO, GM*; HOWARD, JJ; University of New Orleans ; *gprofett@uno.edu*

Management of P. montana Effects on Plant Community Diversity

Invasive species have well-documented negative effects on native communities, but trajectories of community recovery after the removal of invaders are still relatively poorly understood. Kudzu, *Pueraria montana var. lobata* (Fabaceae) (Willd.), a leguminous invasive vine, has spread throughout the southeastern United States, overgrowing and eliminating native vegetation, primarily through shading. To understand the impacts of *P. montana* on forest communities in northern Mississippi I quantified vegetation on actively infested, control, and removal sites of varying ages. I compared species richness, herbaceous cover, and abundance of woody seedlings and saplings on infested and control sites to determine how *P. montana* affected native plant communities. I also compared vegetation on removal sites to determine how long these effects last compared to which management strategy was implemented and whether community composition approaches that of pre-infested sites over time. Preliminary results show that species richness of woody and herbaceous species and herbaceous cover were significantly reduced by*P. montana* infestation. Abundance of woody seedlings and saplings was not significantly different between infested and control sites. After removal of *P. montana*, species richness of herbs initially rebounded but declined over time, due to subsequent infestation of the herbaceous weedy species, *Echinochloa crus-galli* and *Lolium perenne*. This study shows the plant communities previously invade by*P. montana* do not revert to a pre-invade state but, consistent with Invasion Meltdown theory, reach an alternative state where other invasive species can dominate the community.

71-2 PROVINI, P; Centre for Research and Interdisciplinarity, Paris, France; *pauline.provini@cri-paris.org*

Birdsong for human(e) voices: Building efficient voice prostheses inspired from bird vocal system

Our voice is used to communicate but also defines our identity. Thus, a voice alteration can cause emotional and social issues. Patients suffering from an advanced stage of laryngeal cancer often have to undergo a total surgical removal of the larynx, which is the human voice source. To recover the ability to speak, a prosthesis, mimicking the vocal folds, is usually placed between the trachea and the oesophagus. The exhaled air crosses a vibrating element and produces a substitute voice. Unfortunately, the created voice is of poor quality: it is weak, with a low pitch and sounds mechanical. In addition, the limited lifetime of the devices, due to biofilm coming from mucus/material interactions, forces a frequent device replacement. To date, there is no voice prosthesis lasting more than 3 months and able to reconstruct a natural-sounding human voice. In this context, birds should attract attention. First, their vocal repertoire is incredibly diverse, with pitch spanning from 100 to 12 000 Hz, compared to only 85 to 255 Hz in human speech. Moreover, their unique vocal organ, the syrinx, produces sounds from the vibration of membranes, located in the wall of the syrinx, meaning that the air is flowing through the vocal tract without crossing any structures, unlike in mammals. By quantifying the 3D motions of the vocal system during sound production and modulation, we will build a predictive aero-acoustic model we can use to ask "what if" questions and understand cause-effect relationships between shape, motions, and produced sounds. Our interdisciplinary approach, integrating biology, physics and computer science will provide fundamental principles we want to apply to the design of a new generation of vocal prostheses that will produce voices that are more humane.

P1-182 PUFFEL, F*; LABONTE, D; Imperial College London, UK; *fp4418@ic.ac.uk*

Scaling of bite forces in leaf-cutter ants

Leaf-cutter ants are the prime consumers of plant material, and key pest species throughout the Neotropics. A mature colony may cut thousands of square meters of leaf area per year, deploying foraging parties which consist of differently-sized workers performing distinct tasks: smaller ants tend to cut tender leaves, while larger ants harvest tougher leaves. This 'division of labour' is believed to provide the colony access to a larger variety of food sources, and hence increase its fitness and resilience. The ability of a worker to cut a given food source is constraint by the available bite force, and understanding how bite forces vary with size is hence crucial for further assessing this hypothesis. We measured bite forces for *Atta vollenweideri* workers across the entire size-range, covering approximately one order of magnitude in body mass. Bite forces were measured with a custom-built force rig based on force-sensitive capacitors connected to adjustable cantilevers, which allowed us to control the gap width and hence the mandibular opening angle. Even after accounting for the effects of size expected from isometry, large workers produced significantly higher forces than small workers. This positive allometry originates from (I) disproportionally larger head capsules accommodating greater mandible closer muscles and (II) a systematic increase in the mechanical advantage. Bite forces of larger ants are comparable to those of considerably heavier cockroaches, underlining the adaptation of leaf-cutter ants to produce the high forces required to overcome the mechanical resistance of their food sources. Our results indicate that large ants are particularly well-suited for cutting tough leaves, but why are tender leaves mainly cut by smaller ants? We speculate that this behaviour is explained by the ergonomics of cutting, which will be investigated in future studies.

P2-170 PULLEY, KL*; PERCIVAL, C; TAPSAK, ST; TSCHEULIN, T; PENTANIDOU, T; GONZALEZ, VH; HRANITZ, JM; BARTHELL, JF; University of Texas at El Paso, Pomona College, Claremont, CA, Bloomsburg University of Pennsylvania, University of the Aegean, Mytilene, Greece, University of Kansas, Lawrence, Bloomsburg University of Pennsylvania, University of Central Oklahoma, Edmond; *Klpulley@miners.utep.edu*

Differences in critical thermal maximum between crepuscular vs. diurnal species of Xylocopa

Predicting the response of pollinators to temperature has become increasingly important due to global warming trends. The critical thermal maximum (CT_{max}), the temperature at which an organism loses motor control when exposed to high temperatures, serves as a good indicator for their response to rising temperature. However, this remains unknown for many pollinating bees. Here we compared the heat tolerances of three species of carpenter bees (*Xylocopa violaceae, X. olivieri*, and *X. iris*), which differ in their daily foraging patterns. One of them is crepuscular (*X. olivieri*) while the other two are diurnal, thus we expect the latter species to be more heat tolerant. We also assessed the effect of sex, body size, relative age, and body water content on their CT_{max} and measured bees' thoracic temperature. The crepuscular species was as heat tolerant as *X. violacea*, but less heat tolerant than *X. iris*. Sex, body size, relative age and body water content did not have an effect on CT_{max}. Thoracic temperatures were always higher than 40 °C, independent of ambient temperature, and a few Celsius degrees lower than CT_{max}. Our results are consistent with our expectation that diurnal species tend to display greater thermal tolerance and provide additional explanations supporting the hypothesis of interspecific interference competition as the main factor driving the evolution of dim-light foraging behavior in these bees.

138-3 PUTLAND, RL*; MACKIEWICZ, AG; ROGERS, LS; MENSINGER, AF; University of Minnesota Duluth, University of North Carolina, Chapel Hill, University of Washington; *rputland@d.umn.edu*

Effect of anthropogenic sound on the communication space of the oyster toadfish, Opsanus tau

Many animals rely on sound for important cues about their environment, yet there is an increasing awareness that anthropogenic sound may be threatening the ability of individuals to communicate. For the oyster toadfish, *Opsanus tau*, vocal communication and sound detection are critical for reproductive success, however little is known about how they may respond to changes in their acoustic environment. Passive acoustic monitoring was conducted in a small harbour (Eel Pond, MA, USA) to pinpoint the location of male oyster toadfish producing mating vocalizations, termed boatwhistles, to attract females. Significantly less vocalizations were detected following exposure to continuous vessel sound (100 – 12,000 Hz, source level 130 dB re 1 µPa), suggesting individuals changed their vocal behavior in response to anthropogenic activity. To investigate the physiological effects of anthropogenic sound, toadfish auditory sensitivity was also tested in laboratory experiments using the auditory evoked potential technique, before and after exposure to 1 hour of vessel sound. Auditory sensitivity (100 – 500 Hz) significantly decreased following exposure to vessel sound and did not return to baseline levels until 6 days after. This study highlights that vessel sound influences both the behaviour and physiology of aquatic life. The masking effect of overlapping frequencies from continuous vessel sound, and temporary threshold shifts in auditory sensitivity, is suggested to reduce communication space: the ability to detect, perceive and response to conspecifics and ultimately lead to a failure in mate attraction and detection.

P3-209 PYATT, JE*; LI, CY; WAITS, A; EARLEY, RL; University of Alabama; *jepyatt@crimson.ua.edu*

Mechanisms underlying temperature-dependent sex change

Temperature-dependent sex change (TSC) is common in fishes and reptiles but the physiological mechanisms are not fully understood. Mangrove rivulus fish (Kryptolebias marmoratus) is an ideal model for exploring the physiological mechanisms governing TSC. Adult rivulus exist predominantly as self-fertilizing hermaphrodites and change sex into secondary males in response to high temperature (≥28°C). Androgenic and estrogenic hormones play important roles in regulating sex change, and most studies have focused on the aromatase gene (Aro), which encodes an enzyme that converts testosterone to estradiol. However, other steroid biosynthesis enzymes such as 11β-hydroxylase (11βH) and 17β-hydroxysteroid dehydrogenase (17βHSD), which drive androgen synthesis, have received relatively little attention. We hypothesized that high temperature would decrease Aro expression but increase 11βH and 17βHSD expression to establish an androgenic environment that would promote sex change. To test this hypothesis, adult hermaphroditic rivulus were maintained at three temperatures (high: 30°C, normal: 25°C, low: 20°C) for 21 days. Expression of brain and gonad Aro, 11βH and 17βHSD were quantified using quantitative-PCR. Pre- and post-treatment testosterone (T), 11-ketotestosterone (11KT) and estradiol (E2) levels were also quantified using enzyme immunoassay. The results showed increases in all three hormones at high temperature and decreases in E2 and 11KT at low temperature. Low temperature also decreased the E2/T ratio, suggesting suppression of aromatase function. Temperature did not affect expression of brain Aro, 11βH or 17βHSD. However, low temperature significantly decreased gonad Aro expression, while high temperature significantly increased gonad 11βH and 17βHSD expression. This study demonstrates that high temperatures establish an androgenic environment conducive to initiating sex change.

P1-184 QUIMBY, K*; CREWS, SC; SPAGNA, JC; William Paterson University; *quimbyk1@student.wpunj.edu*

Impact of Leg Loss on Rotating Prey Strikes in "Flattie" Spiders of Genus Karaops

Spiders in the family Selenopidae, commonly called "flatties,"- have been characterized as having the fastest rotational prey strikes of any animal. Previous work developed a model of rotational striking based on intact spiders from the genus *Selenops*- here we test this model to analyze the strikes of flatties from genus *Karaops* including those missing one or two legs. Flatties (*Karaops* sp.) were collected in Australia and filmed using high-speed digital video cameras attacking fruit fly prey. Legs were operationally defined as inner flexion (IFL), outer extension (OEL) and aerial adduction (AAL). Intact *Karaops* showed less variation in leg usage than *Selenops* (p <0.05), consistently assigning a single IFL closest to the fly paired with 2 OELs to its opposite back legs. Using rotational speed as performance proxy, we found spiders missing one leg were marginally slower (13% reduction, p =.054) than intact ones (2.13 ± 0.38 deg/ms for seven legs, vs 2.48 ± .61 for intact), though capture rate was lower than in intact individuals (87% strike success vs 98% of intact strikes, p <0.001). By contrast, those missing two legs were much slower (54% reduction, p <0.001, mean speed 1.15 ± 0.50 deg/ms), and caught prey in only 76% of strikes. The leg use of autotomized spiders was also compared to the intact spiders. Analysis of changes in leg use by seven-legged spiders showed that those that had lost a single rear leg would compensate by changing the roles of the back two legs, usually shifting the role of the inner flexion leg (IFL) to the next closest leg to the prey. This maintained the three leg roles in all strikes. However, the six-legged spiders often allowed certain legs to function as both a flexion and extension leg during different portions of one strike. While rotational speed alone supports the proposed "spare leg" hypothesis, prey-capture is still negatively impacted.

42-6 QUINN, BL*; MORALES, AE; SIMMONS, NB; Temple University, American Museum of Natural History; *brooke.quinn@temple.edu*

Predicting Foraging Strategies from Morphological Traits in Myotis

The mouse-eared bats (*Myotis*) are found on every continent except Antarctica and comprise three primary ecomorphs with different feeding strategies (i.e. aerial hawking, gleaning, and trawling for aquatic prey). Despite striking morphological similarities within ecomorphs, molecular phylogenies have shown that these groups are not monophyletic. In this study, we use phylogenetic comparative methods, machine learning tools and morphological data to understand which traits are linked to the convergent phenotypes and foraging strategies of *Myotis*. We evaluated 15 traits hypothesized to be of significance for predicting foraging strategies in an analysis of over 300 specimens representing 54 species from 6 continents. No phylogenetic signal was found for any of the traits, with each trait displaying a low K value and lacking statistical significance, suggesting that similarities among different species in these traits is due to convergence rather than shared ancestry. Convergence analyses using comparative methods revealed significant changes in the mean values for each trait at particular nodes of our tree, and detected a lower number of regimes than shifts for each trait, which together are indicative of convergent evolution. A machine-learning analysis to predict feeding type resulted in an accuracy rate equal to or greater than 75%. The three most important traits for prediction of foraging strategy in *Myotis* are ear length, tibia length, and foot length. Ear length may play a role in the ability of bats to hear prey-generated sounds, and tibia and foot length may play a role in prey capture using the uropatagium and feet.

P2-179 QUINTANILLA RAMIREZ, GS*; TREIDEL, LA; WILLIAMS, CM; Univ. of California, Berkeley; *sigridquinta@berkeley.edu*

Aerobic Scope is increased to support flight in wing-polymorphic female crickets, Gryllus firmus

Flight is an energetically demanding activity, which may require a remodeling of metabolic pathways to support higher aerobic scope. This is likely to be a component setting the costs of flight for wing-polymorphic species. Adult wing-polymorphic crickets (*Gryllus firmus*) specialize either in dispersal (LW) or reproduction (SW) due to a resource-based trade-off between flight and ovary synthesis. We hypothesize that the LW morph has higher tissue-specific mitochondrial activity and hence higher whole-organism respiration to support flight compared to the SW morph. Using a treadmill respirometer, we measured resting metabolic rate (RMR), maximal metabolic rate (MMR), and locomotor performance. LW morphs had greater endurance than SWs as they ran for longer and reached higher speeds prior to exhaustion. This was accompanied by a higher mass-specific MMR but similar RMR compared to the SW morph, reflecting a larger aerobic scope for the LW morph. Tissue-specific mitochondrial activity was determined for jumping-leg muscle, dorsoventral flight muscle, and fat body and correlated to the aerobic performance of the same individuals. Higher MMRs were found to be positively correlated with higher citrate synthase activity in LW fat body but not in leg or flight muscle. Fat body plays an important role in lipid synthesis, storage, and mobilization and this work suggests that it is also important for meeting the energy demands of dispersal in LW crickets. Combined, the higher tissue-specific activity in fat body and aerobic capacity in the LW morph presumably support dispersal through flight. Overall, our study provides a novel perspective on how processes at the organ- and tissue-level can constrain whole-organismal performance.

S10-8 RADER, JA*; MOHAMMADI, S; HEDRICK, TL; WALDROP, LD; University of North Carolina, Chapel Hill, NC, Chapman University, Orange, CA; *jrader@live.unc.edu*

Modeling diversification and constraint in avian wing morphology

Morphological evolution, especially in the context of adaptive radiation, can be thought of as a process of niche filling wherein species diversify in their ecological habits to exploit the available resources. Interspecific competition is avoided, generally, via phenotypic divergence that facilitates specialization on subsets of the total available resource set. Classic studies of adaptive divergence have focused on morphological characteristics, linking form to function, and function to evolution. While these studies have provided valuable insight into the processes that drive and shape morphological evolution, they do little to explain the processes that may constrain it. This is, in part, because it is difficult to assess the total available niche space that species could theoretically diversify to fill. Without this critical piece, it is difficult to ascertain where within this theoretical space species are competitively excluded, where they are constrained by their ancestry, or where their evolutionary trajectory has led them to the edge of theoretical parameter space. Furthermore, the biomechanical performance landscape conferred by morphological attributes may be a complex assemblage of peaks of high performance amid less advantageous valleys. We used computational fluid dynamics to model lift to drag ratio as a measure of flight performance in a morphological parameter space for bird wings composed of three axes: aspect ratio, camber, and Reynolds number. We then used a large dataset of 3-dimensionally scanned wings from 101 species of birds to assess what proportion of the theoretical performance they have diversified into, and what regions and proportion of that space they occupy.

119-5 RAGLAND, GJ*; DOWLE, EJ; POWELL, THQ; FEDER, JL; HAHN, DA; University of Colorado, Denver, University of Otago, State University of New York, Binghamton, University of Notre Dame, University of Florida; *gregory.ragland@ucdenver.edu*

Genome-wide variation and transcriptional changes in diverse developmental processes underly the rapid evolution of seasonality in a temperate fly

Seasonal timing, or phenology, is a critical adaptation that has long served as a model for evolution across spatial, climatic gradients and for rapid evolution in response to changing environments. In animals, however, we have a limited understanding of the genetic variation that facilitates this evolutionary flexibility. The most well-developed studies focus on photoperiodically-cued phenology, whereas there is very little known about the genetic and physiological basis for phenology that is primarily determined by environmental temperature. We used full genome resequencing in combination with a comparative, time series analysis of transcription during the course of diapause (winter dormancy) to explore how a recently derived population of the apple maggot fly, *Rhagoletis pomonella*, has evolved earlier phenology compared to an ancestral population with relatively later phenology. The results robustly support a polygenic model for phenology, wherein many genetic variants affecting diverse developmental processes lead to a more rapid progression through diapause in the recently evolved population. We link these comparative results with observations from *Drosophila melanogaster* to further suggest that diapause represents an extreme slowing, but not arrest of development, and that the same variants that may affect the duration of any developmental process also govern the duration of diapause.

47-5 RAGSDALE, A.K*; DUTOIT, L; BESSON, A.A; KING, T; GEMMELL, N.J; HORE, T; JOHNSON, S.L; University of Otago, NZ, University of Alberta, Canada;
alexandria95ragsdale@gmail.com

Paternal hypoxia exposure primes offspring for increased hypoxia resistance

Increasingly, studies are revealing that the environmental challenges experienced by an organism can not only have multiple effects on an individual level, but that these challenges may also impact unexposed offspring. Hypoxia is a physiological challenge that many aquatic organisms encounter in their environment, resulting in in numerous physiological, phenotypic, and epigenetic changes in aquatic organisms. In this study, we use zebrafish (*Danio rerio*) as a model to investigate how paternal hypoxia experience impacts subsequent progeny. Males were exposed to moderate hypoxia (11-13 kPA) for 2 weeks, bred to create an F1 generation, and progeny underwent an acute hypoxia (0-1 kPA) tolerance assay. Using time to loss of equilibrium as a measure of hypoxia resistance, we show that paternal exposure to hypoxia endow offspring with a greater tolerance to acute hypoxia, compared to offspring of unexposed males. In addition to phenotypic alternations, we also investigated changes in gene expression in offspring. We conducted RNA-Seq on whole fry and detected 89 differentially expressed genes, including two hemoglobin genes and a selenoprotein that are significantly upregulated by more than 4-fold in hypoxia offspring. Paternal exposures to physiological challenges are thus able to impact the phenotype and gene expression of their unexposed progeny. Future research will investigate whether changes in DNA methylation underpin the observed changes in phenotype and gene expression.

86-1 RAHMAN, MS*; RAHMAN, MS; University of Texas Rio Grande Valley; *mdsadequr.rahman01@utrgv.edu*

Effects of Heat Exposure on Antioxidant Expression and Redox Status in the American Oyster: A Laboratory Study

Increasing atmospheric temperatures significantly influence the physiological functions in aquatic organisms, particularly the marine invertebrates which are extremely susceptible to elevated temperature. In this study, we observed the effect of elevated temperatures (16, 22, 26, and 30°C for 1-week exposure) on the morphology as well as on the prooxidant and antioxidant homeostasis in gills and digestive glands of American oyster, *Crassostrea virginica*. Immunohistochemical analysis was performed to observe the expression of heat shock protein 70 (HSP70, an indicator of heat stress), dinitrophenyl (DNP, a biomarker of reactive oxygen species, ROS), nitrotyrosine protein (NTP, an indicator of reactive nitrogen species, RNS), catalase (CAT, an antioxidant), and superoxide dismutase (SOD, an antioxidant) in gills and digestive glands of oysters. Histological analysis showed an increase in mucus secretion, a common response to different stressors, with increasing temperature in both tissues along with the enlargement of lumens of digestive glands. Immunohistochemical analysis showed a significant increase of HSP70, DNP, and NTP protein expressions with elevated water temperature from 16 to 30°C, indicating rising temperatures induce thermal stress which leads to increased oxidative stress as well as nitrosative stress. Interestingly, the expression of CAT and SOD increased from 16 to 26°C in oyster tissues, however, a significant drop in expression of CAT and SOD was observed at 30°C which indicates that oyster tissues become defenseless against the attack of ROS and RNS at high temperature. Collectively, we conclude that elevated seawater temperature induces oxidative and nitrosative stresses which may trigger cellular apoptosis in American oyster.

39-8 RAJA, SV*; SANE, SP; National Centre for Biological Sciences, Tata Institute of Fundamental Research;
sreekrishnavr@ncbs.res.in

Collective movements of mound-building termites

Social insects maintain order despite large and varying number of group members and changing environmental conditions. For instance, in termite mounds, the numbers of individuals can fluctuate a great deal, as do the ambient conditions under which they operate in their underground nests. Previously, we showed that when a mound surface is breached, the termites (*Odontotermes obesus*) can repair the breach within a short duration through their collective actions. This observation suggested that there is an increased traffic towards the breach. How well-ordered is this collective movement within the nests? In general, how do termites modulate their traffic towards a breach in the mound? To address these questions, we developed a laboratory assay to study collective movement of termites. Termites were introduced in a circular arena, and their milling behaviour monitored while altering the ambient conditions within the arena. Our experiments show that whereas mechanosensory cues are required to initiate the milling behaviour, after some duration the termites lay pheromone trails that provide chemical cues to help maintain other members on a trail. This behaviour is density-dependent such that greater number of termites within the arena means that behaviour is initiated earlier. We have also conducted experiments to monitor such movements in natural conditions by introducing a camera deep within the mound through a breach. We observed termites moving in small groups towards the breach through tunnels, and forming transient lanes as they moved towards the breach, and their number increased with time. Together, these results show that termite movement in both laboratory and nature is highly ordered, and maintained by mechanical and chemical cues.

P3-216 RAJARATNAM, G*; SUPEINTHIRAN, A; SU, KFY; MEIER, R; National University of Singapore, University of Toronto, Scarborough, National University of Singapore, Lee Kong Chian Natural History Museum; *gowrirajaratnam91@gmail.com*

Sex brushes and dirty flies: The development and evolution of a novel abdominal appendage in male sepsid flies

Most adult winged insects follow a highly conserved body plan which consists of an abdomen without any non-genital appendages. Sepsid flies are one of the exceptions; males of some species have modified a flat, sclerotized plate on the abdomen into a remarkable brush-like appendage that varies in shape and size across the family. These novel brushes are used to stimulate the females during courtship, are ontogenetically expensive to build and have a complex evolutionary history. Using CRISPR/Cas9, we attempt to unravel the gene regulatory network (GRN) underlying the brush in two species with morphologically distinct brushes and possible independent evolutionary origins, *Themira biloba* and *Perochaeta dikowi*. *T. biloba* has an elaborate brush that extends substantially from the abdomen with long, distal bristles while *P. dikowi* has a simple brush that is mostly flat against the abdomen with short bristles. We test four candidate genes (*doublesex*, *abdominal-A*, *extradenticle* and *Distal-less*) and show that both the limb- and sex-patterning pathways are co-opted in the development of this novel brush. In both species, *doublesex* and *abdominal-A* have been similarly co-opted into the GRN for both elaborate and simple brushes. However, in *T. biloba* alone, *Distal-less* and *extradenticle* are additionally necessary for brush development whereas in *P. dikowi*, there is no evidence for the involvement of *Distal-less*. This suggests that *Distal-less* might have been co-opted specifically in the genus *Themira* to facilitate the development of a more elaborate brush with large cuticular extrusions.

93-3 RAMENOFSKY, M*; PRADHAN, D; AUSTIN, SH; SOMA, K; SCHLINGER, B; University of California Davis, Idaho State University, Pocatello, Oregon State University, Corvalis, University of British Colulmbia, Vancouver, University of California, Los Angeles; *mramenofs@ucdavis.edu*
Phenotypic Flexibility of Glucocorticoid Signaling in Skeletal Muscles of White-crowned Sparrows Preparing to Migrate
Glucocorticoids (GC) are associated with responses to stress and also energy metabolism, tissue remodeling and homeostasis. At low circulating levels GC bind high-affinity mineralocorticoid receptors (MR) and affect anabolic pathways including tissue repair and homeostasis. At elevated levels, they bind to GC receptors (GR) activating catabolic pathways. Avian migrants express phenotypic flexibility by seasonally modifying anatomy, physiology and behavior to accommodate energetic demands of each stage. We hypothesized that GC signaling may contribute to the phenotypic flexibility in the pectoralis (flight) and gastrocnemius (leg) muscles in sparrows on the wintering grounds at three distinct stages leading up to migratory departure in spring: winter, pre-nuptial molt, and pre-departure. CORT was detected in plasma and in both muscles but CORT signaling differed across muscles and stages. Both plasma and pectoralis CORT were elevated at pre-departure ($p<0.05$). Expression of 1lβ-hydroxysteroid dehydrogenase (1lβ-HSD) Type 2 (inactivates CORT) increased in the pectoralis at pre-departure ($p<0.05$), whereas, 1lβ-HSD Type 1 (regenerates CORT) did not change. Neither isoform was detected in the gastrocnemius. Expression of MR only was elevated in pectoralis at pre-departure ($p<0.05$). These data suggest that anabolic functions predominate in the pectoralis only while catabolic activity is undetected in either muscle at pre-departure. Thus, we find evidence for potential pathways by which GC signaling may function to regulate the phenotypic flexibility expressed by birds anticipating migratory departure.

100-4 RAMIREZ, RW*; RIDDELL, EA; WOLF, BO; University of New Mexico, University of California, Berkeley; *ricram@unm.edu*
Seasonal and geographical variation in thermoregulatory performance of Cricetid rodents in the Mojave desert
Desert environments challenge animals by exposing them to extreme heat while simultaneously providing little water. When exposed to environmental temperatures above body temperature, rodents rely on evaporative cooling as means for dissipating excess heat. However, the high water requirements associated with evaporative cooling produce a physiological trade-off between conserving water to maintain hydration and using water to cool evaporatively. For many desert rodents, we lack a complete understanding of the thermoregulatory strategies in the heat, especially the simultaneous responses in evaporative cooling, metabolic heat production, and body temperature variation. We examined seasonal and geographic variation in thermoregulatory strategies of four species of Cricetid rodents to understand physiological response to local climatic variables. We used flow-through respirometry to measure evaporative water loss, metabolic heat production, and body temperature as a function of ambient temperature. Our research focused on *Neotoma albigula, N. lepida, Peromyscus eremicus,* and *P. crintus* at four sites with elevations ranging from 300-1600m in the Mojave Desert. We found interspecific differences in the use of hyperthermia as a strategy to conserve water, and in general, thermoregulatory strategies appeared to focus on water conservation during the summer during periods of extreme heat and water scarcity. Moreover, thermoregulatory strategies also depended on recent exposure to local temperature, humidity, and precipitation patterns. Understanding physiological responses to local climate variability will improve predictions for forecasting the physiological impact of climate change.

P1-65 RAMOS-GUIVAS, B*; JAWOR, J; WRIGHT, T F; New Mexico State University, Las Cruces; *brianrg@nmsu.edu*
Glucocorticoids and reproductive success in captive Puerto Rican Parrot Amazona vittata
Many species are threatened with extinction and captive breeding programs to protect these species from extinction and produce individuals for eventual reintroduction are becoming more common. Under captivity, animals experience different stressors and have different levels of glucocorticoid hormones compared to individuals in the wild, potentially altering reproduction and other key behaviors and complicating captive breeding. The Puerto Rican Parrot *Amazona vittata)* recovery program provides a good platform to understand how glucocorticoids levels may relate to reproductive success under captive conditions. We measured fecal glucocorticoids of males of breeding pairs from 2 captive populations of Puerto Rican Parrots over 2 breeding seasons. Fecal samples were collected overnight from males while females incubated eggs and/or chicks in the breeding cavity and fecal glucocorticoids were measured with a corticosterone ELISA kit. We found considerable individual differences among males, with peaks after egg laying and chick hatching. The mean value of fecal glucocorticoids in 2017 was higher than in 2018. There was no clear relation between mean glucocorticoids of males and our primary measure of reproductive success, the number of fledglings produce by each male. These results provide a baseline for comparison with reintroduced populations of this endangered species.

P2-167 RAMSARAN, S/K*; WATERS, J/S; Providence College; *sramsara@friars.providence.edu*
Heat shock physiology: measuring the metabolic impacts of thermal stress in Drosophila melanogaster
Organisms live in thermally dynamic environments and have evolved mechanisms to survive acute thermal stress. These include behavioral responses such as movements toward preferred temperatures and postural modification and molecular mechanisms such as biochemical adaptation and expression of heat shock proteins which act as chaperones to protect the three dimensional structure and function of critical cellular machinery. These responses have consequences for organismal fitness and evolutionary adaptation, but what are the costs of the stress response? We hypothesized that the energetic costs of resilience to acute thermal stress are detectable as elevations above resting metabolic rate and are likely to persist long after the initial exposure and during recovery. Before and following exposure to short, acute, hot or cold temperature shocks, we measured the metabolic rates of adult male and female Drosophila melanogaster in a controlled and repeated measures experimental design. This research was conducted as part of a collaborative project (www.thermofly.org) and was supported by funding from NSF EPSCOR RII Track 2 FEC (1826689): From Genome to Phenome in a Stressful World: Epigenetic regulatory mechanisms mediating thermal plasticity in Drosophila.

7-8 RANGEL, RE*; SORTE, CJB; University of California Irvine, Irvine, CA; *racine.rangel@gmail.com*
Staying local: small-scale environmental history influences the metabolic response of marine invertebrates to increased temperature
As ocean temperatures steadily rise, marine species will be exposed to temperatures that are increasingly over their physiological optima. In order to anticipate species' responses to rising temperatures, we need to know the relationship between metabolic rate and thermal history, which itself may vary at small-scales in space and time. We measured metabolic rates of hermit crabs (*Pagurus hirsutiusculus*) and mussels (*Mytilus trossulus*) and evaluated the relationship between thermal sensitivity and thermal history. Organisms were collected from 24 tide pools in Sitka, Alaska in which we also recorded temperature every five minutes for three months prior to metabolic rate assays. Using respirometry, we estimated resting mass-specific oxygen consumption (MO_2) at three different temperatures (10°C, 18°C, and 26°C) for one hermit crab and one mussel from each tide pool at three seasonal time points. We tested for linear relationships between thermal sensitivity (individual MO_2 slopes) and the following environmental parameters: average, variance, maximum, minimum, and range of pool temperatures. For both species, there were relationships between thermal sensitivity and thermal history; however, the direction of the relationships and most important thermal parameters differed between species and seasons. These findings show that thermal environmental history at small scales strongly influences metabolic response to temperature increase within populations and in ways that differ notably between species and seasons.

P3-214 RASHID, S*; HALANYCH, K; MOSS, A; Auburn University; *sbr0012@auburn.edu*
Differential Gene Expression of Wound Repair in Mnemiopsis leidyi
Differential Gene Expression of Wound Repair in Mnemiopsis leidyi Susan B. Rashid, Kenneth M. Halanych, Anthony G. Moss Department of Biological Sciences, Auburn University, 101 Rouse Life Sciences Bldg. Auburn, AL 36849 Wound repair is a highly conserved, multiphasic process essential for organismal health. Classically, terrestrial animal wound repair has been recognized to encompass three phases: hemostasis, inflammation and remodeling, and can take a few weeks to a few months to complete. In the marine invertebrate, Mnemiopsis leidyi, a ctenophore, undergoes a scar-free wound repair occurring over only a few minutes to hours, dependent upon the size of the original injury. The genetic program in which healing occurs in M. leidyi has yet to be determined. We conducted a time course study where tissue was collected over the healing process in M. leidyi. We removed standardized 6 mm-long tissue slabs from the oral regions of subsagittal comb rows. The tissue slabs, encompassed the epithelial layer, including the epithelial monolayer and the pseudostratified epithelial polster cells that bear the comb plates, the underlying canal, and associated mesoglea superficial to the canal surface. During healing, samples of the were taken over a six-hour time course at visually identifiable cellular/tissue events that we named; 1) early response, 2) epithelial repair, and 3) comb row regeneration. Tissue samples were snap frozen in liquid nitrogen and were total RNA was extracted and subjected to RNA-seq. Reads were mapped back to the M. leidyi genome to identify differentially expressed genes during repair and recovery. This will allow us to discover the genetic profile of rapid repair and determine the phasic nature of healing in ctenophores. We expect to see an alteration in the classic program due to the rapid nature of repair, as seen in other marine invertebrates, such as Hydra.

P2-148 REARDON, K M*; HUSAK, J F; University of St. Thomas; *kara.reardon21@gmail.com*
Effects of aerobic exercise training on mitochondrial function in lizards
Endurance performance is an important survival trait for many vertebrates and can be improved in both mammals and nonmammals by aerobic exercise training. Mitochondria biogenesis likely contributes to this through the upregulation of certain genes such as PPARδ. However, it has been hypothesized that adaptations to skeletal muscle and oxidative phosphorylation capacities in mitochondria may also play a role in increased endurance in response to exercise. Green anole lizards enhance their endurance performance in response to aerobic exercise, but they also have lower standard metabolic rates, suggesting there is not an increase in mitochondria biogenesis. We hypothesized that after six weeks of aerobic exercise, trained green anoles would have improved endurance performance due to adaptations in their skeletal muscle leading to better mitochondria efficiency. We performed an XF Cell Mito Stress Test and measured the oxygen consumption rates (OCR) of gastrocnemius muscle cells from 19 male anoles and 19 female anoles, half of which were trained and half sedentary controls. We found that both male and female trained lizards increased their endurance performance. We did not see a difference in OCR between treatments for or ATP-linked respiration; however, control muscles had increased maximal respiration while trained muscles did not. This suggests that the trained lizards are unable to consume as much oxygen as control lizards with an increase in ATP demand. Nevertheless, both trained and control muscles increased OCR with the addition of pyruvate, but trained muscles increased more. Therefore, the trained lizards were able to consume the oxygen necessary to meet a rise in ATP demand but only when supplied with additional substrate. We discuss the possible changes to mitochondria function or metabolic substrates to explain these results.

P1-32 REDAK, C*; WILLIAMS, AS; HALANYCH, KM; WHELAN, NV; Department of Biological Sciences, Auburn University , School of Fisheries, Aquaculture, and Aquatic Sciences, Auburn University, Warm Springs Fish Technology Center, United States Fish and Wildlife Service; *czr0057@auburn.edu*
Effects of reservoirs on genetic diversity and gene flow of an endangered freshwater snail, Pleurocera foremani
River impoundments rapidly alter freshwater habitats, often resulting in species decline or extirpation. Yet, fine-scale response of remaining species to such habitat alternation is not well studied, especially for the invertebrate taxa that are often most affected by river impoundments. The Coosa River in Alabama experienced one of the largest faunal declines in modern history after impoundment making it an ideal system for studying how species are affected by reservoir creation. One such species, the rough hornsnail *Pleurocera foremani*, is a freshwater snail in the family Pleuroceridae endemic to the Coosa River system. It is one of the few endemic freshwater snails that persists in Coosa River reservoirs. *P. foremani* has been federally listed as an endangered species since 2010, but new populations of *P. foremani* have been discovered within the Coosa River system since the initial listing. Primary threats to the snail are manmade factors, like fragmentation or removal of habitat areas, and decreased water quality. We sampled all known localities of *P. foremani* and use 2bRAD-Seq to detect genetic diversity. We assessed patterns across the current range of *P. foremani* and measured gene flow within and between impoundments. Ultimately, this study will inform management strategies and potential down-listing decision for *P. foremani* as well as provide insight into genetic connectivity of invertebrates within the Coosa River drainage.

P3-137 REDMANN, E*; WARD, AB; Adelphi University;
eredmann@adelphi.edu

The Effect of Substrate on Terrestrial Locomotion in Lepidosiren paradoxa, the South American Lungfish, Informs the Water-to-Land Transition

The transition of life onto land was a pivotal moment in evolutionary history. In order to better understand this important event, we can look to the closest relative of early tetrapods: the lungfish. These fish have been studied primarily to understand the physiological changes which must have taken place to allow for life on land, but their terrestrial locomotion is a significant characteristic which can inform the water-to-land transition as well. Snakes, which rely on axial locomotion, can be good models for describing the terrestrial locomotion of amphibious fish, but the differences in musculature and the axial skeleton mean that the locomotion of amphibious fish must be examined independently. This research assessed the locomotion of the South American Lungfish, *Lepidosiren paradoxa*, in water and on three terrestrial substrates: sand, loose pebbles, and fixed pebbles, to understand how substrate affects their locomotion. While there was a distinction between aquatic and terrestrial locomotion, the type of substrate did not affect the locomotor performance. However, this may have conferred an advantage to the ancestors of early tetrapods by allowing them to effectively invade new terrestrial territory regardless of the substrate composition and thus may have been essential in the water-to-land transition.

P3-134 REED, SE*; MANN, SDW; BERGMANN, PJ; Clark University, Clark University ; *sareed@clarku.edu*

Mechanisms That Determine Success At Running On Water In The Quadrupedal Lizard Anolis sagrei

Walking on water is a form of locomotion employed by many different species of animals ranging in size from water-walking insects to dolphins. The best studied is the basilisk lizard (*Basiliscus* spp.) Basilisks are able to run on water using a variety of different hydrodynamic forces that are produced during the stride cycle, which is comprised of a slap, stroke, and recovery phase. Lift forces are only generated during slap and stroke, during which the lizard is moving its foot down and posteriorly through the water at a high velocity and a high stride frequency. Juvenile basilisks have relatively larger feet and are able to generate relatively higher hydrodynamic forces than large basilisks. Basilisks are big enough that surface tension of the water does not contribute to lift. Recent work has shown that smaller animals, such as small geckos use both surface tension and hydrodynamic lift forces to keep them above the water's surface. However, there is a lot of intra- and inter-individual variation in how much of the animal is pushed out of the water while it is running. Here we show that the small, quadrupedal lizard, *Anolis sagrei*, is also able to run on water. We use high-speed video (480fps) to understand what factors explain how far out of the water *A. sagrei* run. We consider variation in running velocity, stride frequency, foot velocity, foot depth, and foot surface area to explain variation in how far out of the water the animal is while running. We find that there is no significant relationship between how much of the body is out of the water and the surface area of either the front and hind feet, but, there is a significant relationship with both the maximum and average forward velocity of the lizard.

126-8 REED, AJ*; WOFFORD, SJ; Behavioral and Sensory Ecology Laboratory, Dept. of Biology, Jacksonville State University;
areed10@stu.jsu.edu

Turn It Down! The Effects of Acoustic Stimuli on Contest Dynamics in Crayfish

Agonistic interactions are ubiquitous across animals and these behaviors can establish dominance hierarchies that play a role in mating and resource distribution. Stressful environments can have effects on this behavior, influencing these hierarchies. For example, Anthropogenic noise has been shown to negatively influence social behaviors in several aquatic and terrestrial organisms. Crayfish, like many other aquatic crustaceans, rely heavily on chemical stimuli to find food, mates, and to interact with conspecifics. However, limited studies have shown that some aquatic decapod crustaceans produce and react to acoustic stimuli. The extent to which crayfish can detect and react to acoustic stimuli is still largely unknown. The purpose of this study was to investigate the potential impacts of non-natural noise, in the form of introduced vibrations, influenced agonistic behaviors in crayfish. Crayfish were socially isolated from opponents for one week before being paired together for a contest. Control animals were isolated without vibrational stimuli for this period, while noise treated animals were isolated in aquaria connected to a vibrational stimulus. Dyadic contests were recorded and analyzed based on the length of the first agonistic bout as well as the maximum behavioral intensity reached during the first bout. Initial findings have not shown significant differences in contest duration or maximum intensity between control and treatment animals. These findings imply that a sound stimulus of this frequency does not play a significant role in contest dynamics, or this frequency is not a physiological or behavioral stressor.

83-5 REESE, SJ*; MILLION, KM; PROFFITT, MR; Howard University, Indiana University; *sierrajreese@gmail.com*

Response to Visual and Olfactory Stimuli in Darters (Etheostoma) during Mate Choice Trials

Sensory integration (the coordination of multiple sensory systems to carry out a behavior) has rarely been evaluated in the context of female mate choice in fishes. Understanding the sensory modalities of mate choice can provide critical insights into mechanisms of sexual selection within a group. Darters are a common model system in studies of behavior, including two species endemic to North America, *Etheostoma caeruleum* (Rainbow Darters) and *Etheostoma flabellare* (Fantail Darters). The goal of this study was to use three experiments to test female responses to olfactory and visual mate choice-related stimuli in both Darter species: In each experiment, female choice was assessed by how much time she spent in either of two preference zones. First, females were presented with an olfactory stimulus from live males of the same species. Second, females were introduced to a visual stimulus that consists of painted male models. The third phase combined both the olfactory and visual stimuli. Our results showed that the female darters of both species needed both the visual and olfactory stimulus to interpret the information effectively. Rainbow Darters were repelled by the olfactory stimulus alone in phase one, while Fantail Darters showed no response. In phase two, both species were somewhat more responsive to the visual stimulus. Finally, in phase three, females demonstrated a stronger response to the olfactory and visual cues combined, although the female Fantail Darters were still less responsive to the stimuli overall. These results suggest that female Darters may be using olfactory cues to make their decisions, but the olfactory cues need to be paired with a visual stimulus in order for them to interpret the olfactory information effectively.

123-2 REGAN, MC*; ASHLEY-ROSS, MA; Wake Forest University; *regamc13@wfu.edu*
Morphological Scaling and Ontogeny of Shark Caudal Fins
Sharks are critical to ocean ecosystems and have been studied in many ecological and biomechanical capacities. One area of study that is relatively lacking is analysis of caudal fin shape with respect to ecological changes throughout ontogeny. Caudal fins are the sharks' main propulsion structures and as such can dictate a certain amount of their behavior such as what prey they go after, what habitats they occupy, and how they grow over time. Many sharks begin in a nursery environment, such as mangroves, which can protect against predation before becoming large enough to occupy their adult habitats. This study aimed to focus on how the caudal fin may be changing as the shark grows both within a species and amongst a variety of species. After analyzing nine species across five orders it was found that certain linear tail measurements are changing allometrically but many are growing isometrically. Those that are allometric may be adjusting their caudal lobe ratios to better fit their adult environments after leaving their juvenile nursery habitats. Further studies should focus on quantifying the fluid dynamics behind these shape changes to better understand the role the caudal fin is playing in their lifespan.

P1-210 REHOREK, SJ*; ELSEY, R; BEECHING, SC; Slippery Rock University, Louisiana Department of Wildlife and Fisheries, Grand Chenier, LA; *susan.rehorek@sru.edu*
Morphometrics of the American Alligator (Alligator mississippiensis) Embryonic Head.
Morphometric analysis seeks to describe variation in form among taxa in an evolutionary or functional context. Although both traditional (linear) and new (geometric) techniques have been used, limitations and advantages exist for each with respect to ease of data acquisition and analysis. Little is known about the ontogenetic morphometrics of vertebrate heads, including a single published study of crocodile postnatal head development. Thus, the purpose of this study was characterize ontogenetic changes in the alligator cranium throughout embryonic development. We recorded and analyzed six linear cranial measurements in 77 preserved embryonic American alligators representing 20 different stages. Examination of the individual measurements revealed dynamic inter-relationships among the measured dimensions during development. Using both principal components analysis (PCA) and estimates of cranial component volumes, we found three distinct phases in embryonic alligator head growth. We identified a critical second phase which disrupts an otherwise monotonic developmental trajectory characterized by a period of reduced snout growth with respect to cranial growth. A similar growth pattern, without the intervening second phase, has been observed in prenatal humans, and the reversed pattern was observed between postnatal humans and crocodiles. The exact nature of the pre- and postnatal developmental allometries requires further elucidation.

56-6 REICH, HG*; RODRIGUEZ, IB; TRIPP, SE; WARNER, ME; KEMP, DW; HO, TY; LAJEUNESSE, TC; Penn State Univeristy, University of the Philippenes, Penn State University, University of Delaware, University of Alabama at Birmingham, Academia Sinica, Penn State University; *hgreich16@gmail.com*
Symbiotic dinoflagellates pump iron (and other trace metals) to beat the heat
Trace metals, especially iron, are required for virtually all biochemical and metabolic processes. Coral thermal tolerance is attributed mostly to individuals pre-conditioned to thermal stress, access to greater nutrient reserves (from heterotrophy), and the photo-physiological capabilities of their resident algal symbiont. However, the underlying role of trace metals in these processes remains largely unknown due to several technical challenges when applying trace metal clean methods. With continued ocean warming, a possible decrease in iron availability raises questions about how this may affect reef coral physiology. To examine the importance of trace metals for Symbiodiniaceae physiology and metallome (elemental content), cultures were exposed to various (ecologically relevant) iron concentrations and temperatures. Additionally, metallomes of Symbiodiniaceae (in hospite) were compared between reefs with different thermal regimes. Sufficient iron concentrations (>50 pM Fe'), were needed by cultured symbionts to cope with heat stress. Moreover, one species that actively acquired more iron (and other metals) during thermal stress, exhibited greater thermal tolerance and cell growth. Furthermore, symbiotic algae extracted from corals living in high temperature environments exhibit different elemental compositions relative to conspecifics living in cooler habitats. Such differences in elemental composition among heat tolerant corals may correspond to increased enzymatic activity or other protective processes. The scope and significance of trace metals to biochemical pathways that support coral-algal symbioses under normal and adverse conditions deserves more attention.

131-6 REICHERT, MS*; KULAHCI, IG; DAVIDSON, GL; QUINN, JL; Oklahoma State University, University College Cork, Cambridge University; *michael.reichert@okstate.edu*
Scrounging Versus Learning Strategies in Foraging Songbirds
Cognition is important for foraging because individuals can learn and remember profitable sources of food. However, cognition is not the only way to find food. Particularly in group living species, some individuals may successfully forage by scrounging from others. Both tactics may be effective, but there are likely trade-offs in their expression because both cognitive ability and competitive scrounging entail high developmental costs. However, few studies have investigated individual variation in cognitive ability and scrounging, and trade-offs between these traits, in wild populations. We measured individual learning speeds and scrounging rates in large mixed-species flocks of 3 songbird species: great tits, blue tits and marsh tits. We used arrays of bird feeders that were programmed so that each individual was only able to access food in one of the five feeders at an array. We measured the speed to learn to use the rewarded feeder as well as rates of scrounging at the non-rewarded feeders. Individuals that scrounged more often were slower to learn the task, suggesting a trade-off between cognition and scrounging. Blue tits scrounged more than the other species, perhaps because they were less competitive in accessing their own rewarded feeder. Nevertheless, scrounging behavior was not repeatable. In reversal learning experiments, birds tended to scrounge more at previously rewarding feeders, but did not preferentially scrounge from other birds that had also been assigned to that feeder. Our results reveal a fundamental trade-off between foraging strategies based on learning and scrounging, but the drivers of individual variation in these traits are complex and additional experimental studies are needed to determine how these strategies are related.

P3-140 REID, H E*; ZHOU, H; DENG, J; JANKAUSKI, M; Montana State University, Binghamton University; *heidi.reid@student.montana.edu*

Towards the Design of Dynamically Similar Isospectral Isomodal Artificial Insect Wings

The morphological and mechanical properties of insect wings have been studied extensively. However, experimental studies on fresh wings are challenging due to material degradation that occurs rapidly after the wing has been removed from the insect's body. To overcome this challenge, we developed artificial wings that are dynamically similar with respect to real *Manduca sexta* forewings. The artificial wings are designed to be isospectral and isomodal to their biological counterparts, which implies they have identical frequency response functions (FRF) and vibration mode shapes and thus deform similarly when subjected to realistic flapping. To inform the artificial wings, we measured the FRF and vibration modes of fresh *M. sexta* forewings. Based upon our results, we constructed artificial wings using fused filament fabrication to print a PLA vein structure. We used thin polymer film to emulate the membrane, and the flat wings were molded to match natural curvatures. We determined that (1) the first and second vibration modes of real and artificial wings correspond to bending and torsional modes respectively, and (2) the FRF of real and artificial wings have similar magnitude at the first natural frequency whereas the response magnitude at the second natural frequency is nearly double for the artificial wing. Our results demonstrate the potential to construct artificial wings that behave like real insect wings while flapping.

137-6 REISENFELD, K*; MCELROY, E; ROOSENBURG, W; The College of Charleston , Ohio University ; *reisenfeldk@g.cofc.edu*

Functional Ecomorphology in the Diamondback Terrapin (Malaclemys terrapin); the Effect of Head-starting on Morphology and Bite Force

Head-starting describes the captive rearing and care of animals through their juvenile life stage, followed by release into their native habitats. The goal of head-starting programs is to avoid high mortality of hatchlings and thus increase overall population size. *Malaclemys terrapin* populations are declining throughout their range due to increased nest predation, road mortality, habitat loss, commercial harvest for food, and bycatch in crab pots (Dorcas et al., 2007). A *M. terrapin* head-starting program in Chesapeake Bay suggest that survival of accelerated animals is lower than wild animals (Jenkins, 2018). Morphological performance may effect an individual's ability to gain resources (Elnitsky and Claussen, 2006; Herrel et al., 2002), and therefore reduce survivorship. Bite force is one morphological performance measurement that is affected by diet and corresponding head and body morphometries (Herrel et al., 2018; Marshall et al., 2012). Head-started *M. terrapin* are fed a soft pellet diet, which may yield individuals with reduced bite force that are unable to forage on the hard-shelled prey accessible to them upon release. Bite force, head, and body morphometries were collected from *M. terrapin* across all ages on Poplar Island, MD. Bite forces were correlated to body and head size to determine their effect across ontogeny. The force needed to crush prey items found in the Chesapeake Bay was obtained to determine if head-started terrapins are able to forage post-release. We evaluate if bite force and morphometries are different in head-started M. terrapin and therefore explain the reduced survivorship of released individuals.

52-5 RENNOLDS, CW*; BELY, AE; University of Maryland, College Park, MD; *rennolds@umd.edu*

Injury improves short-term environmental stress tolerance in a freshwater annelid

Both the loss of tissue and the regeneration of tissue are expected to impose considerable physiological costs on animals. Although injury is common in nature and regeneration is widespread among animals, the impacts of injury and regeneration on physiological performance remain poorly studied in many animal groups, especially aquatic invertebrates. Furthermore, distinguishing the costs of injury from those of regeneration specifically is challenging, and studies that attempt to distinguish these are rare. Working with the freshwater annelid *Pristina leidyi*, we tested the effects of traumatic tissue loss and regeneration on performance, focusing specifically on environmental stress tolerance. Amputation injury either decreased or did not affect acute cold tolerance, depending on the location of the injury. However, contrary to our expectations, amputation injury actually improved tolerance to both acute heat stress and salinity stress. Regeneration of tissue only significantly reduced heat tolerance, an effect that was also dependent upon injury location. Based on our finding that injury improves tolerance to multiple distinct stressors, we hypothesize that injury induces a generalized cellular stress response that can prime animals to better manage subsequent homeostatic challenges. RNA-seq and microrespirometry experiments are ongoing to test this hypothesis and further explore the physiological responses to injury and regeneration.

P3-103 RENNOLDS, CW*; BELY, AE; University of Maryland, College Park, MD; *rennolds@umd.edu*

Reproductive investment is enhanced by food but independent of injury history in an asexual annelid

In nature, many animals routinely suffer physical injury and some species can subsequently regenerate damaged or lost tissue. In sexually reproducing species, one of the most commonly observed effects of injury and regeneration is a reduction in reproductive investment. However, in asexual species, how injury and regeneration affect reproduction remains poorly studied. We investigated how the frequency of injury and regeneration affects reproductive investment under both high and low food conditions in the asexual annelid *Pristina leidyi*. This species regenerates readily after injury and reproduces by fission by releasing offspring (zooids) from the posterior end. In our experiment, we amputated the anterior end of the body zero, one, two, or three times and assessed reproductive output. Unexpectedly, injury frequency had no effect on total fecundity or offspring quality. Food availability had a large effect on reproduction and survival, with high food availability significantly increasing reproductive rate, total reproductive output, and offspring quality while reducing injury-related mortality. Although offspring size varied substantially across our treatments, regeneration rate of offspring showed low variation and was independent of parent feeding treatment. Findings indicate that in *P. leidyi* reproductive investment is largely a function of resource availability but is not constrained by injury and regeneration. Reproduction proceeds in injured "parent" worms even if it results in their death, indicating that allocation towards offspring is strongly favored over self-preservation. This study demonstrates that asexually reproducing animals can evolve distinct mechanisms of resource management between reproduction and regeneration.

P2-229 REPPE, F*; HUSS, JC; FRATZL, P; EDER, M;
Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany;
friedrich.reppe@mpikg.mpg.de

Banksia seed pod opening - structure and mechanics of a long-term functional pericarp

The seed pods (follicles) of many *Banksia* species, native to Australia, store their seeds on the plant for years before they open upon the heat of a bushfire and release their seeds after rain. For this purpose, the follicles must stay intact and functional. We could show in the past that opening temperatures depend on the local climate and can change even within one species. However, follicle properties are only partly understood and hardly anything is known about the 2nd water triggered opening step. Here we determine structural, mechanical, and hygroscopic properties of selected follicle tissues (endocarp and mesocarp) for a fundamental understanding of both initial opening and seed release. Within the endocarp, cellulose fibrils are oriented rather along the longitudinal fiber axis, in the mesocarp their orientation is perpendicular. Experiments on the hygroscopic behavior of the pericarp layers show gradually increasing swelling behavior from the follicle inside to the outside. The maximum shrinkage of 20 % for mesocarp tissue close to the exocarp is exceptional for lignified fibers. The tensile stiffness of both dry and wet tested tissue strips revealed large differences between endo- and mesocarp and between different moisture-states. These values largely exceed those of other lignocellulosic materials such as wood. Nanoindentation showed differences in indentation moduli depending on the pericarp layers and their water content. We hypothesize that the drying-induced increase in stiffness and the softening upon wetting enables the seed pod to perform the two-step opening which is essential for the reproduction and survival of *Banksia* species.

98-6 RESH, CA*; BENESH, KC; MAHON, AR; Central Michigan University; *carlee.resh@gmail.com*

Sourcing Invaders: A Northern Snakehead Story

The introduction and subsequent expansion of the Northern snakehead (*Channa argus*) in North American waters is one of many problematic biological invasions in the United States. This harmful aquatic invasive species is a predatory freshwater fish native to Asia that has established itself in multiple water basins in the eastern United States, as well as an expanding range in the Midwest. Previously, we assessed the population structure and estimated long-term effective population sizes of the populations present in the United States. However, the source of introduction for these fish remains unknown. In this work, we aim to determine the source of the North American introductions. To accomplish this, we used whole genome scans (2b-RAD genomic sequencing) to analyze single nucleotide polymorphisms (SNPs) that allow us to screen the genomes of captured fish from both United States waters and from a number of sites in their native range. Using this cost-effective approach, we recovered 2,632 single-nucleotide polymorphism (SNP) loci from genomic DNA extracted from 194 fish: 164 fish sampled from the eastern United States and Arkansas, and 30 fish sampled from three regions of the Yangtzee River basin in China (n=10 per basin). Preliminary analyses directly link a fish captured in the Upper Hudson River basin to two Lakes that are part of the Yangtzee River basin in China. This valuable information has the potential to result in more effective management of this harmful invasive species. Furthermore, additional sampling from the native range could help to determine the source(s) of introduction for the other fish in the eastern United States and Arkansas, and therefore aid management in preventing future introductions into United States waterways.

P3-210 REYNOLDS, JA; The Ohio State University;
reynolds.473@osu.edu

Coordinated microRNA and Endocrine Regulation of Insect Diapause

Diapause, an alternative developmental pathway, provides animals a means to "escape" from hostile environments. This dormant state, defined by arrested development, depressed metabolism, and increased stress tolerance, is regulated endogenously, at least in part, by the endocrine system including ecdysone and insulin signaling pathways. Accumulating evidence suggests microRNAs regulate diapause and may work in conjunction with the endocrine system. *Helicoverpa zea* (i.e., the corn earworm) enters diapause during the pupal stage following exposure to short day-lengths during the larval stage. Diapause in this species is associated with downregulation of both the ecdysone and insulin signaling, and with significant changes in the miRNA abundances. High-throughput sequencing was used to identify and quantify microRNAs in diapausing and nondiapausing *H. zea*. Overall, 108 microRNAs were differentially regulated. Forty conserved (i.e. previously identified) and 20 putative, novel microRNA sequences were more abundant in diapausing pupae, and 31 conserved and 16 novel miRNAs were less abundant in diapausing pupae compared to nondiapausing pupae. Notably, miR-34 and miR-252 were, respectively, 3.87 and 1.79-fold more abundant in diapausing pupae. These miRNAs are involved in ecdysone biosynthesis and signaling in insects. Computationally predicted gene targets of miR-34 include *ecdysone-induced protein 74EF* and *ecdysone receptor*, and one target of miR-252 is *cytochrome p307A1*, a gene in the ecdysone synthesis pathway. In addition, miR-277 abundance was 60 % lower in diapausing pupae than in nondiapausing pupae. miR-277 regulates metabolism via insulin signaling in diapausing insects. Taken together, these changes in microRNA abundance provide preliminary evidence that microRNAs work in conjunction with the endocrine system to regulate diapause in H. zea and possibly other insects.

P3-160 RIBAK, G*; URCA, T; DEBNATH, AK; STEFANINI, J; GURKA, R; Tel Aviv University, Coastal Carolina University, TSI France, Coastal Carolina University; *gribak@tauex.tau.ac.il*

The Aerodynamics and Energetics of a Long-Distance Flying Beetle Studied Using PIV

The mango stem-borer (*Batocera rufomaculata*) is a large beetle (body mass up to 7.5 gr) capable of long dispersal flights to find suitable host trees. A previous study has shown that: 1) in flight-mills, the beetles are capable of flying distances >20 km without replenishing energy reserves, and 2) smaller beetles (body mass< 3 gr) tend to fly larger distances compared to larger individuals. To study the aerodynamic and physiological mechanisms enabling long-distance flights, we examined the tethered flight of these beetles in a wind-tunnel. The aerodynamic power and drag force of the flying beetles were analyzed from the kinetic energy and velocity profiles, respectively, measured in the wake of the insect using Stereo-PIV. The data were compared to quasi-steady aerodynamic forces and power output estimated from the flapping kinematics, or measured directly with force transducers connected to the tethered insects. The kinetic energy balance of the flow field of the insect matched mechanical power estimates from quasi-steady modelling. Both estimation methods gave values of aerodynamic muscle mass-specific power that is approximately 65% of the aerodynamic mass-specific power of other insects, with asynchronous flight muscles, during hovering. The drag estimates from the wake velocity profiles matches the drag of the beetles as measured with the force transducers. Thus, the results link the unsteady wake of the forward flying insect to its mechanical power output. The low mass-specific power output during forward flight is likely instrumental in long distance flights by ensuring the demands are adequately met by the substrate supply rate to the flight muscles, thus delaying their fatigue.

38-1 RICE, N*; JEONG, S; NISHIKAWA, K; Northern Arizona University; *kiisa.nishikawa@nau.edu*

How do Muscle Length and Activation Interact to Determine Muscle Force Production?

Previous studies demonstrated dissociation of muscle activation and force during in vivo treadmill running over obstacles in the lateral gastrocnemius (LG) muscles of guinea fowl. There was a long (90-150 ms) and variable delay between EMG onset and force onset, and the correlation between peak EMG and peak force amplitude ($r2 = 0.30$) was small compared to the correlation between muscle length at foot contact and peak force amplitude ($r2 = 0.63$). To further demonstrate decoupling between force and activation, we used ex vivo extensor digitorum longus muscles (EDL) of mice as an "avatar" for the in vivo guinea fowl LG. Instead of sinusoidal or triangular length inputs typically used in workloop experiments, we used length records from the guinea fowl LG recorded in vivo using sonomicrometry as inputs for ex vivo workloop experiments. Muscles were stimulated submaximally with similar onset and duration to in vivo guinea fowl muscles. Work loops recorded ex vivo in EDL strongly resembled those from the guinea fowl LG during in vivo treadmill running. Both ex vivo EDL and in vivo LG workloops deviate substantially in shape from traditional ex vivo workloop experiments, demonstrating the importance of small high-frequency perturbations to muscle force production. A titin-based muscle model accurately predicted muscle force for both in vivo and ex vivo muscles ($r2 > 0.80$). While these studies demonstrate that muscle length and velocity regulate muscle force production, the results suggest that neither the isometric force-length relationship nor the isotonic force-velocity relationship describes their roles during in vivo force production.

P2-24 RICE, AM*; HUYNH, AV; SPINELLI, JMC; ROTH, TC; TAYLOR, SA; Lehigh University, Franklin & Marshall College, University of Colorado Boulder; *amr511@lehigh.edu*

Effects of hybridization on cognition in chickadees: A common garden approach

When hybridization occurs, selection against hybrids reduces gene flow and maintains species barriers. Although learning and memory are known to play important roles in preventing hybridization, whether they contribute to selection against hybrids is less understood. Further, although hybridization is widespread and cognition is linked to fitness in many taxa, whether and how hybridization affects cognition remains unclear. Our previous research suggests that hybridization leads to reduced cognitive abilities in chickadees. Black-capped *(Poecile atricapillus)* and Carolina chickadees *(P. carolinensis)* naturally hybridize, and also rely on learning and memory to cache and retrieve food as an adaptation for overwinter survival. In tests of wild-caught adult chickadees, we found that hybrid chickadees exhibited poorer spatial memory and were less likely to solve a novel problem than their parental species counterparts. Here, we ask whether deficiencies in hybrid cognition persist after controlling for differences in experience and environment during development. We collected hybrid and parental species chickadee nestlings and reared them under common conditions. We tested performance on a series of cognitive tests, including associative spatial learning, reversal learning, and problem solving. Our preliminary results provide insight into the mechanism by which hybridization affects cognition in chickadees. Future work will be necessary to determine whether and how hybridization affects cognition in other taxa, and in turn, the potential for cognition to contribute to postzygotic reproductive isolation more generally.

89-2 RICHARDSON, C.S*; LOONEY, C.; INESON, K.; FOSTER, J.; SILLAH, A.; EISEMAN, H.; Lesley University, Northeastern University, University of New Hampshire, University of Massachusetts-Amherst, Tufts University; *crichard@bu.edu*

Understanding the Role of Intrinsic Physiological Factors in the Population Recovery of Myotis lucifugus (little brown myotis) from White-nose Syndrome

Since 2006, white-nose syndrome (WNS) has had a devastating impact on populations of *Myotis lucifugus* (little brown myotis) in North America. However, some remnant populations are starting to recover. As soon as they emerge from hibernation, many bats continue to fight the *Pseudogymnoascus destructans* (*Pd*) fungus infection, the cause of WNS, and then recover from the disease, which costs energy. Understanding the energetic cost of the immune response of the little brown myotis to this fungal infection is important for understanding how this important species is recovering from this disease. We examined basal metabolic rate (BMR), an important measure of energy expenditure, and bacterial killing ability of blood and white blood cell count, both important measures of immune ability in the bats. We also assessed wing damage due to the *Pd* fungus, because the extent of wing damage reflects the course of immune response and recovery by the bat to the fungus. *Pd* fungal load of the bat was assessed as well. We hypothesized that fungal activity will cause increased immune response, costing energy that would otherwise be used towards pregnancy. We examined whether population growth and recovery in some bat maternity colonies is affected by energy cost of immune response and recovery to WNS. We found the colony with the highest rate of growth did not have the highest energy use or immune response, but the differences among colonies in energy use and immune response changed with pregnancy. Additionally, contrary to our hypothesis, no significant relationship between fungal load and BMR was found.

74-4 RIDDELL, EA*; IKNAYAN, KJ; WOLF, BO; BEISSINGER, SR; University of California, Berkeley, University of New Mexico; *riddell.eric@gmail.com*

Thermoregulatory costs drive responses of mammal and bird communities to climate change in the Mojave Desert

Climate change might dramatically increase extinction risk by threatening the most basic, physiological requirements for survival. Despite the threat of overheating and dehydration, very few studies have demonstrated a physiological basis for population-level responses to climate change, especially in endotherms. Climate change has the potential to challenge endotherms by disrupting their ability to maintain a stable body temperature, a fundamental requirement for survival. We evaluated community responses to climate change in the Mojave Desert over the last century using occupancy surveys for birds and mammals. As part of the Grinnell Resurvey Project, we compared the change in occupancy from modern surveys with surveys originally conducted by Joseph Grinnell *et al.* in the early 20th century. We then explored the physiological basis of species' responses to climate change using heat flux models that estimated the climate-driven change in thermoregulatory requirements for birds and mammals. For bird communities, we found a nearly 50% reduction in biodiversity across our resurvey sites. Mammal communities however were relatively stable over the same time period. Avian declines were largely explained by the increase in thermoregulatory cooling costs over the last century, whereas mammal communities were not affected by thermoregulatory costs. Moreover, heating costs from climate change declined more in mammals compared to birds, and most mammals did not experience an increase in cooling costs. Our study demonstrates that birds and mammals have markedly different thermoregulatory experiences of climate change that influence population-level responses to recent climate change.

P1-252 RIDENOUR, M; GRINDSTAFF, JL*; Oklahoma State University; *matthew.ridenour@okstate.edu*

Hormonal Mediation of Sibling Rivalry in Eastern Bluebirds (Sialia sialis)

Altricial young are not capable of securing food for themselves, and must solicit feeding from parents. The ability of an individual to outcompete its siblings for this parental provisioning is, therefore, integrally related to its future reproductive potential. Several adaptations may be beneficial to young animals in this regard. For example, large size relative to siblings may promote success in sibling competition and draw increased provisioning from parents. Similarly, aggression may increase success in this context. However, the physiological mechanisms underpinning effective sibling rivalry are not well understood. Sibling rivalry may be hormonally mediated. Hormonally mediated traits such as rapid growth could provide an advantage in scramble competitions such as those exhibited by altricial birds. In this study, we analyzed the effects of the peptide hormone insulin-like growth factor 1 (IGF-1) on markers of sibling rivalry in Eastern Bluebirds (*Sialia sialis*) and assessed the ability of nestlings to adaptively modulate levels of this hormone in response to brood size. Free-living bluebird nestlings were cross-fostered in order to artificially modify brood size, body measurements were taken, and endogenous IGF-1 levels were quantified. In a subsequent experiment, exogenous IGF-1 was administered to nestlings in order to elucidate its effects on body size and behavior. This study has the potential to contribute to our understanding of both sibling rivalry and hormonal plasticity.

114-3 RIESER, JM*; LI, T-D; GOLDMAN, DI; MENDELSON III, JR; Georgia Tech, CUNY, Zoo Atlanta, Georgia Tech; *jennifer.rieser@physics.gatech.edu*

Evolutionary convergence in nanostructural adaptations in sidewinding viperid snakes

Snakes inhabit and move successfully within a wide range of environments, from sandy to rocky substrates, forest floors to tree trunks and branches, swampy areas to aquatic environments, and environmental interactions are mediated solely through skin contact. We performed atomic force microscopy (AFM) measurements to characterize the microscopic structures on the shed skins of a variety of viperid snakes that inhabit a diversity of environments. We find that, while most snakes have microfibrils oriented from head-to-tail, a few distantly-related snake species have convergently lost this structure in favor of a more isotropic morphology. We hypothesize that these microstructures affect the frictional interaction with the substrate and we use resistive force theory to model the effects of isotropic and anisotropic frictional interactions on snake locomotion. For lateral undulation, we find that an anisotropic frictional interaction in which craniad, or foreward, movement is favored over side-to-side movement is predicted to improve performance (measured in distance traveled per cycle), and that larger anisotropies yield larger displacements. In sidewinding locomotion, however, we see the opposite trend: more isotropic frictional interactions are predicted to improve performance. These predictions are consistent with our observations of microscopic structures on snake skins and provide a hypothesis for why sidewinding species of vipers share an evolutionarily convergence in morphology that is structurally distinct from other viperids examined.

103-3 RIFFELL, J*; CHAN, J; OKUBO, R; University of Washington; *jriffell@uw.edu*

Sensory biology of of mosquito-flower interactions

Mosquitoes are important vectors of disease and require sources of carbohydrates for reproduction and survival. Unlike host-related behaviors of mosquitoes, comparatively less is understood about the mechanisms involved in nectar-feeding decisions, or how this sensory information is processed in the mosquito brain. Here we show that Aedes spp. mosquitoes, including Aedes aegypti, are effective pollinators of the Platanthera obtusata orchid, and demonstrate this mutualism is mediated by the orchid's scent and the balance of excitation and inhibition in the mosquito's antennal lobe (AL). Furthermore, we show that the combination of odor and visual cues increase the ability of mosquitoes to locate the flowers. The P. obtusata orchid emits an attractive, nonanal-rich scent, whereas related Platanthera species – not visited by mosquitoes – emit scents dominated by lilac aldehyde. Calcium imaging experiments in the mosquito AL revealed that nonanal and lilac aldehyde each respectively activate the LC2 and AM2 glomerulus, and remarkably, the AM2 glomerulus is also sensitive to DEET, a mosquito repellent. Lateral inhibition between these two glomeruli corresponds to the level of attraction to the orchid scents: whereas the enriched nonanal scent of P. obtusata activates the LC2 and suppresses AM2, the high level of lilac aldehyde in the other orchid scents inverts this pattern of glomerular activity, and behavioral attraction is lost. Moreover, olfactory stimulation with the attractive orchid scent gates the attraction to visual objects, especially those with features similar to the orchid flowers. These results demonstrate the ecological importance of mosquitoes beyond operating as disease vectors and open the door towards understanding the neural basis of mosquito nectar-seeking behaviors.

P1-82 RILEY, AK*; GRINDSTAFF, JL; Oklahoma State University; *agoffri@okstate.edu*

Paternal removal leads to changes in learning ability and sociality in zebra finch (Taeniopygia guttata) offspring

Maternal removal enhances fearfulness, increases the expression of antisocial behaviors, and induces learning deficits in both mammalian and avian offspring. Maternal removal may also influence hypothalamic-pituitary-adrenal (HPA) axis function, as demonstrated in zebra finches (*Taeniopygia guttata*). Zebra finches provide bi-parental care, as do 80% of all bird species, yet few studies have tested the effects of paternal removal on offspring. Therefore, we set up groups of zebra finches that experienced paternal removal at hatching, paternal removal at fledging, and a control group where both parents were present throughout the nestling and fledgling stages. Once mature, we subjected each offspring to a novel foraging task to test learning ability. We also conducted a sociality test, in which we recorded the behavior of each bird when housed with three same-sex, novel conspecifics. Birds that experienced the removal of the father during the fledgling period solved the foraging task in significantly fewer trials. Additionally, birds that experienced paternal removal during the fledgling period exhibited significantly more aggressive behaviors as adults. These results suggest that mothers are unable to fully compensate for the loss of paternal care, when the removal occurs during the fledgling period. Our results are also consistent with past studies that found that stress exposure increases learning ability and boldness.

P2-187 RINGENWALD, BE*; BOGACKI, EC; STARK, AY; Villanova University; *bringe01@villanova.edu*

Crawl or Fall: The Effect of Variable Temperature and Humidity on Gecko Locomotion

Adhesion and locomotor performance of geckos are inherently linked through specialized morphological and biomechanical features. However, adhesive performance of clinging geckos does not always predict the locomotor performance of running geckos (i.e., sprint speed). Indeed, studies of geckos failing to cling to wet substrates are not met with compensatory reductions in sprint speed when running in the same conditions. The reason for this discrepancy is unclear, but may be related to the rate at which geckos move their feet when running verses the rate they are pulled in cling performance studies. This is particularly important when considering the potential role of material and/or capillary interactions on gecko adhesion in variable humidity. Specifically, as humidity increases, whole animal adhesion increases, but only at low temperatures. Rate-dependent viscoelastic material properties, and/or rate-dependent capillary interactions may allow geckos to increase adhesion and thus traction while running when compared to clinging in some conditions. To test this, we measured gecko locomotor performance (sprint speed) in variable temperature and humidity (i.e., 12˚C and 32˚C; and 30%, 55%, 70%, and 80% relative humidity). We predicted that sprint speed on a hydrophilic substrate would increase as humidity increased at low temperatures, but not high, matching adhesive performance data. In contrast, we predicted that on a hydrophobic substrate, when capillary interactions are limited, adhesion would not change across all treatments. The results of our study provide insight into potential variation in locomotor performance of a tropical species of gecko that routinely experiences high temperature and humidity, but also helps to elucidate complex surface interactions between the gecko's adhesive pads and the substrate at varying rates and conditions.

P1-262 RIPPAMONTI, JR*; DE SILVA, IW; DZIALOWSKI, EM; VERBECK, GF; PRICE, ER; University of North Texas; *JessicaRippamonti@my.unt.edu*

Investigation of Lipid Changes During the Ontogeny of Endothermy

During development, mammals and birds go through a remarkable developmental change from an ectothermic to endothermic phenotype. Although well documented, the regulation of this transition to endothermy is not as well understood. In hatching chickens , there is an increase in circulating plasma thyroid hormones triiodothyronine (T3) and thyroxine (T4) that correlates with the developmental increase in metabolic capacity that may be responsible for the enhanced ability to respond to a cold challenge. Our lab has investigated developmental time periods, morphology, and mitochondrial responses during this transition and is now exploring changes in membrane lipidomics. The membrane pacemaker hypothesis proposes that increased levels of docosahexaenoic acid (DHA) in the membrane are associated with increased metabolic rate. Thus, increases in basal metabolic rate associated with hatching and attainment of endothermy may be driven in part by changes in DHA levels. Here we investigate how manipulations of plasma T3 concentrations affect membrane lipid levels in cardiac and hepatic tissues during this transition to ex ovo life. Embryos were given supplemental T3 or methimazole, a thyroperoxidase inhibitor on day 17 of incubation, and changes in docosahexaenoic acid and linoleic acids were measured during and after hatching. Our novel experiment provides a more thorough understanding of the cellular changes associated with the ontogeny of endothermy and potential membrane effects on metabolism.

23-4 RIPPE, JP*; DIXON, GB; MATZ, MV; University of Texas at Austin; *jpr6mg@gmail.com*

Genomic evidence of environmental specialization and cryptic speciation in two massive coral species on the Florida Keys Reef Tract

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 a considerable barrier for demographic exchange between disparate reef habitats. We investigated whether the cross-shelf gradient (nearshore - offshore - deep) is associated with spatially varying selection in two common coral species, *Montastraea 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 across two cross-shelf transects to identify signatures of selection occurring within a single generation. Preliminary results from the first transect revealed unexpected results. Each species was found to be composed of four to five genetically distinct subpopulations, with gene flow between them highly reduced in 30-50% of the genome. Each species includes two sympatric populations that are only found in the deep (20 m) habitat, while the other populations are found almost exclusively on the shallower reefs (3-7 m). Here, we compare these initial findings with data from a second cross-shelf transect to investigate possible along-shore variability in the patterns environmental specialization and to establish whether cryptic genetic subdivision in these two coral species may be a general feature throughout the Florida Keys. *Siderastrea siderea* and *M. cavernosa* have emerged as two of the most ecologically successful species on the degraded Florida Keys Reef Tract, and this work offers important insight on the genomic background of divergent selection and speciation that may in part explain their broad environmental range in this ecosystem.

P2-245 RIPPE, JP*; BAUMANN, JH; BOVE, CB; AICHELMAN, HE; DAVIES, SW; CASTILLO, KD; University of Texas at Austin, University of North Carolina, Chapel Hill, Boston University; *jpr6mg@gmail.com*

Environmental drivers of coral growth across the western Caribbean Sea and Florida Keys

Over the past 30 years, large-scale coral die-offs throughout the Caribbean Sea have shifted reef communities to primarily weedy and stress-adapted coral taxa. For these degraded reefs, just as consequential as the continued impacts of acute bleaching events are the chronic, nonlethal effects of climate change that can influence community calcification and, in effect, the ecological role of coral reefs as productive ecosystem engineers. Many confounding factors have been shown to influence coral calcification across broad geographic ranges, leading to an incomplete picture of the extent to which climate change is impacting coral reef growth. Here, we apply a fully replicated and comprehensive sampling scheme of two widespread coral species, *Siderastrea siderea* and *Pseudodiploria strigosa*, across inner and outer reefs of three reef systems to characterize the environmental factors controlling coral growth rates in the western Caribbean and Florida Keys. Growth histories reveal that on the Mesoamerican Barrier Reef System (MBRS) in Belize and the Bocas del Toro Reef Complex (BTRC) in Panama, both species have experienced recent downturns in growth rates; however, on the Florida Keys Reef Tract (FKRT), they have largely maintained baseline growth rates over this same interval. We find that these recent patterns in growth are associated principally with the Atlantic Multidecadal Oscillation, particularly in the higher latitude reef systems (FKRT and MBRS). Additionally, baseline growth of *S. siderea* is significantly correlated with water column turbidity, but no such relationship for *P. strigosa* is observed.

P2-13 RITMEESTER-LOY, SA*; MARTIN, GG; APPY, R; Occidental College, Los Angeles, CA; *sritmeesterl@oxy.edu*

A Trypanorhynch Cestode in Shrimp and Skates: Morphology and Partial Life Cycle

Two different larval cestodes were found at similar abundances in two penaeid shrimp (*Sicyonia ingentis* and *S. pencillata*) collected in trawls at a depth between 20 and 150m off the Palos Verdes coast in Southern California. The presence of two bothria and four retractable tentacles identified them as trypanorhynchs; one of 17 orders of the subclass Eucestoda within the class Cestoda. Trypanorhynchs are commonly found in marine organisms. One larval trypanorhycnh was further identified as part of either genus *Dolfusiella* or *Eutetrarhynchus* based on the morphology of the microthrix patterning and tentacular armature. Adults of the tapeworm, identified as such by the similarity in tentacular armature, were found in the skate *Raja inornata*. The stomach of one of the skates contained a shrimp containing a larval tapeworm, partially completing the life cycle for at least one of the species with the passage from the final skate host back to the shrimp still to be discovered. It is predicted to involve a small crustacean such as a copepod. Genetic sequencing is being used to further confirm that the larvae found in the shrimp and the adult worms found in skates are the same species. The possible route of nutrient absorption was addressed by following permeability of the larvae to tracers such as ferritin and lanthanum. The composition of the film surrounding the larvae within the digestive gland of the shrimp and of possible shrimp hemocyte origin is also being examined.

31-3 RIVERA, HE*; DAVIES, SW; Boston University; *hrivera@bu.edu*

What does it take to stay together? Uncovering symbiosis gene networks in a facultatively symbiotic coral

Symbioses with unicellular algae in the family Symbiodiniaceae are common across marine invertebrates. Reef-building corals offer a unique example of cellular dysfunction that leads a dysbiosis (coral bleaching) that is visible to the naked eye and occurs at an ecosystem scale. Due to their obligate symbioses, understanding the molecular underpinnings that sustain this relationship in reef-building corals is challenging, as any aposymbiotic state is inherently coupled with severe physiological stress. Here, we use the sub-tropical, facultatively symbiotic and calcifying coral *Oculina arbuscula*, to investigate gene expression differences between aposymbiotic and symbiotic host tissues from branches of the same colonies. This framework allows us to unravel the molecular networks that regulate symbiosis in the absence of a stress response. We find that many of the previously implicated pathways identified in studies using bleached corals, aposymbiotic larvae, or model systems (i.e. *Aiptasia*), are also differentially regulated between aposymbiotic and symbiotic tissues of *O. arbuscula*. We then take a comparative approach to investigate symbiosis pathways across other marine taxa. Our results point to key processes such as cell adhesion, control of cell division, and immune response, which appear necessary for the maintenance of symbiosis across organisms. Understanding the mechanisms that sustain a healthy symbiosis with Symbiodiniaceae is of urgent importance given the vulnerability of these partnerships to changing environmental conditions and their role in the continued functioning of key marine ecosystems such as coral reefs.

P2-198 RIVERA, G*; NEELY, CMD; Creighton University; *gabrielrivera@creighton.edu*

Patterns of fluctuating asymmetry in the limbs of freshwater turtles

Understanding how selective forces influence patterns of symmetry remains an active area of research in evolutionary biology. One hypothesis, which has received relatively little attention, suggests that the functional importance of morphological characters may influence patterns of symmetry. Specifically, it posits that features with greater functional importance should be more symmetric. The aim of this study was to examine the patterns of fluctuating asymmetry (FA) present in the limb bones of freshwater turtles (family Emydidae). Aquatic emydid turtles of the subfamily Deirochelyinae employ a hindlimb-dominant swimming style, suggesting that hindlimbs should display lower levels of FA. In contrast, some emydids are more terrestrial (subfamily Emydinae). As terrestrial locomotion places more equal importance on fore- and hindlimbs, such behaviors may minimize differences in FA. This dichotomy in propulsive modes provides an excellent test of the morpho-functional hypothesis of symmetry. Consistent with the hypothesis, we found a strong, clade-wise pattern of higher forelimb FA in aquatic species (Deirochelyinae). This pattern was not detected in the more terrestrial subfamily Emydinae, although it is possible that factors other than ecology impact may impact this. We also detected a phylogenetic signal in FA within the femur and discovered that FA has evolved at vastly different rates between the fore- and hindlimbs.

59-7 RIX, AS*; O'BRIEN, KM; University of Alaska Fairbanks and Institute of Arctic Biology, Fairbanks, AK; *asrix@alaska.edu*

Characterizing the Hypoxia-Inducible Factor-1 Pathway in Response to Acute Thermal Stress and Hypoxia in Antarctic Notothenioid Fishes

The master regulator of oxygen homeostasis in most metazoans is the transcription factor, hypoxia-inducible factor-1 (HIF-1), a heterodimer of HIF-1α and HIF-1β subunits. In Antarctic notothenioid fishes, HIF-1α has a polyglutamine/glutamic acid (polyQ/E) insert that varies in length with phylogeny and is longest in members of the most derived family, the Channichthyidae (icefishes), lacking hemoglobin. The impact of this insert on the function of HIF-1 is unknown. We sought to determine if the HIF-1 pathway is activated in hearts of the red-blooded notothenioid, *Notothenia coriiceps*, and the icefish, *Chaenocephalus aceratus*, in response to exposure to their critical thermal maximum (CT_{MAX}) or hypoxia of 5.0 mg L^{-1} O_2 for two hours. Additionally, *N. coriiceps* was exposed to a longer, more severe hypoxia of 2.3 mg L^{-1} O_2 for 12 hours. Levels of HIF-1α protein were quantified in nuclei using western blotting and mRNA levels of several genes regulated by HIF-1 were quantified using quantitative real-time PCR. Only severe hypoxia resulted in an increase of HIF-1α levels in *N. coriiceps*; despite this increase, mRNA levels of genes known to be regulated by HIF-1 did not increase. However, mRNA levels of lactate dehydrogenase-A decreased in *C. aceratus* exposed to mild hypoxia. Together, these results suggest that in notothenioids HIF-1α accumulates and translocates into the nucleus in response to hypoxia but may not transactivate gene expression.

105-5 ROBERTS, A*; WAINWRIGHT , P; University of California, Davis ; *asroberts@ucdavis.edu*
Anatomical basis of jaw protrusion directionality in ponyfishes (Leiognathidae)
Jaw protrusion is a key morphological innovation that enhances suction feeding performance in fishes. Though almost universally present among percomorph fishes, the biomechanical mechanism, direction, and extent of jaw protrusion varies widely. Ponyfishes (Family Leiognathidae) comprise a group of 48 deep-bodied species that inhabit the sandy shores of the Indo-West Pacific Ocean. These fishes are characterized by high jaw protrusion and unusual diversity in the direction of protrusion, with species that protrude their oral jaws in either a ventral, dorsal, or rostral orientation. While ponyfish anatomy has received some attention in the literature, no study has examined the morphological differences underlying jaw protrusion directionality. We measured craniofacial morphology from photographs of 35 cleared and staining specimens representing 21 species, spanning the range of jaw protrusion direction. We then used a functional interpretation of morphology and phylogenetic comparative methods to characterize key differences in craniofacial anatomy and determine the anatomical basis of jaw protrusion directionality within this unique family. We found that the lengths and orientations of many craniofacial elements including the ascending process, mandible, maxilla and jaw joint discriminate between the three oral jaw types. Among the many differences in anatomy, the position of the jaw joint appears to be key to the direction of jaw protrusion as its movement from a more posterior to an anterior position when looking across ventral, rostral and dorsal protruders, significantly changes the orientation of the adducted mandible from a nearly horizontal position in ventral protruders to an upright posture in dorsal protruders.

100-1 ROBERTS, KT*; WILLIAMS, CM; Univ. of California, Berkeley; *kevrob@berkeley.edu*
A gradual release of metabolic suppression during diapause termination in a montane insect
To conserve energy during winter many insects enter diapause, a dormant state in which metabolic rate is suppressed. Metabolic suppression is gradually reversed during diapause termination. Thermal conditions experienced during winter impact the degree of metabolic suppression through phenotypic plasticity. In winter, snow modifies the thermal environment by acting as an insulator that buffers from cold and variable air temperatures. The stable, constant temperatures experienced under snow may impact the degree of metabolic suppression, and the time course over which suppression is released during diapause termination. Incorporating winter metabolic plasticity in energetic models will allow us to more accurately predict how climate change will impact winter energy stress. Populations of the willow leaf beetle *Chrysomela aeneicollis* in the Sierra Nevada Mountains overwinter as adults for up to eight months of their one-year life cycle. In these environments there is highly variable interannual snowfall, which can lead to dramatically different thermal environments. Beetles were collected from the wild and overwintered under simulated stable below-snow conditions and variable exposed conditions in the laboratory. We quantified temperature-metabolic rate curves monthly from February to May through the transition of diapause to post-diapause quiescence. We found that beetles had similar thermal sensitivity and metabolic suppression regardless of winter thermal environment. As beetles transitioned out of diapause, there was no shift in thermal sensitivity, but a steady decrease in general suppression. This implies that our current models are underestimating winter energy use and that late winter warm bouts will pose greater energetic challenges for overwintering insects.

P1-44 ROBERTSON, CM*; GIAKAS, JA; STYGA, JM; FORTUNATO, JA; EARLEY, RL; University of Alabama, Centre College; *cmrobertson5@crimson.ua.edu*
Phenotypic and Genetic Correlations between Life History Traits in a Self-Fertilizing Hermaphroditic Fish
Offspring size and number are essential components of individual fitness. However, the ideal phenotype (producing many, large eggs) generally cannot be achieved because individuals have limited energy to invest in reproduction or because the two traits are negatively genetically correlated. Such trade-offs are often studied at the phenotypic level, but mangrove rivulus fish (*Kryptolebias marmoratus*) have a unique, mixed-mating reproductive system that allows for isolated analysis of the genetic contribution to phenotypic variation with replication within a genotype. We can thus determine whether genetic trade-offs exist between fitness-related traits and how this might impact life history evolution. We hypothesized that there would be significant genetic variation underlying life history traits and their relationships. Eggs were collected once weekly for 6 weeks from 14 genotypes with 5 replicate fish/genotype, and the number of eggs laid by each fish was recorded. Eggs were photographed and size (diameter) quantified with ImageJ software. We predicted a strong trade-off between egg size and egg number and that there would be a significant negative genetic correlation between these life history traits, allowing us to project evolutionary responses to natural selection. Egg size and egg number both showed significant among-genotype variance (i.e., were heritable). At the phenotypic level, egg size and egg number were positively correlated but preliminary evidence suggests that the relationship is reversed at the genetic level. These results raise the question of how the environment alters relationships between fitness-related life history characteristics.

P2-194 ROBIN, H*; STAYTON, CT; Bucknell University; *hgr004@bucknell.edu*
Are there common patterns of ontogenetic shell shape changes between aquatic and terrestrial emydid turtles?
All turtles have a higher mortality risk as juveniles due to their smaller, less ossified, and weaker shells. Thus juveniles must use other strategies such as concealment or escape to avoid predation. Previous research has hinted that juvenile aquatic turtles hatch with relatively hydrodynamic shells, and only develop stronger shapes as they grow. However, these ideas have never been examined across multiple species. We collected data from 8 emydid species, both terrestrial and aquatic. 3D landmark data was used to analyze the relationship between shell shape and size. We predicted that juvenile's shells in aquatic, but not terrestrial, species will be more streamlined than adults. Relationships between size and shape, species and shape, and their interactions were significant. Juvenile turtles have more circular shells in dorsal view, with flatter carapaces and greater distances between carapace and plastron; shells become more ovate and domed with growth. These changes are consistent with decreased hydrodynamic efficiency, as predicted. However, in contrast to predictions, terrestrial turtles share these same general trends. Box turtles show the strongest deviation from this pattern, most likely due to their hinged shells. We find strong consistency of patterns of shell growth, independent of habitat, perhaps indicating a lack of time for early developmental changes to accumulate in terrestrial lineages, lack of selective pressure for changes in hatchling shell shape, or constraints imposed by the need to fit inside an egg during development. By understanding juvenile turtle shell ontogeny, conservation efforts can be developed to protect turtles in their most vulnerable stage.

91-7 ROBINSON, KE; HOLDING, ML; CLARK, RW*; San Diego State University, Florida State University; *rclark@sdsu.edu*
Biochemical Warfare: The Coevolution of Rattlesnake Venom and Venom Resistance in Prey Species
Many animals use toxic chemicals to defend themselves or immobilize prey. The use of such compounds frequently leads to antagonistic coevolution, wherein impacted species evolve physiological resistance to the effects of these toxins and create reciprocal selection for increasingly novel toxins or delivery systems. For example, many pitviper venoms contain high levels of metalloproteinases, a class of toxins that cause hemorrhaging, tissue damage, and facilitate the spread of other toxins through the tissues of injected prey. Several different lineages of mammals (including sciurid and neotomine rodents) have evolved metalloproteinase inhibitors, proteins in the blood serum which neutralize metalloproteinases and impede the effectiveness of the venom. Individuals with high levels of inhibitors can survive envenomations that would rapidly immobilize or kill non-resistant mammals. However, there are apparently evolutionary and physiological factors that constrain snake venom resistance, because individuals of resistant species of ground squirrels and woodrats are still the primary prey items of local rattlesnakes. Venom resistance and venom chemistry can vary at the level of species, populations, and individuals. We are studying the venom of two rattlesnakes (*Crotalus oreganus* and *C. ruber*), and resistance of two mammals (*Otospermophilus beecheyi* and *Neotoma lepida*) which all co-occur at four different locations. We use fluorescent gelatinase assays to quantify metalloproteinase efficacy and resistance among individuals. We have paired venom and serum samples within and between populations to assess variation in these traits at multiple biological levels of organization.

120-6 ROBINSON, TL*; DIAZ, K; OZKAN-AYDIN, Y; WAN, KY; GOLDMAN, DI; Georgia Tech, University of Exeter; *trobinson89@gatech.edu*
Gait dynamics of a quadriflagellate robophysical model
Quadrupedal animals locomote by coordinating their limbs to generate different gaits. While limb coordination is thought to be an exclusive capability of macroscopic systems, microscopic organisms have been found to exhibit similar capabilities. Different species of micron-sized, pond dwelling algae are capable of coordinating four flagella to generate swimming gaits similar to those of quadrupeds (Wan & Goldstein, 2016). To explore microscopic locomotion control, we developed a robophysical model of quadriflagellate microorganisms which models swimming at low-Reynolds number. We focus on two distinct gaits - the pronk and the trot. The pronk gait consists of moving each flagellum simultaneously, without any phase difference between flagella. The trot gait consists of two alternating pairs of flagella each of which generates a pattern analogous to a breaststroke. The robophysical model includes four two-link flagella connected by a joint that allows each flagellum to bend, breaking drag symmetry during locomotion. The robot emulates microorganism swimming patterns, forward motion was measured at 0.30±0.09 body lengths per gait cycle (BL/cyc) using the trot gait and at 0.19±0.03 BL/cyc using the pronk gait. Results are comparable to microorganisms' performance, where using the trot gait enables a higher speed (0.39±0.18 BL/cyc) than the pronk gait (0.18±0.05 BL/cyc). The results show that hydrodynamic performance is highly sensitive to swimming gait, consistent with recent findings which suggest flagellates are capable of actively modulating flagellar phase differences for gait selection and directional navigation. However, unlike the organisms, the robot does not swim smoothly, suggesting a role of the algal cytoskeleton for gait stabilization.

P1-216 ROBISHAW, TE*; SECOR, SM; University of Alabama; *terobishaw@crimson.ua.edu*
Comparative Allometry and Contribution of Snake Skeletal Mass
Among vertebrates the variation in the allometry of skeletal mass has been attributed to differences in habitat. Terrestrial mammals because of greater gravitational load exhibit positive allometric scaling of skeletal mass, whereas for fishes, neutral buoyant in their environment, skeletal mass scales isometrically. Interested in the effects of habitat and phylogeny on the skeletal masses of snakes, we examined the intra and interspecific allometry of skeletal mass and the relative contribution of skeletal mass to body mass among semi-aquatic, terrestrial, and arboreal snakes. From neonates to adults, semiaquatic diamondback water snakes (*Nerodia rhombifer*), terrestrial Burmese pythons (*Python molurus*), and the arboreal Amazon tree boa (*Corallus hortulanus*) possessed skeletons that exhibited positive allometric, negative allometric, and isometric scaling with body mass, respectively. For individuals of similar body mass (10 - 600 g), skeletal mass was equivalent to 5.93%, 7.88%, and 9.66% of body mass, respectively for *P. molurus*, *N. rhombifer*, and *C. hortulanus*. Although these differences may be a function of phylogeny, other species of boas (largely terrestrial species) possess skeletons equivalent to 6% of body mass, similar to that of terrestrial pythonid and colubrid snakes. However arboreal pythons and colubrids also possess skeletons nearly 10% of body mass. For snakes, an arboreal habitat appears to have contributed to heavier skeleton relative to body mass.

P1-67 ROBLES, KD*; LIN, C; OSBORN, K; Brown University, Providence, RI, Smithsonian Institution, Washington, DC; *karen_robles@brown.edu*
Visualizing Deep-Sea Eye Adaptations Using Micro-CT 3D Reconstructions
Hyperiid amphipods are small crustaceans that live in the midwater (all the ocean water below the surface but above the sea floor) where light diminishes exponentially and there is nowhere to hide from predators. Hyperiids have developed a large variety of eyes, at least 11 distinct types, across the ~350 species. Many of these eyes are gigantic in size with various complexity. This study examined how hyperiid eye and brain size compared to other animals and how eye and brain size scale to body size within the group. Volumes of eyes, brains, and bodies of four hyperiid species were determined using 3D reconstructions from x-ray micro-computed tomography (µCT). The eyes and individual eye components, brains, and the whole body were manually reconstructed using Amira. Results show that larger hyperiid species don't have equivalently larger brains as the rate at which brain size increases with body size in hyperiids is far smaller than those of other animals. Additionally, correlation between eye volume and brain volume against the body volume of four hyperiid species with large compound eyes shows that, on average, their eyes are 40 times larger than their brains. These results indicate a unique adaptation to living in the midwater. Possibly, hyperiids invest in large eyes for better low light vision, as larger eyes are more sensitive to light, but smaller brains for processing the relatively simple and homogenous visual field of the midwater. To understand the full range of hyperiid diversity and how they compare to other animals and to each other, reconstructing hyperiids with smaller eyes would be the next step.

126-4 ROCCO, AJ*; WOFFORD, SJ; Behavioral and Sensory Ecology Laboratory, Dept of Biology, Jacksonville State University; *arocco1@stu.jsu.edu*

Battle of the Benthic: Studying Agonistic Interactions Between a Native and Invasive Crayfish Species

Competition between individuals is often decided via agonistic interactions. When individuals encounter each other, both must assess the costs of fighting against the benefits of a potential resource gained. If both individuals' assessments determine that the cost of continued interaction is less than the benefits gained, the agonistic interaction will intensify until one individual gives up and flees. This has far-reaching ecological consequences, as losers in fights are often displaced to poorer quality food, shelter, and mate resources. Biogeographical invasion studies have shown that aggression differences between alien and native species factor into invasion success. In part, these differences mean invaders often outcompete natives for better resources. In this study, we examined the agonistic differences between a new invader to Alabama, *Faxonius virilis*, and a native crayfish, *Faxonius erichsonianus*, in dyadic interactions. Crayfish were socially isolated prior to trials. During trials, individuals were placed in a fighting arena where they acclimated for 15 minutes. Crayfish were then free to interact for 20 minutes and were video recorded from above. Interactions were scored to determine total interaction duration and the maximum behavioral intensity reached. Using this data, we can determine whether one species demonstrates significantly different levels of aggression. Preliminary trials show no significant agonistic differences across native and invasive treatments in fights between conspecifics. It is possible that success in agonistic interactions is largely irrelevant to invasion success: high fecundity and generalism may be what gives the invasive *F. virilis* its edge over Alabama's native crayfishes.

P3-81 ROCERETO, SK*; WHITTALL, JB; WHEAT, CW; RANK, NE; DAHLHOFF, EP; Santa Clara Univ, Univ Stockholm, Sonoma State Univ; *srocereto@scu.edu*

Non-synonymous variation at a metabolic enzyme locus (Pgi) under purifying selection

Mechanisms driving selection on protein coding genes may be best understood by examining them in a comparative evolutionary context. For loci undergoing purifying selection, non-synonymous SNPs leading to functional amino acid changes are unusual and may signal local adaptation. In montane populations of the leaf beetle *Chrysomela aeneicollis*, electrophoretic variation at the glycolytic enzyme locus *phosphoglucose isomerase* (*Pgi*) is concordant with environmental gradients in temperature and oxygen. *Pgi* genotypes differ in effects of these stressors on survival, performance and reproductive success. In this study, the complete coding sequence of *C. aeneicollis Pgi* was obtained using PoolSeq and 10X genomics. These data were combined with homologous insect *Pgi* sequences located from Genbank using a variety of BLAST options. A multiple sequence alignment of 22 insect *Pgi* coding sequences was 1,689 bp long. There was 30% variation in nucleotide coding sequence leading to 21% variation in amino acids. Pairwise sequence and individual codon comparisons revealed strong evidence for purifying selection at *Pgi*. The willow beetle *Pgi* gene is 1,674 base pairs long and contains 7 exons and 6 introns. The SNP responsible for previously described allozyme variation at *Pgi* is in exon 2. A 3D structure of *Colias eurytheme Pgi* monomer was used to posit locations of this and other key SNPs on the protein. This analysis revealed a charge-changing substitution (K426D) near the subunit binding site not observed in other insects. In contrast, the SNP characterizing *Pgi* variation in Sierra populations (D138N) appears to be on the surface of the protein, suggesting a non-enzymatic (moonlighting) function driving differences in performance and reproductive success among *Pgi* genotypes.

P3-187 RODRIGUEZ, SD*; DE JESUS-SOTO, MG; FLETCHER, SJ; PRETENDS EAGLE, TJ; PENTANIDOU, T; TSCHEULIN, T; BARTHELL, J; GIRAY, T; ABRAMSON, CI; St. Philip's College, Univ Puerto Rico, SE Okla. St Univ , NDSU, Univ of the Aegean, Univ Central Okla., Okla. St Univ.; *sierradeerodriguez@gmail.com*

Observation learning of the cap pushing response in honey bees (Apis mellifera)

In a novel conditioning procedure, we trained honey bees to push a cap to uncover a hidden food source (the cap pushing response or CPR). We have used this procedure to demonstrate a variety of conditioning effects such as greater resistance to extinction in bees given 12 training trials rather than 6, memory of cap pushing lasting at least 48 hours, discriminative punishment, and the effect of extended training and punishment. We have also discovered that the consumption of small amounts of aluminum affects the choice behavior in the CPR paradigm. We now turn our attention to whether a honey bee can learn the CPR behavior by watching another honey bee perform it. We trained several bees to the target where they consumed a sucrose syrup solution but were never trained to push the cap. We wanted to take advantage of the fact that several bees can approach the target at the same time. Thus, we created a natural situation where a trained bee would return to push the cap while other bees would be near the target. In the course of training several bees, we discovered that 16 bees learned to push the cap by watching a bee who had already learned to do so. 16 control animals who were trained to consume sucrose syrup from the sucrose well but not trained to push the cap failed to push the cap over a 30 min interval. These results are exciting as they represent the first time a honey bee has learned an arbitrary response through observation. This research was supported by NSF REU grant 1560389 and NSF PIRE grant 1545803 and performed at Skala Kalloni Greece.

P2-87 RODRIGUEZ, SD*; DE JESUS-SOTO, MG; FLETCHER, SJ; PRETENDS EAGLE, TJ; PENTANIDOU, T; TSCHEULIN, T; BARTHELL, J; GIRAY, T; ABRAMSON, CI; St. Philip's College, Univ of Puerto Rico, SE Okla. St Univ , NDSU, Univ of the Aegean, Univ Central Okla., Okla. St Univ.; *sierradeerodriguez@gmail.com*

Extended training and punishment reduced extraneous errors of the cap pushing response in honey bees (Apis mellifera)

We trained bees to push a cap to uncover a hidden food source. The experiment sought to gauge the effect of experience based on the number of trials as well as the effect of punishment through shock. Our study revealed that landing errors are reduced by experience and by the administration of punishment. Landing on an incorrect target can be defined as landing on the target not used in training. Two groups of 16 randomly selected bees received 12 training trials, one group received shock punishment for failing to push the target covering the sucrose reward while the other group did not. After the first 6 trials, we performed a test trial with each bee by relocating the trained target and covering the sucrose reward with the opposite target to observe which target the bee would push. Trials 7-12 were performed exactly as trials 1-6. After trial 12, each bee received 4 test trials, for a total of 5 test trials. Results from test trial 1 showed that 6 of 16 bees in the non-punishment group pushed the original trained target after it was moved from the reward to the periphery of the platform. While 9 incorrectly pushed the original target type, rather than the target over the reward. Consequently, 8 of 16 bees in the punishment group mistakenly identified the original target type in test trial 1, while 16 of 16 bees in each of the last 4 trials successfully identified the sucrose reward under the opposite target with which they were trained. This research was supported by NSF REU grant 1560389 and NSF PIRE grant 1545803 and performed at Skala Kalloni Greece.

71-4 RODRIGUEZ-SALTOS, CA*; RAMSAY, G; MANEY, DL; Psychology Department, Emory University, Atlanta, Georgia, Department of Pediatrics, Emory University, Atlanta, Georgia and Marcus Autism Center, Children's Healthcare of Atlanta, Atlanta, Georgia; *bio.carodrgz@gmail.com*

An R package to measure the similarity of natural sounds via mutual information

Measuring how similar two sounds are to each other has diverse applications in biology, such as quantifying imitation in vocal learners or reconstructing patterns of sound variation across populations and species. A powerful way to measure sound similarity is to calculate the statistical dependence, or mutual information, between the power spectra of the sounds being compared. Mutual information allows the researcher to measure similarity even when spectra are not linearly correlated. Non-linear dependencies can occur, for example, when two complex sounds differ because one of them displays additional elements or some of its elements are slightly shifted in pitch relative to the other sound. In those cases, using measures that assume linearity may lead to misleadingly low values of similarity. Here, we present an R package that allows measurement of sound similarity via mutual information. The package allows the researcher to automatically compare hundreds of sounds in one batch. As an example, we present measurements of the accuracy with which several juvenile zebra finches (*Taeniopygia guttata*) imitated the vocalizations of adults. The package also allows the researcher to determine the extent to which elements from multiple sounds are represented in one composite sound. We used this feature to test the extent to which juvenile zebra finches imitated the song of one tutor versus that of a second tutor. This package is expected to increase the use of mutual information to measure similarity in natural sounds by making this method more accessible to biologists.

39-6 RODRIGUEZ-SANTIAGO, M*; JORDAN, LA; HOFMANN, HA; Institute for Neuroscience, University of Texas at Austin, Max Planck Institute of Animal Behavior, University of Konstanz, Germany, Department of Integrative Biology, University of Texas at Austin; *mari.rodriguez221@gmail.com*

Social Context Affects Learning and Neural Activity Patterns in Dynamic Social Groups

During social interactions, the brain integrates current events with previous memories and predictions about future outcomes in order to respond in a context-appropriate manner. Animals are tasked with expressing context-appropriate behavior in complex social hierarchies that can undergo dynamic changes depending on group composition and individual experience. These interactions induce neuronal and physiological responses in individuals that impact their subsequent learning and decision-making. Here we examine the neurobiological correlates mediating learning in a dynamic social context in groups of the social cichlid fish, *Astatotilapia burtoni*. We first assayed the behavioral response of social groups to a simple association task with an informed individual either present or absent, and quantified how informant behavior affects the group response rate. To identify the neural substrates that mediate learning across social contexts, we analyzed the induction of the immediate-early gene *cFos* in candidate brain regions known to play a role in social decision-making and learning and memory. We find that the presence of an informant greatly facilitates group response, independent of the social status of the informant. We also find that patterns of neural activity vary according to social context rather than an individual's social status. By combining behavioral observations of social groups before and during learning with examinations of the underlying neurobiological correlates, our research provides novel insights into the neural substrates that regulate learning within dynamic social groups.

18-1 ROGERS, LS*; VAN WERT, JC; MENSINGER, AF; University of Minnesota Duluth, Marine Biological Laboratory; *loranzie@uw.edu*

Multimodal sensory integration of the utricle in freely swimming toadfish, Opsanus tau

Unlike the inner ear of terrestrial vertebrates, fishes have a less pronounced separation between auditory and vestibular inner ear organs. In fishes, the inner ear is composed of three paired otolithic end organs, which are multimodal and encode auditory and vestibular stimuli. To determine the effects of vestibular (movement) and auditory (pure tones or conspecific vocalizations) input, microwire electrodes were implanted using a 3D printed micromanipulator chronically into the utricular nerve of oyster toadfish, *Opsanus tau*. Fish swam freely or were moved forward at variable speeds while affixed to a sled. All utricular afferents responded to movement by increasing neural activity and remained sensitive to pure tones (125 – 200 Hz) and playbacks of conspecific boatwhistles throughout movement. This research is the first to simultaneously investigate the effects of multimodal input to the utricle during self-generated movement in free-swimming fishes.

P1-6 ROJAS , AM*; SMITH , FW; University of Connecticut , University of North Florida ; *ariana.m.rojas1@gmail.com*

A Secondarily Simplified Mechanism Patterns the Tardigrade Through-Gut

A highly conserved mechanism typically patterns the through-gut of nephrozoans. This mechanism is predicted to pattern the gut of tardigrades. However, tardigrades are highly simplified and miniaturized, presenting the possibility that the developmental mechanism that patterns the tardigrade gut is also secondarily simplified. Simplification of gut patterning could be identified by the loss of an ancestral gut patterning gene, the loss of a gene's function in patterning the gut, or by reduction in the degree to which gut patterning genes exhibit regionalized expression patterns during gut development. We investigated the genomes of two representatives of Tardigrada—*Hypsibius exemplaris* and *Ramazzottius varieornatus*. We identified single orthologs of *forkhead (fkh)*, *gata456,*, *orthodenticle (otd)*, *caudal (cad)*, *goosecoid*, *hnf-4*, *even-skipped*, and *fgf8/17/18*—genes that play important roles in gut patterning in other nephrozoans. However, we were unable to identify orthologs of *foxq2*, *brachyury*, *nk2.1*, or *wingless*, genes that typically pattern the through-gut of other nephrozoans, suggesting that these genes were lost in the tardigrade lineage. We have investigated the expression patterns of *otd*, *fkh*, *gata456*, and *cad* in *H. exemplaris* embryos. *He-otd* and *He-cad* were expressed in the anterior and posterior of the developing body axis in *H. exemplaris* embryos, as predicted. *He-fkh* is expressed throughout the developing gut, as predicted. However, we detected expression of *He-gata456* broadly throughout the developing gut, rather than it being restricted to the developing midgut as it is in other nephrozoans. Together, our results provide preliminary evidence of a simplified gut patterning mechanism in Tardigrada.

46-2 ROJO ARREOLA, L*; ROMERO , R; DIAZ DOMINGUEZ, L; GARCIA CARREñO, F; Centro de Investigaciones Biologicas del Noroeste; *lrojo@cibnor.mx*

Proteolytic profile through larvae development in Penaeus vannamei: activity and transcriptional approach

Peptidases are hydrolases that cleave peptide bonds within protein chains. In arthropods, the cleavage of specific proteins by proteases has pivotal roles in multiple physiological processes including oogenesis, immunity, nutrition, and parasitic invasion; these enzymes are also key players in larval development, well-described triggers of molting and metamorphosis, as well as fat body dissociation and tissue remodeling. *Penaeus vannamei* is a Penaeid shrimp and a key species for the aquaculture industry, but descriptions of the molecular mechanisms of many important physiological conditions including larval development are rather poor. Penaeid shrimp undergo a biphasic life cycle, meaning pelagic larvae stages followed by benthonic juvenile and adult stages. Larvae develop gradually and each stage presents morphological, physiological and ecological adaptations that fulfill its locomotive and feeding changes. In this work the proteolytic profile along the larvae development of *P. vannamei* was determined at transcript and activity levels, we quantified the gene expression of 21 annotated shrimp peptidases by qPCR. Since changes in mRNA abundance do not necessarily correlates with the corresponding mature protein products, the proteolytic activity was also assessed using fluorogenic substrates designed to be recognized by 13 specific peptidases, the data presented here will contribute to understand the proteolytic dynamics occurring during *P. vannamei* larvae development.

P3-249 ROLFE, S; WINCHESTER, J; PIEPER, S; BOYER, D; SUMMERS, A; MAGA, M*; University of Washington, Duke University, Isomics Inc; *maga@uw.edu*

SlicerMorph: Retrieve, Visualize and Analyze 3D Morphology with Open-Source

Large scale digitization projects like *#ScanAllFishes* and *oVert* are generating high-resolution microCT scans of vertebrates by the thousands. Data from these projects are shared with the community using aggregate 3D specimen repositories like MorphoSource through open-source licenses. MorphoSource currently hosts almost 16,000 3D scans of eukaryotes, and the number of available specimens is expected to double in next couple years. We anticipate an explosion of quantitative research in organismal biology with the convergence of available data and the methodologies to analyze them. Yet, the road from a series of image sequences to analysis is typically fraught with challenges for most biologists. It involves tedious tasks of data format conversions, preserving spatial scale of the data accurately, 3D visualization and segmentations, acquiring measurements and annotations. Users opt-to use commercial software with proprietary formats that constitutes a roadblock for data exchange, collaboration and reproducibility. Our project is extending the functionality of the **3D-Slicer** with tools that biologists need to conduct 3D specimen-driven research. **SlicerMorph** is as an extension of Slicer that provides users with tools to conduct shape analyses and 3D visualizations. Soon, functionality will be supplemented with semi-automatic landmark generation, and with a landmark-free shape correspondence method. We are also organizing weeklong intensive workshops that cover the fundamentals of 3D imaging and morphometric analyses. Our goal is to establish a community of organismal biologists centered around Slicer and SlicerMorph to facilitate easy exchange of data and results and collaborations using 3D specimens.

P1-8 ROMANO, L*; BROADY, C; JI, K; MADAR, M; SCOGGINS, N; WONG, M; Denison University; *romanol@denison.edu*

Comparative analysis of developmental mechanisms and their plasticity with regard to changes in the environment: derived species versus the pencil urchin, Eucidaris tribuloides.

We use the sea urchin as a model system to explore the evolution of developmental mechanisms, particularly with regard to the larval skeleton. Skeletogenic cells ingress into the blastocoel and form two ventrolateral clusters in response to cues from the overlying ectoderm. These cells then secrete a variety of proteins, which leads to the formation of a pair of triradiate spicules on either side of the archenteron. Recently, we have been focused on the molecular basis of differences in skeletogenesis between derived species and the "primitive" pencil urchin, *Eucidaris tribuloides*. We have been working to characterize the expression of genes that regulate the epithelial-mesenchymal transition associated with ingression as a first step in gaining insight into a heterochronic shift that has occurred during sea urchin evolution. We also have preliminary data for the effects of changes in factors such as pH, salinity, and temperature on embryogenesis as we begin to compare the pencil urchin with progressively more derived species for insight into differences in the plasticity of their response to changes in the environment. All of our work at the critical intersection of ecology, evolution, and development is conducted by undergraduate students in the context of a small liberal arts institution.

P2-64 RONCALLI, V*; CIESLAK, MC; HOPCROFT, RR; LENZ, PH; University of Barcelona, Spain , University of Hawaiʻi at Mānoa, USA , University of Alaska, Fairbanks, USA; *roncalli@ub.edu*

Capital Breeding In a Diapausing Copepod: a Transcriptomics Analysis

In highly-seasonal and food-limited environments, life histories have evolved strategies to synchronize growth and reproduction to peaks in production. Diapause is a type of dormancy that ensures survival during periods of extreme cold and energy-poor conditions. The adult female of the subarctic copepod *Neocalanus flemingeri* enters a period of diapause prior to spawning seven to eight months later. As a capital breeder *N. flemingeri* depends on a short annual phytoplankton bloom to acquire and store the energetic resources to support both diapause and the reproductive program. Gene expression profiling was used to investigate the relationships between energy utilization, cellular maintenance and oogenesis in *N. flemingeri* . The transition from diapause to egg release was characterized by the sequential up- and down-regulation of genes involved in cellular maintenance and metabolic pathways. Timing of three major transitions in transcriptional patterns coincided with emergence from diapause and early oogenesis, mid to late oogenesis, and finally spawning and end-of-life. The down-regulation of genes involved in cellular homeostasis occurred in parallel with the up-regulation of genes related to mid-late oogenesis and protein degradation. As females began spawning, genes involved in protein ubiquitination and programmed cell death became up-regulated. The data suggest that females match fecundity to available resources by limiting germline development to early post-diapause coincident with the up-regulation of genes involved in cellular homeostasis, glycolysis and lipid catabolism. This strategy decreases the risk of reproductive failure by assuring that all oogonia can mature successfully.

P3-128 ROSADO, KA*; KRUPPERT, S; SUMMERS, AP;
Monmouth University , University of Washington ;
Rosadok13@gmail.com

Armor and Maneuverability of Poachers

Agonidae body armor: performance and prize Kayla A. Rosado1, Sebastian Kruppert2, Adam P. Summers2 1 Monmouth University 2 Friday Harbor Laboratories, University of Washington Fishes of the family of Agonidae show an intriguing amount of body armor. The majority of the 47 described poacher (Agonidae) species is found in the Pacific. All poachers lack a swim bladder and are found in benthic habitats of different depth. Their armor is made out of bony plates covering the whole body. The plates converge in a spine in most species and in one species these plates are even found on the eyeballs. The amount of armor as well as the question of the trade-off that has to come along with it render poachers an excellent group to study animal body armor and its costs. Based on the hypothesis that heavy body armor should come with a trade-off we performed this study in order to evaluate the performance of poacher body armor and analyze their maneuverability. A heavy body armor can reduce an animal's movement capabilities. That can be considered direct or indirect costs of this defensive trait. We here present our findings on the poacher armor performance as well as on the fishes maneuverability. We tested four species from the Salish Sea using penetration tests, bending tests and high speed footage of c-starts. Our results revealed no significant difference of force needed to penetrate poacher armor on the plates versus in between the scales. Furthermore, the poacher armor was equally tough on the dorsal, lateral and ventral side. All analyzed species showed quite high forces in the penetration tests with Anoplagonus inermis having the toughest armor. The results of our bending tests and c-start footage proved the poachers surprisingly maneuverable.

75-4 ROSS, SA*; RIMKUS, B; KONOW, N; BIEWENER, AA; WAKELING, JM; Simon Fraser University, University of Massachusetts Lowell, University of Massachusetts Lowell and Harvard University, Harvard University; *saross@sfu.ca*

The Effects of Muscle Internal Mass on the Contractile Behaviour of In Situ Rat Plantaris Muscle

Most of what we know about whole muscle contractile behaviour comes from measures on isolated muscle fibres or small muscles that have been extrapolated to larger sizes without considering the mechanical consequences of the additional muscle mass. Previous studies have shown that the mass of muscle tissue acts to slow the rate of force development and maximum velocity of muscle during shortening contractions and decrease the work and power per cycle during cyclic contractions. However, these studies have relied solely on model predictions and so the effects of inertial resistance due to tissue mass have not yet been confirmed by experiments on living tissue. Therefore, in this study we conducted *in situ* work-loop experiments on rat plantaris muscle (n = 7) to determine the effects of increasing the internal mass of muscle on contractile performance. We also simulated the *in situ* experimental conditions using a mass-enhanced Hill-type muscle model to validate the results of the previous modelling studies. We found that experimentally increasing the mass of *in situ* muscle results in lower mechanical work per cycle, and this result was confirmed in the model simulations. Further, we found that this mass-dependent reduction in work is influenced by the muscle length change per contraction cycle, with greater length changes resulting in greater reductions in work. These results confirm that muscle mass is an important consideration for a complete understanding of whole muscle contractile behaviour.

5-7 ROSS, CF*; LAIRD, MF; GRANATOSKY, MC; University of Chicago, University of Southern California, New York College of Osteopathic Medicine; *rossc@uchicago.edu*

Energetic costs of locomotion and feeding in capuchin primates.

It is often assumed that natural selection minimizes energetic expenditure during cyclical feeding and locomotion so that energy might be allocated to growth, reproduction, predator avoidance, or mate competition. While this assumption has been supported in the locomotor system, the feeding system is small, and the muscles responsible for jaw opening and closing represent a mere fraction of total body weight. Because of this size disparity, we hypothesized that selection does not to minimize the metabolic costs of feeding. To test this hypothesis we measured respirometry-based metabolic energy expenditure during cyclic chewing and walking in tufted capuchin monkeys (*Sapajus* sp.) ranging in body size and metabolic costs. Mass-specific metabolic cost and cost per cycle during walking reached values up to ~15 times higher than cyclical chewing. During locomotion, we observed a negative relationship between the body size of the animal and the mass-specific metabolic cost, as well as the mass-specific metabolic cost per cycle. In contrast, both mass-specific metabolic cost and mass-specific metabolic cost per cycle increased along with body size during cyclical chewing. This result likely stems from anatomical and mechanical patterns in the feeding system inconsistent with energetic minimization, such as: a high proportion of myosin heavy chain masticatory isoforms known for their high rates of ATP consumption; relatively low joint angular excursions that correspond to higher than expected costs of movement; and a relatively stiff system that does not utilize passive mechanisms. Taken together, these features suggest that in the feeding system, minimizing energy costs may be less important than the control of force and displacement.

33-3 ROSSO, AA*; LOGAN, ML; MCMILLAN, WO; COX, CL; Georgia Southern University, University of Nevada Reno, Smithsonian Tropical Research Institute, Florida International University; *ar20855@georgiasouthern.edu*

Phenotypic Plasticity and the Response to Increasing Temperatures in a Tropical Lowland Lizard

Climate change is an important agent of selection on physiology and phenology, and can affect the range and distribution of organisms. Organisms may respond to climate change through behavior, genetic adaptation or phenotypic plasticity. However, these predictions are not consistent across latitude. Tropical ectotherms are predicted to be negatively impacted by climate change because 1) most have a narrow range of thermal tolerance while already living close to their thermal optima, and 2) they are thought to have decreased capacity for phenotypic plasticity because they have evolved in thermally stable environments. We used a mesocosm experiment to test the capacity for phenotypic plasticity of the Panamanian slender anole (*Anolis apletophallus*) under warming temperature. We caught lizards from Soberania National Park and randomly assigned an equal number of males and females to a control and warming treatment. We measured voluntary thermal maxima, critical thermal minima, and behavior in a thermal gradient before and after 28 days of treatment. We found that voluntary thermal maxima and maximum temperature chosen in a thermal gradient increased in the warm treatment, but not the control treatment. In contrast, we found that critical thermal minima and the mean temperature chosen in a thermal gradient decreased in both treatments. Our results provide evidence that tropical organisms can use phenotypic plasticity to respond to a changing climate, despite previous theoretical work suggesting that they lack plastic potential. This work highlights that phenotypic plasticity should be considered when predicting the future of tropical ectotherms under a changing climate.

95-3 ROSVALL, KA*; LIPSHUTZ, SE; Indiana University, Bloomington; *krosvall@indiana.edu*

Obligate cavity-nesting shapes the evolution of territorial aggression, but not testosterone, in both female and male birds

Our understanding of the proximate and ultimate mechanisms shaping competitive phenotypes primarily stems from research on male-male competition for mates, even though female-female competition is also widespread. Obligate secondary cavity-nesting provides a useful comparative context to explore the phenotypic effects of competition because this reproductive strategy has evolved repeatedly across avian lineages, and it is thought to generate strong competition for a pre-made cavity in which to nest, for both males and females. We tested the hypotheses that cavity-nesting elicits more robust aggressive responses to conspecifics and that this behavioral trait is facilitated by elevated testosterone levels in circulation in both sexes. We assayed aggression in males and females in two obligate cavity-nesting species and two related non-cavity-nesting species in the same avian family: tree swallow (*Tachycineta bicolor*) vs. barn swallow (*Hirundo rustica*); Eastern bluebird (*Sialia sialis*) vs. American robin (*Turdus migratorius*). We found that both male and female cavity-nesting species were more aggressive than their non-cavity-nesting close relatives. However, we did not find higher testosterone in cavity-nesting females or males, despite some correlative evidence that testosterone is associated with territorial defense. These patterns support the long-held hypothesis that cavity-nesting may select for greater territorial aggression in both sexes, but parallel increases in aggression are not associated with greater testosterone secretion in either sex.

P3-48 ROWLEY, AA*; ADELMAN, JS; DALLOUL, RA; VINKLER, M; HENSCHEN, AE; HAWLEY, DM; Virginia Tech, University of Memphis, Charles University; *aarowley@vt.edu*

Are There Broader Immunological Effects of Evolved Disease Tolerance in House Finches?

It remains largely unknown how selection from novel pathogens influences host immune phenotypes more broadly, such as immune responses to unrelated pathogens and antigens. In 1994, the bacterial pathogen *Mycoplasma gallisepticum* (MG) jumped from poultry into house finches in Virginia, causing severe conjunctivitis and reducing survival. MG then spread across the continental United States, causing strong selection on host populations and creating a geographical timeline of host co-evolutionary history with the pathogen. In populations with longer histories of MG endemism, hosts have evolved tolerance to MG, and past work suggests that reductions in pro-inflammatory immune responses are associated with this tolerance. However, it remains unknown whether these immunological changes are limited to MG-specific defenses or whether broader immune responses differ between more- and less-tolerant populations. To examine potential broader effects of MG tolerance, we used four immune antigens to challenge house finches from four populations, ranging from no history of MG endemism to 20+ years of MG endemism. When challenged with phytohemagglutinin, populations differed significantly in the strength of wing web swelling, with populations with longer MG exposure (and thus the highest MG tolerance) on average exhibiting the weakest swelling response. However, population differences were absent for responses to three other antigens (LPS, FSL-1, sheep erythrocytes). These results suggest that the evolution of MG tolerance may have downstream consequences for responses to some antigens, with the potential to influence a host's ability to respond to novel pathogen challenges, but many components of the host immune system remain unaffected.

100-3 ROWSEY, LE*; REEVE, C; SAVOY, T; SPEERS-ROESCH, B; University of New Brunswick, Saint John; *lrowsey@unb.ca*

Thermal Constraints on Anaerobic Exercise and Aerobic Performance are Not Major Drivers of Winter Dormancy in Cunner

Winter dormancy (an inactive, fasting, slow metabolism state) is used by certain fishes to endure the frigid and food-poor winter and persist at poleward latitudes. However, little is known about the mechanisms and drivers of winter dormancy. We hypothesized that winter dormancy arises because of severe constraints on physiological performance at frigid temperatures. To test this, we measured the thermal sensitivity of fitness-linked physiological performance (burst swimming, metabolic rate, and aerobic scope) and related biochemical characteristics (metabolite levels and enzyme activities) in the winter-dormant cunner (*Tautogolabrus adspersus*), which enters dormancy below 7.4°C on average. Performance was measured after acute exposure to 2-26°C and after acclimation (≥5 weeks) to 2-14°C. As expected, performance declined with cooling below the thermal optimum in both exposure groups. In acutely exposed fish, the thermal sensitivity of all performance traits was greater below the dormancy threshold temperature than above, suggesting a major constraint of cold. However, at 2°C, acclimated cunner had greater performance and lower thermal sensitivity compared to acutely exposed cunner (Q_{10} of 1.1-2.0 vs. 3.9-4.3 between 8-2°C, respectively). Thus, dormant cunner show partial compensation of swimming and aerobic performance in winter cold temperatures, similar to cold-active species. However, compensation of metabolic enzyme activities did not underlie the whole-animal performance compensation. We conclude that thermal constraints on anaerobic exercise and aerobic performance are not major drivers of winter dormancy in cunner.

S2-5 RUBENSTEIN, DR; Columbia University; *dr2497@columbia.edu*

Epigenetic Programming and the Evolution of Adaptive Coping

Stressors during development can influence physiology, phenotype, and ultimately fitness later in life. Such development programming can be both adaptive by preparing organisms to deal with environmental conditions later on, or it can be maladaptive by constraining organismal phenotypes no matter the type of environment experienced as adults. Although epigenetic changes that alter the structure of DNA are thought to be one of the primary mechanisms that underlie developmental programming, we lack a general understanding of how early life stressors impact epigenetic changes in the genome. Using superb starlings (Lamprotornis superbus), which inhabit a range of East African environments where conditions vary unpredictably from year-to-year, I will explore how early life conditions influence epigenetic programming. I will discuss how patterns of DNA methylation across the entire starling genome vary with rainfall during development, discussing the gene regulatory networks that show signatures of adaptive capacity versus those that show signatures of being constrained by early life conditions. Taking a more fine-scale approach, I will then focus on a suite of genes known to be related to stress and reproduction to determine how epigenetic programming acts at different scales to potentially alter physiology and fitness. Ultimately, I will not only illustrate the different ways that variable early life conditions shape patterns of DNA methylation across the genome, but I will develop an evolutionary framework for understanding adaptation and constraint in the context of developmental and epigenetic programming.

132-5 RUDDY, BT*; LONG JR, JH; VERMA, S; PORTER, ME; Florida Atlantic University, Boca Raton, Fl, Vassar College, Poughkeepsie, NY; *bruddy2018@fau.edu*
Swimming efficiency influences schooling position of volitionally swimming blacktip sharks.
Fish gain hydrodynamic benefits such as increased swimming efficiency when schooling. The group structure, or arrangement within a school, necessary for increased efficiency is modeled as four animals in a diamond formation, but this hypothesis has not been tested in the wild. Previously, we quantified wild *Carcharhinus limbatus*, blacktip sharks, volitional swimming kinematics and found individuals traveled in groups of 4, in a diamond formation, and had significantly lower Strouhal number values when compared to other group sizes. Here, we examine hydrodynamic models produced by our volitional swimming kinematics data. We utilized an aerial drone to capture footage of wild, straight swimming *C. limbatus* in various group sizes and used motion tracking software to examine kinematic variables (tailbeat frequency, amplitude, velocity, and Strouhal number). ImageJ was used to quantify nearest-neighbor distance, school density, orientation angle, and position within a formation from still photos. Kinematic data were then used as inputs for numerical simulations solving the Navier-Stokes equations to examine wake produced by varying group sizes (2-12 sharks). Reynolds' flocking models were used to assess coordination among sharks within a school. Our results indicate that individuals within a group are placed to interact constructively with wake, and coordinated movement exists within pairs of individuals. This work provides validation to previous mathematical simulations from the literature conducted on hydrodynamics of collective formations, and insight into priorities of schooling arrangements in the wild.

101-6 RUDZKI, EN*; KOHL, KD; STEPHENSON, JF; University of Pittsburgh; *elr82@pitt.edu*
Skin Microbiome Significantly Predicts Susceptibility to Ectoparasite Infection in Trinidadian Guppies, Poecilia reticulata
The role that microbes play in host-parasite interactions is currently poorly understood. In aquatic environments, the host-associated microbiome (HAM) of fish and salamander skin has been found to be highly important to their general health and ability to fend off other pathogens. Current research focuses primarily on end-infection dysbiosis, or an altered microbial state from normal thought to be caused by parasitic infection or activation of the immune system. Here, we were interested in elucidating whether the microbiome present on the host pre-infection could predict subsequent infection susceptibility to the parasite. To address this question, we used a monogenean ectoparasite, *Gyrodactylus turnbulli*, and its host the Trinidadian Guppy (*Poecilia reticulata*) to untangle the relationships between host, parasite, and the HAM. Guppies were either experimentally- or sham-infected with *G. turnbulli* and housed individually. The number of parasites present on each fish was counted every 48 hours, and we quantified each fish's infection susceptibility using the area under the curve of infection load over time. We swabbed fish skin to inventory the skin HAM before infection (Day 0) and during late infection (Day 15). We identified several bacterial taxa whose relative abundance in the skin HAM prior to infection significantly predicts subsequent *G. turnbulli* infection susceptibility (*Sphingobium*, *Agromyces*, *Methylococcaceae*, and *Gemmata*). Our results therefore demonstrate that skin microbiome community composition significantly predicts susceptibility to an ectoparasitic helminth. Future experiments will elucidate the mechanisms underlying this effect – do bacteria and parasite interact directly, indirectly, or are they correlates of a third process?

51-7 RUIZ, CA*; THEOBALD, JC; Florida International University; *cruiz093@fiu.edu*
Fruit Flies Respond to Ventral Parallax During Strong Sideslip Disturbances
Flies and other insects use incoherent motion (parallax) to the front and sides to measure distances and identify obstacles during translation. Although additional depth information could be drawn from below, there is no experimental proof that they use it. The finding that blowflies encode motion disparities in their ventral visual fields suggests this may be an important region for depth information. We used a virtual flight arena to measure optomotor responses to unintended sideslip and rotational optic flow in fruit flies. The stimuli appeared below (n=51) or above the fly (n=44), at different speeds, with or without parallax cues. Dorsal parallax does not affect responses, and similar motion disparities in rotation have no effect anywhere in the visual field. But responses to strong ventral sideslip (70 deg/s) change drastically depending on the presence or absence of parallax (p=0.023). Ventral parallax could help resolve ambiguities in cluttered motion fields, and enhance corrective responses to nearby objects.

133-4 RUMMEL, AD*; FAURE, PA; SMOTHERMAN, MS; SWARTZ, SM; MARSH, RL; Brown University, Providence, RI, McMaster University, Hamilton, ON, Texas A&M, College Station, TX; *andrea_rummel@brown.edu*
Is Reduced Thermal Sensitivity in Distal Wing Muscles a Functional Adaptation to Bats' Unique Wing Morphology?
Bat wings contain muscles whose fast, coordinated contractions are integral to the flight stroke. Muscle cooling slows contractile rates, however, and flight exposes bats to substantial convective and radiative heat losses. Since bat wings are poorly thermally insulated, a temperature gradient exists from the proximal core (warm) to the distal periphery (cool). During flights at ~22°C, in *Carollia perspicillata* the distal extensor carpi radialis longus muscle (ECRL) operates at ~12°C below core body temperature (T_b) while the proximal pectoralis muscle operates near T_b. The ECRL is also less temperature sensitive than the pectoralis, i.e., it experiences a proportionately smaller decline in contractile rates after a given drop in temperature. This finding raises an important question: Is this high-to-low gradient in temperature sensitivity from proximal-to-distal in the bat wing a functional adaptation to the wing's local thermal environment, or the climate in which the bats live? To address this, we measured contractile rates in the ECRL and pectoralis muscles of *C. perspicillata* and *Eptesicus fuscus*, and in the ECRL muscle of *Tadarida brasiliensis* at a range of experimental temperatures (22–42°C) to determine if muscle temperature sensitivity varies interspecifically. There was little difference in the thermal sensitivities of the ECRL or pectoralis muscles between species; however, the ECRL was less temperature sensitive than the pectoralis. These results suggest that the low temperature sensitivity of the ECRL muscle in bats may be due to local thermal challenges rather than as an adaptation to largescale environmental conditions.

50-4 RUPP, AE*; MOON, B; University of Louisiana Lafayette; *arianarupp91@gmail.com*

Feeding and Digestive Anatomy of Mud Snakes

Mud snakes are dietary specialists that regularly consume elongate amphibian prey such as siren and amphiuma salamanders. This study described the unique feeding behaviors of adult and juvenile mud snakes on elongate prey items using video recorded feeding trials. The digestive anatomy of both adult and juvenile mud snakes is also described in order to identify any specialized structures of the digestive tract that may aid in the consumption of elongate salamanders. Both gross morphology and histology of the digestive tract are described.

67-5 RUSSELL, A; BORRELLI, S; FONTANA, R; LARICCHIUTA, J; PASCAR, J; BECKING, T; GIRAUD, I; CORDAUX, R; CHANDLER, CH*; SUNY Oswego, SUNY Oswego, Syracuse University, Université de Poitiers; *christopher.chandler@oswego.edu*

A Transition to XY Sex Chromosomes Associated with Y-linked Duplication of a Male Hormone Gene in a Terrestrial Isopod

Sex chromosomes have evolved independently and repeatedly in a wide range of taxa. In some groups, the sex chromosomes are relatively stable, having been conserved for millions of years, while in others, the sex chromosomes undergo frequent turnovers. One possible explanation for the high frequency of turnovers in some organisms is the presence of reproductive endosymbionts such as *Wolbachia*. In terrestrial isopods, for instance, *Wolbachia* can induce host feminization and is thought to drive rapid sex chromosome turnover in this group. The terrestrial isopod *Trachelipus rathkei*, which is widespread throughout North America and Europe, is described as having a ZZ/ZW sex chromosome system in a cytogenetics study. We tested this hypothesis using crosses with experimentally sex-reversed individuals, and surprisingly found that sex is determined by an XX/XY system in our population. Moreover, genomic sequencing and PCR found evidence of past *Wolbachia* infections, plus a male-specific, Y-linked duplication of the androgenic gland hormone gene, which triggers male development in isopods. These results support the idea of frequent transitions in isopod sex chromosomes, and suggest that hosts may evolve mechanisms to counteract the effects of reproductive endosymbionts.

88-3 RUTLEDGE, KM; University of California Los Angeles; *kelsimarie7@g.ucla.edu*

Sniffing out batoid nasal morphology: a model for classification with functional implications

Batoids (rays, skates, sawfishes and guitarfishes) possess a suite of sensory modalities, including vision, hearing, mechanoreception, electroreception, and olfaction. Olfaction is the longest-range sense and is crucial for initial detection of a stimulus and long-range tracking. Olfactory processes are directly tied to, or have implications for: navigation and tracking, food recognition, reproductive signaling and conspecific recognition, and predator avoidance. The anatomy (internal and external) and placement of the olfactory apparatus in batoids is highly divergent from the more recently evolved bony fish relatives (e.g. trout, tuna). Batoid species, while exhibiting considerable morphological and ecological diversity as a group, are all dorsoventrally flattened, with eyes on the opposite side of the head from their nose and mouth. They also possess an unusual nose, enlarged relative to other fishes, with numerous external flap-like structures or projections. Nasal diversity within the group is disparate, with differences in size, position, and angle of the nares, as well as the number of nasal flaps. I hypothesize that the nasal diversity displayed in this group corresponds with functional rather than phylogenetic differences. In order to quantify shape diversity, I created a morphometric model of snout and nasal differences across 15 families and 50 species. Using this model along with CT data, I propose classifications of nasal morphotypes displayed in batoids with functional and ecological implications.

P1-155 RUVINA, K; BERGMAN, D.A*; WRIGHT, M.A; Grand Valley State University; *ruvinak@mail.gvsu.edu*

The Sniff of Victory: The Road to Identify an Aggressive Male Chemosignal in Crayfish

It is well established in the scientific community that decapod crustaceans secrete molecules via nephropores to communicate with each other. These molecules have been shown to affect the animal behavior, especially aggression. However, studies in decapods crustaceans have yet to elucidate the chemical nature of aggressive pheromone during agnostic interactions. The main goal of this study is to identify the chemical profile of crayfish urine released during aggressive interactions and further investi-gate the impact of molecules in question during matched fights. If found, this will be the first time that the identity of the aggressive pheromone(s) will be revealed.

P3-188 RYAN, L M*; GUNDERSON, A; Tulane University; *lryan2@tulane.edu*

Testing for differences in temperature-dependent activity between introduced Anolis sagrei and native Anolis carolinensis in the U.S.

As we move further into the Anthropocene, introduced species continue to be a major environmental problem . As such, understanding how introduced species become successful is becoming increasingly important. Since the climate is steadily warming, performance at higher temperatures is likely to be an increasingly important factor in species competition. A common invasive species in the Southeastern United States is the Brown Anole (*Anolis sagrei*), which is outcompeting the native Green Anole (*A. carolinensis*) where the two species co-occur. In this study, we tested for differences in temperature-dependent activity levels between *A. sagrei* and *A. carolinensis*. We predicted that *A. sagrei* would be active at a higher and/or wider range of temperatures. The research was conducted in both urban and rural environments in the greater New Orleans area. To collect activity data, we observed subjects for 5-15 minutes each and recorded how long they performed active behaviors such as moving, displaying, and feeding. We estimated body temperature at the end of each observation with a copper model containing a thermal probe. For both species, we observed activity over a 20-degree range of temperatures. Contrary to our prediction, we found no significant difference in activity level between the two species across a range of summer temperatures. Therefore, greater activity at high temperatures does not appear to facilitate the competitive advantage of *A. sagrei*. Our next step will be to measure activity levels during winter months to determine if low temperature activity patterns differ between the species.

99-2 RYAN, DS*; DOMINGUEZ, S; NIGAM, N; WAKELING, JM; Simon Fraser University; *dsryan@sfu.ca*

Mechanisms that Relate Transverse Loading of Muscle to Change in Contractile Performance

Muscles exist in confined spaces, packed in between organs, muscles, bones, and skin. Due to this, any bulging that a muscle undergoes will result in a load on that muscle or another muscle. Experimental work has shown that muscles produce less force when contraction simultaneously. Further experimental work has shown that transverse load on a muscle can lead to a reduction in force production when either unidirectional or multidirectional loading is applied. Our aim is to replicate such loading experiments using a muscle model to probe the mechanisms behind this effect. Here we use a three-dimensional finite element model of muscle based on the mechanics of fibre-reinforced composite biomaterials. The model represents both the passive and active fibre force-length properties, as well as base material properties that include the non-fibre elements such as extracellular matrix, connective tissues, blood vessels, and nerves. The model is written in C++ built on the deal.II finite element library. The model allows the testing of unidirectional and multidirectional loading from transverse directions on various pennate and parallel muscles and the quantification of the resulting changes in muscle architecture and stress. Simulated compressions demonstrate the changes in the muscle force when transverse load is applied, and show that this is a multifactorial phenomenon dependent on both loading conditions and internal architecture.

125-6 RYDER, TB; DAKIN, R*; VERNASCO, BJ; EVANS, BS; HORTON, BM; MOORE, IT; Smithsonian Institution, Carleton University, Virginia Tech, Millersville University, Virginia Tech; *roslyn.dakin@gmail.com*

Testosterone modulates status-specific patterns of cooperation in a social network

Stable cooperation requires plasticity whereby individuals are able to express competitive or cooperative behaviors depending on social context. To date, however, the physiological mechanisms that underlie behavioral variation in cooperative systems are poorly understood. We studied hormone-mediated behavior in the wire-tailed manakin (*Pipra filicauda*), a gregarious songbird whose cooperative partnerships and competition for status are both crucial for fitness. We used automated telemetry to monitor > 36,000 cooperative interactions among male manakins over three field seasons, and we examined how circulating testosterone affects cooperation using > 500 hormone samples. Observational data show that in non-territorial floater males, high testosterone is associated with increased cooperative behaviors and subsequent ascension to territorial status. In territory-holding males, however, both observational and experimental evidence demonstrate that high testosterone antagonizes cooperation. Moreover, circulating testosterone explains significant variation (2-8%) in social behavior within each status class. Collectively, our findings show that the hormonal control of cooperation depends on a male's social status. We propose that the status-dependent reorganization of hormone-regulatory pathways can facilitate stable cooperative partnerships, and thus provide direct fitness benefits for males.

S9-10 RYERSON, WG; Saint Anselm College; *wryerson@anselm.edu*

Captive breeding alters head morphology and behavior in reptiles: implications for headstarting and reintroduction programs

The use of captive breeding for the purpose of supplementing imperiled species is commonplace throughout herpetology, and continues to grow with each decade. For snakes, many of these programs take the form of "headstarting" programs. Individuals are born in captivity, and raised for as many as three years before reintroduction into the wild. The focus of these programs are maintaining genetic diversity in their captive populations, and ensuring that individuals survive to reproduce in the wild. However, it is not clear how the captive rearing environment may play a role in the behavior and morphology of these individuals, and how changes in the behavior and morphology influence the success of individuals upon reintroduction. Examination of feeding behavior across 10 different species of snake reveals that species respond differently to captive care protocols, in terms of strike performance, sensory biology, and prey-handling behaviors. Experimental manipulation of diet in newborn garter snakes, *Thamnophis sirtalis*, reveal that while total mass of food consumed ultimately drives body size, the size of individual food items can drive differences in head shape during the earliest stages of ontogeny. Changes in head shape may impact the ability of individuals to exploit resources later in life, and help drive the likelihood of survival. The additive effects of changes to both behavior and morphology from the native population is likely to alter the likelihood of success of the individual, and the reintroduction program. Taking steps to prevent these changes may increase that likelihood of success.

P1-235 SACKS, PE*; WALTERS, LJ; DONNELLY, MJ; University of Central Florida, Orlando; *sackspe@gmail.com*
Oral Histories to Improve Coastal Restoration
Habitat restoration attempts to bring back critical ecosystem services lost from overharvesting and habitat degradation. Local anecdotal information can be combined with maps/photographs to document an estuary's ecological history. In the northern Indian River Lagoon (IRL) on the east coast of central Florida, intertidal oyster *Crassostrea virginica* distributions dating back to 1943 have been published. In the central IRL, local accounts and commercial harvest records suggest historically dense oyster populations, however, oyster reefs were not visible in historic photography. To solve this discrepancy, we collected oral histories from long-term residents to record knowledge and papers/photographs they were willing to share. This became imperative in Brevard County (central IRL) after a 0.5 cent sales tax passed in 2017 to fund large-scale oyster restoration. First, a History Harvest event brought locals together to share their stories with undergraduate students. This was combined with participation in annual Mosquito Beater reunions and Brevard County historical museum gatherings to which all County residents were invited. Findings include: 1) locals love to talk about the IRL back when times were "good" in terms of water quality; 2) surprisingly large numbers of individuals knew exactly where adult oysters were abundant through the early 1980s and recounted when outside professional harvesters wiped out local populations, 3) historically clear waters allowed subtidal oysters to grow 1-1.5 m below the water's surface, 4) oysters were free food for rural families with limited incomes, and 5) these individuals lament they cannot afford to purchase oysters from out-of-state sellers. Moving forward, we plan to collect more oral history data to improve our maps and use this data to help guide restoration in Brevard County.

S3-10 SADIER, A*; DESSALES, R; SANTANA, S; SEARS, K; UCLA, University of Washington; *asadier@ucla.edu*
Finding new rules for the patterning and shape of mammalian dentition: insights from Noctilionoid bats
Teeth are ones of the most diverse organs in term of morphology. However, most of the extensive developmental work that has been done in mammals is based on mouse which exhibit a very derived dentition. Here, we take the advantage of the ~200 species of noctilionoids bats that encompass nearly all possible mammalian diets. In consequence, noctilionoids have evolved a wide diversity of post-canine dentition morphologies providing a natural experiment with which to investigate the developmental basis of morphological diversification. We will present a new model for the patterning of the mammalian post-canine dentition using this group as a reference. By combining morphometric and quantitative data from 117 adult species, we showed that the number of post-canine teeth is related to the length of the jaw and that premolar and molar proportions are independent, suggesting distinct developmental mechanisms for their formation. To get insight into these underlying mechanisms, we analyzed the development of 12 species across 8 developmental stages by µCT scan and tested markers. We also injected pregnant bats with EdU to link teeth formation to the growth rate of the jaw. Finally, we proposed a new Turing-based model to explain the development of premolars and molars rows. Our data reveal that the premolar and molar rows are established by two independent signaling mechanisms and that teeth number and size is linked to the local growth rate of the jaw. We believe that this work provides a testable framework for other bats and mammals. Then, we present new data on the relationship between molar traits and the underlying gene regulatory networks (GRNs) and pathways, using bat molar as a foundation to test the existence of developmental modules in GRNs that control shape variation. We will present morphological and computational models using machine learning as well as experimental data.

89-1 SAENZ, V*; RICHARDS ZAWACKI, C; University of Pittsburgh; *ves24@pitt.edu*
What role do ephemeral ponds play in the amphibian disease landscape?
As emerging infectious diseases continue to impact wildlife populations, it is critical to characterize the mechanisms that link habitat, host/pathogen biology, and disease dynamics. Batrachochytrium dendrobatidis (Bd), has caused amphibian declines worldwide. Bd's aquatic zoospores cannot survive drying. Thus, the multi-year persistence of Bd in ephemeral pond communities, which dry out completely each summer, is dependent upon infected animals bringing zoospores back to the pond each spring. In contrast, in permanent ponds, which hold water year-round, overwintering larval and adult amphibians can act as reservoir, allowing Bd to persist across years. I predict that hosts that overwinter and breed in permanent ponds but later move to ephemeral ponds will bring new Bd strains and increase disease risk. In this case, Bd dynamics on the landscape would be coupled between permanent and ephemeral pond communities. Alternatively, Bd may be brought to ephemeral ponds by species that emerge infected from terrestrial hibernacula and breed in ephemeral ponds. In this case, the Bd dynamics of permanent and ephemeral ponds will be uncoupled. I captured amphibians entering and leaving two ephemeral ponds from the start of breeding until the pond dries by encircling these ponds with drift fences and pitfall traps. I swabbed the skin of each captured animal and estimated Bd infection load using qPCR. I used a Fluidigm Access Array platform to identify the strain of Bd from Bd-positive swabs. Understanding how Bd spreads to ephemeral ponds and how ephemeral pond communities contribute to the landscape-level dynamics of this host-Bd interaction will be important in developing disease mitigation strategies.

106-1 SAENZ, DE*; WINEMILLER, KO; MARKHAM, MR; Texas A&M University, University of Oklahoma; *dsaenz@tamu.edu*
Derived Loss of Signal Plasticity in a Genus of Weakly Electric Fish
Signal plasticity can maximize the utility of costly animal signals. This is especially true for multi-functional signals such as the electric organ discharges (EODs) of weakly electric fishes. How this plasticity affects the functional and behaviorally relevant properties of animal signals is not fully understood. We compared signal plasticity in four species of *Brachyhypopomus*, a genus of weakly electric fishes (Gymnotiformes, Hypopomidae). Regulated by adrenocorticotropic hormone (ACTH), this type of EOD plasticity allows some species to increase their EOD amplitude in response to circadian cues and social stimuli. ACTH-induced amplitude changes occur via different mechanisms, possibly the rapid trafficking of ion channels to the membranes of the electrocytes (electric organ cells), or by regulating ion channel kinetics. We used *in vivo* injections and *in vitro* electrophysiology to study the effects of ACTH on the behavior of whole fish and individual electrocytes. We also used immunolocalization to map the distribution of ion channels within electrocytes, which contributes to the species-specific EOD waveform. We predicted that the monophasic species, *B. bennetti*, would show increased EOD amplitude plasticity relative to congeners with biphasic EODs. We further predicted that voltage-gated sodium channels would only be present on the innervated posterior membrane as in another monophasic gymnotiform, the Electric Eel. Surprisingly, *B. bennetti* shows significantly less EOD amplitude plasticity compared to closely related biphasic species. Further, we found that sodium channels are present on both electrocyte membranes and that a second action potential drastically reduces the overall head-positive current, likely at great metabolic cost.

P2-221 SAINTSING, AJ*; FULL, RJ; University of California, Berkeley; *andrew_saintsing@berkeley.edu*

Running endurance after leg loss in cockroaches

Cockroaches show remarkable robustness to leg loss, but locomotion is more energetically costly. Previously, we discovered that the loss of one and both middle legs increased the cost of locomotion for cockroaches, *Blaberus discoidalis*. Here, we test the hypothesis that the increased cost relates to a decrease in endurance. We ran cockroaches on a treadmill until they could no longer match the set speed (30-220 m/s) and used the time to exhaustion as a measure of endurance. Simultaneously, we measured steady-state oxygen consumption, stride frequency, and ground contact time. We compared endurance for individuals missing one and two middle legs to intact controls. For all conditions, oxygen consumption increased with speed from 30 to 170 mm/s, but ceased to increase above 170 mm/s, the maximum aerobic speed. There was not a significant change in endurance associated with the loss of one leg. After the loss of two legs, endurance decreased across the range of speeds. At the maximum aerobic speed, endurance decreased by 34% to 10.6 min. Endurance correlated more strongly with stride frequency and ground contact time than with the rate of oxygen consumption. After losing two middle legs, cockroaches took shorter, faster steps to maintain the same speed and fatigued more quickly. Although leg loss altered the relationship between speed and stride frequency and between speed and ground contact time, differences in leg number did not affect the relationship between endurance and these two metrics. The decline in endurance appears to depend on the increased rate of force production.

P3-24 SAIZ, LV*; KELLEHER, ES; University of Houston; *lvsaiz@uh.edu*

Does the Drosophila melanogaster gene bruno impact transposition?

Transposable elements (TE) are obligate genetic parasites that guarantee transmission to offspring by replicating in the nuclei of germline cells. TE replication harms hosts by causing DNA damage and deleterious mutations that prevent the production of viable gametes. In response, hosts can employ two different strategies to minimize these effects: resistance and tolerance. Resistance mechanisms prevent TE replication, while tolerance mechanisms allow host cells to withstand the damaging effects of TE activity. However, cellular mechanisms of tolerance remain largely unknown. P-elements are a type TE whose transposition causes damage to the Drosophila germline. We recently identified the bruno gene as a possible source of natural variation in tolerance of D. melanogaster females to P-element transposition. bruno loss of function alleles are strong suppressors of P-element-induced germline loss, but bruno has no known function in TE regulation. To conclusively evaluate the extent to which bruno regulates P-element transposition, and attempt to confirm its role as a tolerance factor, we are comparing P-element expression and excision rates between bruno mutants and wild-type flies. If P-element transposition is independent of bruno, then expression and excision should not differ between bruno genotypes. Alternatively, if expression and excision are reduced in mutants when compared to wild-type, it will suggest that bruno influences germline loss by positively-regulating P-element activity.

P3-250 SAJDAH-BEY, N*; WYMAN, J; SRINIVAS, A; SALLAN, L; University of Pennsylvania, Philadelphia, PA ; *nyaziab@sas.upenn.edu*

The Hydrodynamic Effects of Pectoral Fins Attached to Back of the Skull in Extinct Cartilaginous Fishes (Iniopterygians)

Most fishes today have paired pectoral fins attached laterally or ventrally to their shoulder girdles, which they use to generate thrust or lift in swimming. Iniopterygians, an order of marine Pennsylvanian cartilaginous fishes primarily from North America, had pectoral fin forms located at the nape and sometimes attached to the skull. This placement is not observed among living fishes, and little is known how such unique paired fin position affects locomotion and hydrodynamics. Previous studies conducted on living fishes (labriforms and salmonids) with laterally attached pectoral fins have demonstrated a relationship between locomotion and fin aspect ratio, a metric combining fin span and area. High aspect ratio fins are long and narrow and associated with greater speed and lift, while low aspect ratio fins are short and stubby and used for maneuvering. We experimentally tested whether the same properties apply to the diverse, dorsally-positioned pectoral fins of Iniopterygians. We hypothesize that both the low and high aspect ratio fins located at the nape are likely to induce greater lift than those located more ventrally, based off Bernoulli's principle, and thus diversity in form likely results from additional functionality. We will use image mapping and 3D modeling software to accurately create computer and 3D printed models of five Iniopterygian taxa. Computational Fluid Dynamics software are used to analyze the forces acting the computer models. To sum the magnitude of lift and drag force acting on the physical model, digital particle image velocimetry will be used, as is standard for similar tests of living fishes. This study represents the first experimental test of fin function in these extinct fishes.

P3-203 SALAZAR-NICHOLLS, MJ*; MACIAS, H; WARKENTIN, KM; Boston University, MA and Smithsonian Tropical Research Institute, Panama, Pontifical Catholic University, Quito, Ecuador; *maciasbazante@gmail.com*

Ontogeny and extent of hatching enzyme accumulation in red-eyed treefrog embryos

The arboreal embryos of red-eyed treefrogs, *Agalychnis callidryas*, can hatch in response to threats to eggs, escaping to the pond below. They hatch in seconds by releasing a hatching enzyme (HE) to digest a small hole in their membrane, then squeezing out. These embryos have two distinct types of hatching gland cells (HGCs) and one HE. From prior scanning electron microscopy, early HGCs appear at 3 d on the snout and dorsal head surface, begin regressing at 4 d and are scarce by 5 d, regardless of hatching. Late HGCs appear at 4 d, become densely concentrated on the snout, and regress only after embryos hatch. Using confocal microscopy and a new, custom antibody to mark *A. callidryas* hatching enzyme (AcHE), we present a more complete description of hatching enzyme expression in *A. callidryas*, and comparisons to other anurans. Abundant AcHe expression is present long before embryos are able to hatch and it increases rapidly over development. HE visualization reveals an astonishing amount of HE accumulation, greater than is known in other species, and HE expression outside the previous reported surface localization of Ac HGCs, such as in the dorsal tail region. Hatching assays indicate that embryos release HE locally from patches of HGC, leaving large amounts unutilized. Unused HE remains in HGCs localized at the skin surface, suggesting retention is related to HGC function rather than localization. Work in progress addresses when and how HGCs become functional. A large, spatially distributed HE reserve may facilitate high-speed hatching and enable embryos to make multiple holes if displaced during the hatching process, or to escape from challenging conditions such as drying egg capsules.

S10-9 SALCEDO, MK*; HOFFMANN, J; DONOUGHE, S; COMBES, SA; MAHADEVAN, L; Virginia Tech, Blacksburg, VA, Harvard University, Cambridge, MA, University of Chicago, Chicago, Illinois, University of California, Davis, CA; *maryksalcedo@gmail.com*

What's in a vein? Using computational tools to explore wing diversity and functional consequences of venation patterns on hemodynamics

Insect wing venation patterns are highly diverse, with some wings partitioned into just a few "domains" (vein-bounded regions) and others into many thousands. To characterize the spectrum of insect wing patterns and compare venation and topologies across insect orders, we created quantitative tools to explore wing geometries. We amassed an unprecedented dataset of scanned insect wings and segmented these wings into features of size, shape, and structure. We analyzed simple morphospaces to compare wings of relatively "dense" and "sparse" venation (e.g. dragonfly versus fruitfly, respectively). Further, to investigate an important function of venation patterning and potential driver in wing diversification, we investigated circulation patterns of hemolymph flow within the wings. Insect wings are dynamic living structures composed of networks of stiff tubular veins, which act as conduits that supply hemolymph to veins containing tracheae and nerves. In addition, sensory hairs and mechanosenosors require a continuous supply of hemolymph. With focus on an insect with complex venation (*Schistocerca americana*, the North American Grasshopper), we quantified hemolymph flow dynamics within adult fore- and hind-wings and determined hemodynamic relationships to accessory pulsatile organs such as wing hearts.This talk will highlight the diversity and multifunctionality of insect wings, and reflect on their development, function, and form, all of which play a role in the phylogenetic and functional diversity of insect wings.

P1-185 SALEM, W*; XU, S; MONGEAU, J-M; The Pennsylvania State University; *was29@psu.edu*

Kinematic control of the yaw optomotor response in Drosophila flight

Flying insects modulate wing kinematics to perform rapid aerial maneuvers. Subtle changes in timing and amplitude of wing motion enable rapid and precise translational and rotational maneuvers. Here, we studied the 3D wing kinematics that mediate the yaw optomotor response in *Drosophila*. Flies were mounted in a magnetic tether enabling free yaw rotation within a virtual reality LED arena. Three high-speed cameras were used to record and extract 3D body and wing kinematics. Flies tracked a visual background rotating at 90 degrees per second by turning and generating occasional optomotor saccades. The angular speed of flies closely matched the background speed, operating at a gain near unity. Analysis of the body heading angle revealed small, 0.5-deg oscillations in yaw at wingbeat frequency (200-220 Hz). These oscillations were due to the aerodynamics of flapping, modulating the overall turning response. Wing kinematics were broadly consistent with those measured in free flight, but with some notable differences, including the use of a clap and fling stroke. During yaw turning, flies generated small changes in the left and right wing stroke and deviation angles that were strongly associated with changes in body velocity within each wingbeat ($p<0.001$). Flies also modulated the timing (phase) of the left and right wing rotation and deviation angles during the forward and backstroke reversal. Interestingly, flies exhibited different stroke planes for each wing. Measured wing kinematics will be used to validate a quasi-steady aerodynamic model of a magnetically tethered fly to investigate compensatory responses to internal perturbations. Our work could provide inspiration for the control and design of agile flapping micro-air vehicles.

P1-87 SAM, A*; MALCANGI, S; LAM, C; LEóN, C; RAMíREZ-ESTRADA, J; BAUER, C; Adelphi University, Garden City, NY, USA , Pontificia Universidad Católica de Chile, Santiago, Chile; *cbauer@adelphi.edu*

Postnatal maternal stress decreases locomotive play behaviors in Octodon degus pups

An activity is considered play if it is not required for an individual's immediate survival and is repeated, spontaneous, voluntary, and rewarding. Play behavior occurs in a variety of organisms including birds, reptiles, and mammals. In this study, we observed whether maternal stress and maternal care were related with adolescent play behavior in the degu (*Octodon degus*), a precocial and diurnal rodent species. By observing pairs of mothers that were either unstressed (habituated to captivity) or stressed (only recently introduced into captivity), the frequencies of both social and locomotive play behaviors in the offspring, along with general behaviors and time of rest, were scored every 2 days from 2–20 days after parturition. All scored play behaviors increased in frequency over time, indicating that degu pups become more active and playful as they mature. Additionally, we also found that pups from unstressed mothers higher frequencies of locomotive play behavior (Running and Frisky Hops) compared to pups from stressed mothers. Furthermore, this behavior was significantly and positively related with the amount of maternal care received. Our results suggest that development of certain play behaviors are affected by maternal stress, likely via alterations in maternal care.

102-6 SANDFOSS, MR*; CLAUNCH, NM; STACY, NI; ROMAGOSA, CM; LILLYWHITE, HB; University of Florida, Gainesville, Florida; *mrsandfo@ufl.edu*

A tale of two islands: stress response and immune function of an insular pit viper following ecological disturbance.

The frequency and intensity of ecological perturbation is expected to increase in the future with animals facing multiple global threats. Our ability to assess the response of free-ranging animals to a stressor is vital to our understanding of how animals cope with ecological disturbance. Seahorse Key is a continental island in the Gulf of Mexico that has historically been the site of a major waterbird rookery. The island also supports a population of Florida cottonmouth snakes (*Agkistrodon conanti*), which has a unique trophic association with nesting waterbirds. In April 2015 the waterbirds completely abandoned the island for nesting purposes and shifted nesting activities and subsequently all food resources to nearby Snake Key. This study takes advantage of this natural ecological "experiment" to evaluate plasma corticosterone, blood glucose, natural antibody agglutination, hemogram, and erythrocyte sedimentation rate to characterize the long-term effects of differential resource availability of two populations in situ. In fall 2018, we collected blood samples at three time points from cottonmouths on Seahorse Key ($n = 6$) and Snake Key ($n = 13$). Our results suggest three years after the shift in waterbird nesting Seahorse Key cottonmouths exhibit lower body condition, a dampened acute stress response, and suspected impaired innate immune functions relative to cottonmouths on Snake Key. Our results highlight the context-dependent nature of physiological biomarkers and suggests that the reduced availability of energy on Seahorse Key has resulted in an inability to maintain adequate stress responses and innate immune functions.

101-7 SANDMEIER, FC*; LEONARD, KL; WEITZMAN, CL; TRACY, CR; BAYER, B; BAUSCHLICHER, S; Colorado State University-Pueblo, Virginia Polytechnic Institute and State University, University of Nevada, Reno; *fcsandmeier@gmail.com*

Indirect, facultative interaction between a commensal microbe and an opportunistic pathogen in the tortoise respiratory tract

Within the medical literature, there is a growing awareness of the complex interactions – even among commensal species – that may cause polymicrobial diseases and increase virulence of opportunistic pathogens. Despite evidence that *Mycoplasma agassizii* causes a respiratory disease in tortoises, other, unknown factors influence the severity and recrudescence of disease. We used a quantitative PCR to compare loads of a commensal, common microbe (*Pasteurella testudinis*) and the opportunistic pathogen (*M. agassizii*) in nasal lavage samples obtained from 389 Mojave desert tortoises (*Gopherus agassizii*). We show that animals with *P. testudinis* have higher loads of *M. agassizii*, which is associated with a higher risk of disease. However, the prevalences of the microbes were not associated with each other, and the presence of both microbes did not predict a higher probability of disease. We used a captive, *M. agassizii*-naïve colony of healthy tortoises to verify that *P. testudinis* alone does not cause disease and is a prevalent member of both the nasal and cloacal microbiomes. We are exploring techniques to understand this possible indirect, facultative interaction between the two microbes, including the possibility of cross-feeding. Cross-feeding occurs when one microbe makes nutrients available to another species of microbe, influencing its persistence or growth rates inside the host. Such mechanisms can include enzymes such as sialidase, which can cleave glycoprotein components of the mucous and provide additional nutrients for microbial growth.

132-3 SANTHANAKRISHNAN, A*; FORD, MP; Oklahoma State University; *askrish@okstate.edu*

(Un)synchronized rowing: importance of phase lag in metachronal swimming performance

Metachronal swimming is a common method of drag-based aquatic locomotion in which a series of swimming appendages are stroked in an oscillatory pattern, such that the movement of each appendage is delayed in time relative to the neighboring appendage. It is often used by crustaceans and other ecologically important marine invertebrates. We developed a dynamically scaled self-propelled robotic model for a comparative study of metachronal swimming performance under varying inter-appendage phase lag. Appendage motion profiles were obtained from published hovering and fast-forward swimming kinematics of *Euphasia superba* (Murphy et al., Mar. Biol., 158, 2011), but the phase lag between adjacent appendage pairs was varied. Time-resolved particle image velocimetry measurements show that interaction between shear layers of adjacent paddling appendages results in the formation of a continuous wake jet directed in the caudoventral direction. Swimming performance was characterized by the maximum swimming speed of the self-propelling model, as well as the forward force generated by the model when tethered. Results show that phase lags of 15% and 25% of cycle time, close to the phase lags reported for *E. superba*, result in the best forward swimming performance when compared to phase lags of 0, 35, and 50%.

S7-7 SANTOS, SR*; HOFFMAN, SK; SEITZ, KW; HAVIRD, JC; WEESE, DA; Auburn University, Alabama, Green River College, Washington, University of Texas at Austin, Texas, University of Texas at Austin, Texas, Georgia College and State University, Georgia; *santos@auburn.edu*

Phenotypic Comparability Arising from Genotypic Variability amongst Physically Structured Microbial Consortia

Microbiomes, representing the collective microbial community living in or on an individual, are recognized as having significant impacts on the development, health, and disease status of multicellular hosts. Given that the mechanistic basis between an individual's genome and phenome requires consideration at different levels of biological organization, this should include interactions with, and the organization of, microbial consortia. As another model in understanding consortia organization, we elucidated the genetic constituents amongst phenotypically similar (and hypothesized functionally-analogues) layers in the unique laminated orange cyanobacterial-bacterial crusts endemic to Hawaii's anchialine ecosystem. High-throughput amplicon sequencing of ribosomal RNA hypervariable regions revealed microbial richness increasing by crust layer depth, with a given layer more similar to different layers from the same geographic site than to their phenotypically analogous one from different sites. Furthermore, samples from sites on the same island were more similar to each other, regardless of which layer they originated from, than to analogous layers from another island. Notably, cyanobacteria and algae were abundant in all surface and bottom layers, with anaerobic and chemoautotrophic taxa concentrated in the middle two layers, suggesting oxygenation from both above and below. Thus, arrangement of oxygenated vs. anoxygenated niches in these orange crusts are functionally distinct relative to other examined laminated cyanobacterial-bacterial communities, with convergent evolution due to similar environmental conditions a likely driver for these phenotypically comparable but genetically distinct microbial consortia.

79-7 SASSON, D*; JOHNSON, T; SCOTT, E; FOWLER-FINN, K; Saint Louis University; *sassonda@slu.edu*

Water deprivation affects mating behaviors and outcomes in the harvestman, Leiobunum vittatum

Individual variation in resource acquisition prior to mating can influence mating dynamics. Water is one resource that may impact reproduction, but little is known how variation in individual hydration status affects mating behaviors. Here, we investigate the effects of short-term water deprivation on mating behavior in the harvestman, *Leiobunum vittatum. Leiobunine harvestmen follow stereotyped stages of mating, with the potential for female resistance to end the interaction at each stage: males first embrace (clasp) females, then copulate, and some males guard females after mating. We ran single choice mating trials between males and females that were either deprived or not deprived of water for four hours prior to interacting to determine how water deprivation affects mating dynamics across each stage. Our results indicate that water deprivation impacts multiple stages of mating, with the stage of reproduction affected depending on whether the male or the female was water-deprived. These results suggest that short periods of water deprivation can alter mating behaviors and may be an important, but understudied, factor in sexual selection research.*

P3-162 SATHE, EA*; DUDLEY, R; University of California, Berkeley; *eksathe@berkeley.edu*

Forelimb Kinematic Variation Alters Body Velocity in Flat-tailed House Geckos (Hemidactylus platyurus) During Directed Aerial Descent

Aerial locomotion has evolved repeatedly and has allowed organisms to occupy habitats and exploit resources that would otherwise be unavailable. Controlled aerial behavior has evolved frequently in arboreal taxa via the mechanism of directed aerial descent, likely because all such organisms frequently experience falls. Many of these organisms lack dedicated airfoils yet exhibit considerable control over their velocity and trajectory while airborne. The flat-tailed house gecko (*Hemidactylus platyurus*) has been observed falling with limbs outstretched, and has shown to engage in aerial control through use of their tails to influence pitch, roll, and yaw. However, any active role of their limbs has not yet been documented. During free fall, these geckos perform reciprocating limb motions whereby the forelimbs synchronously move cranioventrally and caudodorsally. This study characterized the kinematics of such limb motions and their effects on aerial performance. We simulated directed aerial descent in six falling *H. platyurus* individuals through use of a vertically oriented wind tunnel, filmed ten aerial trials for each individual at 400 frames per second, and selected the five exemplary trials for analysis. We used MATLAB software to digitize and reconstruct the lizards' movements in three dimensions, as well as to estimate their velocities by using the first derivative of a quintic spline smoothing algorithm. Initial data suggest a strong correlation between forelimb motions and translational body velocity, suggesting a selective advantage to incipient limb flapping in aerial squamates.

P2-189 SATTERLIE, RA*; HERMANS, CO; NOREKIAN, TN; University of North Carolina Wilmington, Sonoma State University, Whitney Laboratory for Marine Bioscience; *satterlier@uncw.edu*

Ultrastructure of Adhesive Papillae on the Buccal Cones of the Pteropod Mollusc Clione limacina: Evidence for a Duo-Gland Adhesive System

Clione feed on actively-swimming shelled pteropods of the genus *Limacina*. *Clione* rapidly protract six buccal cones that surround and grip the prey. The surface of the buccal cones contains a dense coat of adhesive papillae, each made up of a rosette of upright spires. A single cell (Type 1 cell) forms the tip of each spire and contains a cluster of large secretory granules. A central process of the secretory cell extends medially through the muscular layers of the buccal cone and into the central hemocoelic space. A second type of secretory cell (Type 2 cell) is positioned next to the Type 1 cell in the spires and contains elongated, electron dense structures which are released near the tip of each spire as a flocculent material. Central processes of Type 2 cells extend into the center of the buccal cone in parallel with the Type 1 cells. One specimen of *Clione* was fixed while it gripped a *Limacina*. Following fixation, the prey shell was pulled from the buccal cones and both the shell of the prey and the points of contact on the buccal cones were examined. In the contact area, the tips of the spires were missing the packet of secretory granules and "packet ghosts" were found on the surface of the buccal cones. Similar packet ghosts were found on the *Limacina* shell in the region of contact with the buccal cones. Once a *Clione* captures a *Limacina*, the prey is manipulated by the buccal cones so the opening of the shell is over the predator's mouth. This manipulation requires coordinated gripping and release of the prey. The two types of secretory cells in the spires of adhesive papillae may represent a duo-gland system that allows adhesion and de-adhesion of the buccal cones during prey manipulation.

79-5 SAYAVONG, N*; ESTRADA, M; SALAS, H; GUNDERSON, AR; STILLMAN, JH; TSUKIMURA, B; California State University, Fresno, Tulane University, San Francicso State University; *sayavongnathan@gmail.com*

Effects of preferred temperature, interspecific interactions, and increased population density on vitellogenesis on intertidal crabs Petrolisthes cinctipes and Petrolisthes manimaculus

Increased temperatures from global warming can lead to lethal temperatures for the intertidal crabs *Petrolisthes cinctipes* and *P. manimaculus* (Decapoda: Anomura). Physiological stress from increased temperature may force *P. cinctipes* redistribution into cooler environments (Stillman and Somero 1996). However, these crabs have a preferred temperature (15.0±0.4 °C) that is higher than their ambient temperature, 12 °C (Gunderson et al. 2019). To investigate the effects the preferred temperature on vitellogenesis, *P. cinctipes* and *P. manimaculus* were collected from November 2018 through July 2019 and exposed to their preferred temperature and placed at high and low densities with conspecifics and congeners. Hemolymph samples were taken from each crab before and after seven-day density and temperature treatments. To quantify the effects of treatments, an ELISA was used to quantify vitellogenin levels in hemolymph before and after treatment (Delmanowski et al. 2017). During winter months, *P. cinctipes* showed decreased vitellogenesis when exposed to thermal stress (20 °C) (Salas 2017). Exposing *P. manimaculus* to preferred temperatures increased vitellogenesis. These data support that the preferred temperature of *P. cinctipes* and *P. manimaculus* is 15.0±0.4 °C (Gunderson et al. 2019). Research reported in this abstract is supported by NSF grant #1451423 to BT and JS.

P2-32 SCANLAN, LG*; HERNANDEZ, AI; SCHMITZ, L; Claremont McKenna College, Claremont, CA, Claremont McKenna, Scripps, and Pitzer Colleges, Claremont, CA; *lscanlan20@students.claremontmckenna.edu*

Eye Size Evolution in Mudskippers and Related Gobiid Fishes

As early tetrapods transitioned from life in water to life on land more than 300 million years ago, the eye underwent a remarkable evolutionary transformation. This major event in the history of vertebrates facilitated the transition to the complex optical system used by most terrestrial tetrapods today. Previous research identified that the shift to vision through air was marked by a three-fold increase in absolute eye size. This dramatic increase in eye size remained significant even after the scaling effects were accounted for. It is unknown, however, if this pattern is a general evolutionary response tied to transitions from water to air. We therefore sampled another such event, focusing on a more recent transition from life in water to partial life on land: the evolution of mudskippers. Mudskippers are a potentially paraphyletic assemblage of amphibious fish phylogenetically nested within the Gobiidae. We measured the horizontal eye diameter of preserved specimens for a total of 54 gobiid species, and accounted for body size by measuring standard length, body depth, and body weight. When plotting the species averages of eye size against body size variables, we observed that the eyes of mudskippers tended to be larger than the eyes of their close relatives. Even though the phylogenetic relationships of mudskippers and their closest relatives are currently poorly understood, it appears unlikely that our findings are biased by phylogenetic covariance. While not as dramatic as seen in early tetrapods, mudskippers tend to have relatively large eyes, suggesting that the increase of eye size may be a general evolutionary response tied to transitions from water to air.

67-7 SCEPANOVIC, J*; KOLCHENKO, S; PLESSIER, F; LOWE, C; SPITZ, F; MARLOW, H; University of Chicago and Pasteur Institute, Paris and École normale supérieure, Paris, University of Chicago and Pasteur Institute, Paris and Sorbonne Université, Paris, Stanford University, University of Chicago and Pasteur Institute, Paris; *scepanovic@uchicago.edu*

Modularity in Gene Regulation: Evolution of Combinatorial Cis-Regulatory Inputs

The 3D structure of chromatin is tightly linked to gene expression regulation. It is yet unclear how folding mechanisms may ensure robust and specific gene expression in non-vertebrate lineages. We aim to understand how the 3D folding of the genome impacts the cell-type specific transcriptional program via the interaction of cis-regulatory elements (CREs) with gene promoters. In order to do this, we have examined 3D chromatin structure, regulatory interactions and gene expression in an early-branching deuterostome *Saccoglossus kowalevskii* and the sea anemone *Nematostella vectensis*. We first identified CREs using ATAC-Seq and motif scanning computational methods and promoters via 5' transcript mapping (Tn5Prime). We investigated regulatory interactions involving transcription factor (TF) promoters by performing Capture Hi-C. We computationally identified *Saccoglossus* TFs and characterized their binding specificity. We find that the use of alternative promoters is present in both *Saccoglossus* and *Nematostella*, possibly contributing to cell identity; TF promoters interact with multiple CREs in both species; and regulatory interactions spread through longer distances in *Saccoglossus* than in *Nematostella*. Our data has made progress in understanding the relationship between invertebrate 3D genome structure and regulatory interactions. Ultimately, we aim to combine our understanding of 3D gene regulation via CREs with developmental data on the role of TFs to generate a more complete picture of context-specific gene regulation in invertebrates.

P2-49 SCHACHNER, ER*; DIAZ, RE; HEDRICK, BP; Louisiana State University Health Sciences Center, California State University, Los Angeles; *eschac@lsuhsc.edu*

Anatomy of the crocodylian bronchial tree and implications for the ancestral archosaurian lung

To understand the origin and evolution of the morphologically and functionally divergent avian and crocodylian respiratory systems, it is necessary to map out the bronchial architecture across the phylogenetic trees of these clades. The aim of this study is to describe the anatomy of the respiratory system of Cuvier's dwarf caiman (*Paleosuchus palpebrosus*) based upon micro-computed tomography (uCT) data of the respiratory system in situ (n=4), and compare these data to other closely related archosaurian taxa. The lungs of four *P. palpebrosus* specimens were inflated artificially via a syringe, and imaged at total lung capacity. The following measures of the bronchial tree were acquired in the DICOM viewer OsiriX MD for intra- and interspecific comparisons: (1) the distance from the carina to the first three large secondary bronchi; (2) the area of the primary bronchus at the first three large secondary bronchi; and, (3) the area of the ostium of each of the first three large secondary bronchi where each one branches from the intrapulmonary primary bronchus. These data were then compared to the same quantitative measures acquired from the same homologous structures in *Alligator mississippiensis* (n=10), *Crocodylus niloticus* (n=3), *Melanosuchus niger* (n=1), and *Caiman crocodylus* (n=2), allowing for interspecific comparisons across Crocodylia. The basic anatomy of *P. palpebrosus* most closely resembles that of *A. mississippiensis*, with fewer large secondary airways and fewer small secondary saccular bronchi in the caudoventral regions of the lung than other crocodylians. These data also permit preliminary comparisons between the bronchial trees of birds and crocodylians so that hypotheses of homology, and initial reconstructions of the ancestral archosaurian bronchial tree may be made.

S7-9 SCHAEFER, RJ*; BAXTER, I; MCCUE, ME; University of Minnesota, St Paul, MN, Donald Danforth Plant Science Center, St Louis, MO; *rob@linkage.io*

Using Camoco to integrate genome-wide association studies with context specific co-expression networks in corn and horses

High throughput technologies are currently a major driver for genetic improvement in many domestic and ecological plant and animal species. In the past decade, genome wide studies (GWAS) have associated changes in DNA to variation in phenotypes of interest. Hundreds of links between genetic markers (SNPs) and important traits have been identified by GWAS. Yet, the causal gene/allele often remains unknown due to many genes being in linkage disequilibrium (LD) with each of potentially dozens of genetic markers. Co-expression networks identify genes that share similar response patterns of gene expression, making them a powerful tool for inferring the biological function of under-characterized genes. In the right biological context, sets of causal genes related to a GWAS trait will exhibit strong co-expression while inconsequential genes in LD with the marker exhibit random patterns of co-expression. Here, we showcase the functionality of Camoco, a computational framework developed to integrate GWA studies with gene co-expression networks. Camoco was used to build gene co-expression networks in many species, however this talk will focus on demonstrative use-cases in maize and the domestic horse. Using Camoco, we built gene co-expression networks in several different biological contexts. Networks were benchmarked for biological signal using curated ontologies (e.g. GO) as well as unsupervised network clustering. Once vetted, networks are used to interpret and prioritize GWAS data using an integrative "overlap” algorithm. Genes are prioritized based on the strength of co-expression among other GWAS tagged genes. Camoco is open source software and available at github.com/LinkageIO.

S8-10 SCHIEBEL, PE*; LIN, B; HUBBARD, AM; CHEN, L; BLEKHERMAN, G; GOLDMAN, DI; Georgia Institute of Technology; *perrin.schiebel@gatech.edu*

Specialization of control strategies in terrestrial slithering snakes.

While traditionally viewed as obstacles to in locomotion, limbless locomotors must use heterogeneities for propulsion. We challenged snakes to traverse a model heterogeneous terrestrial terrain---rigid arrays of posts on a whiteboard substrate. We studied two species adapted to different habitats, the desert specialist shovel-nosed snake *C. occipitalis*, which we previously found used open-loop control supplemented by passive mechanics to negotiate the sparse obstacles in its sand-dominated environment [Schiebel et al. PNAS 2019], and the generalist corn snake *P. guttatus* whose natural range includes a variety of terrains. Principal component analysis (PCA) revealed the specialist's stereotyped sand-swimming wave was omnipresent during motion through the arrays, while results for the generalist were inconclusive, suggesting either the snakes did not have a preferred waveform or two dimensions were not adequate to describe the kinematics. We applied persistent homology, a mathematical technique to search for periodic data without reducing dimension, and found the specialist had long cycles consistent with PCA. The generalist, however, had fewer and shorter cycles, indicating the kinematics were aperiodic. We hypothesized that the generalists were instead targeting a desired pattern of reaction forces and tested this using a simplified terrain, a single force-sensitive post on the whiteboard. Generalists maintained contact with the post for longer durations and had less variation in the direction of the resulting force vector than the desert snake. Our study suggests control specialization; the specialist targets beneficial sand swimming kinematics while the generalist controls for advantageous force generation in accord with early studies of generalist snakes in lattices [e.g. Gray 1955].

P3-68 SCHNEIDER, NG*; MCKAMY, AJ; DIAMOND, KM; BLOB, RW; Clemson Univ.; *kmdiamo@g.clemson.edu*

Do predators take advantage of prey blind spots? In-stream analysis of predator-prey interactions in Hawaiian stream fishes.

The outcome of interactions between predators and prey can depend critically on the environmental context in which they take place. Certain aspects of habitats may give predators an advantage by inhibiting the ability of prey to detect or evade predation attempts. In fishes, one of these habitat features could be water flow. Our previous lab studies of juvenile Hawaiian stream gobies found that prey fish respond less frequently to simulated attacks occurring in the same direction as the dominant flow of water. We sought to test whether predators take advantage of this ‘blind spot' during actual attacks in the field. We used an array of GoPro cameras to film instream attacks on juvenile gobies by *Eleotris sandwichensis*, ambush hunters that sit on the bottom of the steam and attack juvenile gobies as they migrate upstream from the ocean. From these videos, we calculated three measurements. First, we measured the angle between the attacking predator relative to the prey's upstream orientation, the pre-strike angle. Second, we measured the predator orientation relative to the stream bottom, the perch orientation. Third, we measured the success rates of predator's strikes. Our results indicate that *E. sandwichensis*, are successful in approximately one-third of their attacks. There was no preferential association of attacks with a particular direction, suggesting that predators are not targeting their attacks with the ‘blind spot' of their prey. However, when predators do strike from the same direction as stream flow, they are more likely to successfully capture prey. Our study of these interspecific interactions in the natural environment where they occur provided an outstanding opportunity to test lab-based hypotheses under ecologically relevant conditions.

P1-27 SCHNEIDER, SQ*; BASTIN, BR; HO, S; Academia Sinica, Taipei, Taiwan, Iowa State University, Ames, IA; *sqschneider@gate.sinica.edu.tw*

Unique Tektin Gene Complements Support the Position of Xenacoelomorpha at the Base of Bilaterians, and the Inclusion of Chaetognaths within a Spiralian Clade

Currently, the phylogenetic positions of Xenacoelomorpha as a sister group to Nephrozoa (deuterstomes, ecdysozoans, and spiralians), and of many phyla within the spiralian clade including chaetognaths are being scrutinized. Our previous study suggested that the tektin gene complements could add to this debate. Tektins are a family of ciliary coiled-coil proteins. Phylogenetic inferences of tektin evolution suggested a series of ancient duplications that generated one, two, four, and five tektin genes in the common ancestor of holozoan (choanoflagellates + metazoans), metazoan, nephrozoan, and spiralian, respectively. Many extant deuterostomes like echinoderms and cephalochordates, and some ecdysozoans like priapulids retained four genes, tektin-2, -1, -4, and -3/5. Several spiralian species including some annelids, molluscs, and brachiopods retain an ancestral spiralian tektin gene complement of five tektin genes including two distinct tektin-3/5A and 3/5B genes from an ancient duplication of the nephrozoan tektin-3/5 gene at the base of the spiralian clade. Do xenacoelomorphs and chaetognaths have a metazoan, nephrozoan, or spiralian tektin gene complement? To answer this question, we surveyed RNA-seq data of dozens of invertebrate taxa including 12 xenacoelomorph and 10 chaetognath species. All xenacoelomorph species share a unique bilaterian tektin complement of three tektin genes (-2, -1, and 4/3/5) with no indication for distinct nephrozoan signature tektin-4 and tektin-3/5 genes, lending support to their position as sister group to nephrozoans. The tektin gene complements in chaetognaths contain the unique spiralian tektin genes 3/5A and 3/5B, thus supporting their inclusion within a spiralian clade.

140-4 SCHNITZLER, CE; NGUYEN, AD; KOREN, S; BARREIRA, SN; GONZALEZ, P; CHANG, ES; PHILLIPPY, A; MULLIKIN, JC; CARTWRIGHT, P; NICOTRA, ML; FRANK, U; BAXEVANIS, AD*; U. Florida, NHGRI/NIH, U. Kansas, U. Pittsburgh, NUI-Galway; *andy@mail.nih.gov*

The Genomics of Hydractinia: Understanding Regeneration, Allorecognition, and Stem Cell Biology

The cnidarians – organisms unified in a single phylum based on their use of cnidocytes to capture prey and defense from predators – occupy a key phylogenetic position as the sister group to the bilaterians. Given their experimental tractability and great potential for studying regeneration and allorecognition, we have sequenced and annotated the genomes of two cnidarian species: *Hydractinia echinata* and *Hydractinia symbiolongicarpus*. The remarkable regenerative capacity of these species is conferred by migratory interstitial cells (or i-cells) that are pluripotent, expressing genes whose bilaterian homologs are known to be involved in stem cell biology. Using PacBio, Illumina, and Dovetail-based strategies, high-coverage sequencing data indicate a genome size of 774 Mb for *H. echinata* (84x coverage) and 514 Mb for *H. symbiolongicarpus* (94x); these genomes are AT-rich (65%) and highly repetitive (>46%). The vast majority of evolutionarily conserved single-copy orthologs have been identified in these assemblies, and analyses of these whole-genome sequencing data have already provided important insights into the evolution of chromatin compaction and sex determination. These data have also revealed a heretofore-underappreciated complexity of the mechanisms controlling allorecognition in these colonial organisms with the discovery of a new set of candidate allorecognition genes. Our genome-scale data have established a strong foundation for identifying evolutionary novelties contained within these genomes and for functional studies aimed at identifying new targets for therapies in regenerative medicine.

47-6 SCHREY, A*; MILLER, K; LOGGINS, F; WIECZOREK, P; MCCOY, E; MUSHINSKY, H; Georgia Southern University Armstrong Campus, Dartmouth College, University of South Florida , University of South Florida; *aschrey@georgiasouthern.edu*

Epigenetic and Genetic Characteristics of Dispersal of the Florida Sand Skink

Home range and dispersal are fundamental ecological characteristics of a species and molecular markers can provide insights into the consequences of these characteristics. Knowledge of these factors is critical for fine-scale habitat management in a conservation framework. Here, we report an epigenetic and genetic investigation of the Florida Sand Skink to determine its fine-scale dispersal. This small, fossorial lizard is listed as threatened and a species of greatest conservation need. They are precinctive to the highly imperiled Florida scrub habitat, which is fire dependent, highly heterogenous, and now exists as a series of fragmented habitat patches. We use multiple microsatellite loci to screen genetic characteristics and epiRADseq to measure DNA methylation. We address the molecular rationale of why individuals disperse, answer the basic question of how far they disperse, and estimate their home range size. We characterize the spatial patterns of genetic relatedness among individuals, how relatedness affects dispersal, and how the genetic and epigenetic characteristics of individuals change with distance. Specifically, we will determine if more closely related individuals disperse further, or more generally, if there is a predictable molecular signature of dispersal. Finally, we integrate these data with previously collected data from multiple scrubs across the range of the Florida Sand Skink to investigate the driving factors of epigenetic and genetic characteristics among scrubs.

90-3 SCHUECH, R*; TOR NIELSEN, L; HUMPHRIES, S; SMITH, D; KIØRBOE, T; University of Lincoln, Technical University of Denmark, University of Birmingham; *rudi.schuech@gmail.com*
Hydrodynamics Shed Light on Dinoflagellate Evolution
Flagella are crucial to the interactions of many unicellular organisms with their surrounding aquatic environment. The dinoflagellates have a unique but remarkably conserved flagellation morphology: a trailing longitudinal flagellum and an exquisitely complex transverse flagellum that encircles the cell. What are the selective advantages offered by this arrangement? We investigate the dinoflagellate design *in silico* using a high-performance regularized Stokeslet boundary element method and combine these simulations with particle image velocimetry (PIV) observations of dinoflagellate-generated flow fields and swimming kinematics. We find that the helical transverse flagellum provides most forward thrust and, despite its near-cell position, is more hydrodynamically efficient than the trailing flagellum; however, the latter is nonetheless required to enable steering. Flagellar hairs and the sheet-like structure of the transverse flagellum allow dinoflagellates to exert strong propulsive forces and maintain high clearance rates without extending a long conventional flagellum far into the surroundings. This unique morphology has thus been essential to the evolution of the generally large, fast-swimming dinoflagellates.

P2-213.5 SCHULZ, AK*; RINCON, C; HU, DL; Georgia Institute of Technology School of Mechanical Engineering, Georgia Institute of Technology School of Mechanical Engineering and Biology; *akschulz@gatech.edu*
Elephant Trunks Behave like Telescoping Poles
Elephants are the construction cranes of the animal kingdom with the ability to move them to lift heavy objects and reach to branches of trees for food. In this experimental study, we investigate the limits and techniques elephants use to grasp objects outside their reach. We show how elephants extend their trunks like that of a telescoping pole, by first elongating the tip of their trunk and proceeding by elongating the base of the trunk 200 milliseconds later. We show the different phases an elephant exhibits when reaching hanging, lifting, and reaching and describe the transitions between these phases. Examining the strains imposed along the trunk we find if the trunk maintains constant volume during elongation as it can elongate to 125% of its hanging length. Finally, we have examined the trunk skin to determine if wrinkles play a mechanical role in reducing strain and damage to skin. These findings may inspire work to develop soft robotics that exhibit high strength and flexibility.

9-3 SCHULZ, AK*; AYALA, J; ZHAO, W; RONG, H; HU, DL; Georgia Institute of Technology School of Mechanical Engineering, Chengdu Panda Base for Giant Panda Breeding - Husbandry and Reproduction, Georgia Institute of Technology School of Mechanical Engineering and Biology; *akschulz@gatech.edu*
Panda Cub Climbing for Conservation
A juvenile panda's best defense against predators is its ability scamper up a tree. Although climbing has been studied in black bears and the red squirrel, it has yet to be systematically in pandas. We designed and built a table-like structure with legs of diameters comparable to the trees found in their natural environment and tested 8 panda cubs ranging from 14-16 months old at the Chengdu Research Base for Giant Panda Breeding in the Sichuan province in China. Pandas climb up to speeds of speeds 0.1 to 0.3 m/s, and in a helical fashion, angling their body up 40 degrees from the vertical, and performing one cycle per meter. The 8 pandas exhibit a range of predilections for climbing, with 4 pandas have a much higher climbing success rate of 40% and above . We use these metrics to grade the panda cubs, which will provide useful input in deciding which pandas will have the greatest chance of survival when reintroduced into the wild.

22-5 SCHUMM, MR*; CUMMINGS, ME; RAMSEY, ME; UT; *mschumm13@gmail.com*
Testing cognitive flexibility in non-model organisms: Poeciliid fishes vary by species, sex and context in detour performance
Cognitive performance varies between species, and differences in life history characteristics may explain much of that variation. We compare variation in cognitive flexibility and problem solving in two live-bearing poeciliid fish species with different mating systems and invasive tendencies using the detour paradigm, in which individuals must innovate to circumnavigate a transparent barrier to reach a target. *Gambusia affinis* are highly invasive fish with exclusively coercive males, whereas *Limia perugiae* are noninvasive with polymorphic male mating phenotypes. We tested fish in a transparent-barrier detour maze with a female conspecific or predator lure target and in an opaque-barrier control. Performance in the maze was analyzed across species, sexes, and detour contexts for likelihood to solve and time measures for motivation and solving speed. We found no species difference in likelihood to solve or solving speed; however, *G. affinis* fish reached the barrier faster than *L. perugiae*, and both species reached the barrier fastest with a predator target. While neither species demonstrated sex differences in solving speed, *G. affinis* males were significantly more likely than females to solve both transparent detour contexts. Motivation to reach the barrier did not predict solving speed; yet we found a context and sex-dependent correlation between baseline anxiety/exploration in *G. affinis* males but not females. Specifically, high anxiety correlated with slow solving speed in the opaque context but correlated with fast solving speed in the predator context. These data indicate species and sex-dependent variation in detour performance may be driven by distinct life history characteristics (mating systems and invasiveness) and modified by sex-biased patterns in dispersal and noncognitive behavior.

25-4 SCHWAB, RK*; JANKAUSKI, MA; Montana State University; *rschwab03@gmail.com*
Efficient Modeling of Fluid-Structure Interaction in Single Degree-of-Freedom Flapping Wings
Flapping insect wings deform under both inertial and aerodynamic forces. This fluid-structure interaction (FSI) is beneficial to aerodynamic performance and energetic efficiency. However, many flapping wing FSI models rely on direct numerical methods and require considerable computational resources to solve. Here, we present a simple, analytic FSI model for a wing subjected to single degree-of-freedom flapping that can be solved with minimal computational effort. The structural model is developed via the Lagrangian formulation and fluid loading is accounted for through a blade element approach that considers lift, drag and added mass forces. We validate this model experimentally by flapping a paper wing both in air and in vacuum using a custom rotation stage and recording strain at the base of the wing. Agreement between experimental measurements and model predictions is good. In vacuum, the wing experiences a superharmonic resonance when flapping at 1/3 its natural frequency due to periodic softening of this wing – this superharmonic response is attenuated in air due to fluid damping. We then use our model to study the influence of added mass when wing surface density is similar to that of a *Manduca sexta* wing. We show that, in addition to shifting the wing's natural frequency, added mass increases fluid loading on the wing by approximately 15%. The increased loading cannot be accounted for by adjusting the wing's natural frequency in simulation alone and must be treated as an independent forcing function. This work is an important first step towards developing FSI models that account for more realistic multiple degree-of-freedom flapping kinematics and complex wing geometries.

105-6 SCHWAHA, T; University of Vienna, Department of Integrative Zoology; *thomas.schwaha@univie.ac.at*
O anus where art thou? An investigation of ctenostome bryozoans
Defecation is a common process of removing undigestible food resources that can be quite copious in suspension feeders. In bryozoans the anus is situated outside of the food processing tentacle crown or lophophore. Bryozoans have a characteristic defensive behaviour that involves the retraction of their soft-body parts (the polypide) into their protective body wall (cystid). As colonial organisms, defecation represents an important task that requires and involves coordination to remove faecal pellets from the colony. This is particularly evident in species with closely spaced zooids. Among cheilostome bryozoans several different defaecation strategies have been recognized, whereas other bryozoans remain little investigated. Especially within ctenostome bryozoans, a small group of non-calcified bryozoans, the position of shows high variability concerning the location on the tentacle sheath. Some species have the anus situated very close to the mouth opening, which implies high interaction with feeding currents, whereas other have the anus located quite distant from the mouth opening. In any case, faecal pellets need to be removed from the colony. In this presentation I analyse the distribution of anal positions among ctenostomes and assess whether this position evolved independently and its consequences for colonial feeding currents.

P1-236 SCHWALB, A*; LEPKOWSKI, J; RENNINGER, A; DAVIDSON, B; W.B. Saul High School, University of Pennsylvania, Swarthmore College, Swarthmore College; *aschwalb@gmail.com*
Relevance and Complexity: Teaching Cancer Biology to Middle School Students
Connecting science learning to students' everyday experiences increases interest and motivation in students with low success expectations (e.g., Hulleman & Harackiewicz 2009, Harackiewicz et al., 2015). To achieve this goal, we have developed a curriculum for middle-school age youth that uses authentic and cutting-edge cancer biology content. This NSF-supported effort involved an intensive multi-year collaboration between a research professor and inner-city teachers. The resulting 5-week curricular module is designed for middle school age students and centers on the role of cell signaling in cancer biology. We will describe the sequence of topics covered and the instructional practices used to support economically-disadvantaged, middle-school age youth to seriously engage with research findings from studies of cell signaling. We have now implemented teaching of this complex and controversial topic two times, with youth who were 12-13 years, and another group that was 13-15 years. Our program consists of 16 one hour sessions over 5 weeks of an out-of-school inquiry science workshop.We start by building community and providing routines that enable reflection, participation, and questioning. We do not begin by introducing cancer biology. Rather, we wait until students have developed shared vocabulary and knowledge about fundamental cell concepts and cell communication. Data on changes in participants' motivation and learning compared to a control group also will be presented.

131-3 SCHWANER, MJ*; FREYMILLER, GA; CLARK, RW; MCGOWAN, CP; University of Idaho, Moscow, ID, San Diego State University, San Diego, CA; *schw1900@vandals.uidaho.edu*
A heightened vigilance state alters mechanics of jump backs in kangaroo rats (D. deserti)
Predation pressures shape most animals' morphology and behavior. In the presence of a predator, animals have been shown to increase vigilance. Kangaroo rats, a bipedal hopping desert rodent, are known to exhibit a series of stereotyped anti-snake behaviors, such as head bobbing, foot drumming, and jump backs. During jump backs, animals make sudden jumps backwards without changing body or head orientation. These behaviors occur in response to predators, but also to novel objects. According to literature, in a vigilant state, kangaroo rats increase their performances; however, the difference in mechanics of these behaviors is less well studied. We hypothesized that kangaroo rats would respond faster, jump higher during jump backs, and perform more jump backs when experiencing a heightened vigilance state due to exposure to a predator. To test this, we collected data in the Mojave Desert (CA) using high-speed video examining jump height, take-off time, and number of jump backs by kangaroo rats that were in a heightened vigilance state after exposure to sidewinder rattlesnakes and individuals that did not see a snake before their encounter with a novel object. Comparing performance in both behavioral states showed that kangaroo rats in a state of higher vigilance performed more jump backs (4 - 9) in series and jump higher (0.10 – 0.26 m) compared to animals in less vigilant behavioral state (1 - 2 jumps in series, 0.06 – 0.18 m). That behavioral state can alter performance, suggests that laboratory studies might underestimate an animals' predator escape ability in the wild.

P1-126 SCHWARTZ, ML; University of Washington; *megansc@uw.edu*

Nemertean Diversity in the Southern Ocean

Ribbon worms (phylum Nemertea) are regularly collected during benthic faunal surveys of the Southern Ocean and are an important component of their community. However, despite their abundance, Antarctic nemertean ecology, distribution, and diversity remain poorly known. For example, there are approximately 31 recorded species, 95% of which were described prior to 1934. Of these, a third have been designated either *nomen dubia* or *species inquirienda*, and most have short questionable descriptions from poorly preserved material dating from the late 1800's. Only three species have been described using modern taxonomic methods that includes both imaging and description of external features with an accompanying DNA barcode. To assess Antarctic nemertean biodiversity, and to engage undergraduate students in authentic research experiences, I have been teaching a research methods course using DNA barcoding of nemerteans collected by dredge from several agencies. We have generated DNA extractions for 375 samples, and from these samples amplified 276 COI and 337 16S sequences, which are used here in phylogenetic and DNA barcode analyses. So far, we have discovered 62 nemertean species, suggesting there is a substantially richer nemertean diversity in the Southern Ocean than is currently recorded. Unfortunately, voucher images and details of living external anatomy are lacking for these samples, so positive assignment to described species is challenging. We describe geographic locality data and found several species are circumpolar in their distribution, and we can connect several species to planktonic larva. These data also allow us to start testing biogeographic related hypotheses for specific neonemertean clades. Imaging, description of external anatomy of living samples using accepted character sets, and DNA barcoding is the most important next step for describing Antarctic nemertean biodiversity.

70-5 SCHWEIKERT, LE*; DAVIS, AL; JOHNSEN, S; BRACKEN-GRISSOM, HD; Florida International University, Duke University; *lorian.schweikert@gmail.com*

Vision and Bioluminescence in Deep-sea Shrimps: Implications for Conspecific Recognition

Bioluminescence is an important mediator of animal interaction in the deep sea. The forms and functions of bioluminescence are diverse, even among groups with shared evolutionary and ecological histories. In one such family of deep-sea shrimps, the Sergestidae ("*sergestes*" subgroup), light organs known as organs of Pesta have undergone species-specific diversification in morphology. However, the predicted function of these organs in counterillumination (a form of camouflage) has no obvious requirement for this variation, leading to the question: have light organs diversified across "*sergestes*" to serve as visual signals in conspecific recognition? Here, we examined different aspects of "*sergestes*" vision to assess their capacity to detect differences in their bioluminescent emissions. Selecting species with distinct organ morphologies (*Allosergestes sargassi*, *Parasergestes armatus*, and *Deosergestes henseni*), we examined eye to body size scaling relationships, as well as eye morphometrics for models of visual ability. Altogether, the conspecific recognition hypothesis was not supported. We found no sexual dimorphism in eye investment, which scales negatively with body growth across all species. Sighting distance models indicated relatively short distances (sergestes" vision, images of conspecific appearance rendered using 'AcuityView' software suggested the inability of these species to resolve variation in organ morphology. While bioluminescent patterns may not permit species discrimination, it may aid in localizing individuals over short distances; and thus, is capable of serving camouflage and visual signaling in this group, simultaneously.

54-1 SCHWEIZER, RM; JONES, MR; BRADBURD, GS; WOLF, CJ; SENNER, NR; STORZ, JF; CHEVIRON, ZA*; University of Montana, Michigan State University, University of South Carolina, University of Nebraska; *zac.cheviron@mso.umt.edu*

Genomic signatures of selection across the oxygen transport cascade in high-altitude deer mice

Evolutionary adaptation to novel environments often requires coordinated changes in independent physiological systems. For example, deer mice (Peromyscus maniculatus) that are native to high elevations in western North America differ from their low-elevation conspecifics in physiological traits that alter many steps in the oxygen transport cascade, and these changes are associated with improvements in aerobic performance under hypoxia. Here, we employed a population genomic approach to gain insight into the genetic basis of these adaptations. First, we sequenced the exomes of 100 mice sampled from low- and high-elevations to identify loci that bear the signatures of positive selection in highland mice. This analysis revealed 436 unique genes that have experienced a history of selection at high elevations, and these genes have functions that may affect each step of the oxygen transport cascade. Second, we performed geographic cline analyses using whole exomes from an additional 160 mice sampled from an elevational transect of the Rocky Mountains in Colorado. This analysis revealed that clines for outlier loci were centered at significantly higher elevations, and were wider, than those for random loci. This result suggests elevational patterns of allele frequency variation for outlier loci cannot be explained by neutral population structure. Together these analyses provide new insights into how natural selection acts to produce integrated adaptive phenotypes and the spatial scales over which this process occurs.

60-8 SCIBELLI, AE*; TRIMMER, BA; Tufts University, Department of Biology, Medford, MA, Tufts University; *anthony.scibelli@tufts.edu*

A bioinspired compressible soft robot for studying terrestrial crawling

Here we describe a bioinspired crawling soft robot that is capable of emulating the locomotion of soft-bodied insect larvae. The robot uses several design principles derived from neuromechanical studies of the caterpillar, *Manduca sexta*. 1) The body is made from light-weight open cell foam representing the compressible hemocoel of insect larvae. 2) Movement is produced using brushed DC motors that wind tendon-like cables. These generate active force in tension and the tendons are restored to their passive length by elastic recoil. This mechanical cycling resembles natural muscle work loops. 3) The tendons attach to a conformable mesh fabric surrounding the foam body. These attachments are similar to insect apodemes and they serve to distribute locally applied forces to large regions of the body. 4) The robot uses two modes of locomotion: crawling, produced by cycles of compression and extension, or whole body bending that resembles caterpillar "inching". This prototype is the first untethered terrestrial soft robot designed for real world applications such as environmental monitoring or search missions in unstructured, confined environments. For research purposes, several robot modules can be connected to more closely resemble the caterpillar body. This segmented robot could be used to test different motor control strategies and the role of sensory feedback in soft bodied crawling locomotion.

P2-78 SCOBELL, SK*; GIBSON, BL; GIBBS, S; FORLANO, PM; WILSON, AB; St. Edward's University, Austin, University of North Carolina Adams School of Dentistry, Chapel Hill, City University of New York, Brooklyn College, Brooklyn; *sscobell@stedwards.edu*
Comparative prolactin expression in the pituitary of the Northern pipefish and lined seahorse using immunofluorescent markers
Male pregnancy occurs within the teleost fish family Syngnathidae, which includes seahorses, pipefish, and seadragons. Males of this family possess a brood pouch, a specialized layer of epithelial tissue on the ventral side of the trunk, that is used to incubate eggs deposited by females. There is a marked similarity between the syngnathid brood pouch and the mammalian uterus with regard to the physiological functions during pregnancy. Although the hormones that regulate mammalian pregnancy are well described, very few studies have examined the hormonal mechanisms that mediate male pregnancy in syngnathids. Pituitary hormones, particularly prolactin, likely regulate male pregnancy in syngnathids. The osmoregulatory role of prolactin in fish is well known, but the hormone has also been shown to regulate skin secretions, paternal behavior, immune function, and growth - key components of pregnancy and brood pouch function in syngnathids. Using multi-fluorescent immunohistochemistry and traditional histological staining, we have examined the pituitary anatomy and the presence of prolactin in the Northern pipefish, *Syngnathus fuscus*, and the lined seahorse, *Hippocampus erectus*. We quantified immunofluorescence in the pituitaries of males and females of both species using a custom macros plugin suite in ImageJ. We analyzed differences in expression between the sexes and species, and across the reproductive cycle in male pipefish. Several lines of evidence suggest that prolactin is an important regulator of male reproductive physiology in syngnathids.

P1-57 SCOTT, BR*; ANDERSON, PSL; University of Illinois Urbana-Champaign; *brscott2@illinois.edu*
Possible niche overlap based on similarities in body form among early jawed and jawless vertebrates
The agnathan/gnathostome (jawless vertebrate/jawed vertebrate) transition represents one of the most significant faunal turnovers in the earth's history. From the Silurian period (444 million years ago) through the Devonian period (359 mya) vertebrate faunas transitioned from diverse groups of agnathans to faunas dominated almost entirely by gnathostomes. Despite the significance of this transition, the circumstances that drove gnathostome dominance are unclear. Competition between gnathostomes and agnathans is the most commonly proposed hypothesis; however, this hypothesis has remained largely untested. When two groups are in competition, there should be at least some overlap in niche. Greater overlap is associated with greater competition. Body form can act as a proxy of niche, where differences in body form can correspond with differences in habitat use. Gnathostomes with similar body form to agnathans would be consistent with hypotheses of competition, while taxa that have different body forms would not be consistent with a hypothesis of competition. Our dataset consists of distance based measurements for numerous complete or nearly complete body fossils of early vertebrates. In a preliminary principal coordinate analysis we looked for similarities and differences in body form between Silurian and Devonian agnathan and gnathostome taxa. Gnathostome and agnathans body forms show considerable separation by fin position or presence and shape of the head and armor; however, antiarch placoderms (gnathostomes) overlap with osteostracans (agnathans) along these morphospace axes. Future analyses will investigate the amount of morphological separation necessary to reject competition between these taxa.

8-2 SCOTT-ELLISTON, A*; WARNE, R; Southern Illinois University, Carbondale, IL; *ayana.scott-elliston@siu.edu*
Modulation of the gut microbiome affects host developmental and stress response phenotypes
The capability of an organism to metabolize nutrients is crucial for fueling growth, facilitating development, and sustaining immune function, and variation in the gut microbiome during early life stages of an organism is often associated with altered host phenotypes and increased disease susceptibility. However, the biochemical mechanisms by which microbial communities affect an organism's health across ontogeny remain poorly understood. The Warne lab has recently demonstrated that in larval amphibians hatching constitutes a critical window for establishment of a gut microbiome, and gut bacterial diversity, specifically the ratio of Firmicutes to Bacteroidetes, influences development rate, growth, and mortality rate due to *Ranavirus* infection – an emerging disease for ectothermic vertebrates. Consequently, we tested how targeted manipulation of the gut microbiome and a prebiotic treatment can be used to modulate host development and stress response phenotypes. Through gut microbiome manipulation at hatching in these larval frogs and the subsequent prebiotic dietary treatment with a digestion resistant starch, we show that the gut microbiomial community structure affects growth, development, metabolism, and corticosterone responses to stress exposure. Specifically we found that (1) larvae with a disrupted gut microbiome exhibit significantly slower growth and development rates; while (2) disrupted larvae provided the starch experienced a rescue effect whereby they not only recovered growth rates compared to controls, but also exhibited significantly increased development rates; and (3) altered corticosterone responses to an external handling stressor. These results suggest gut microbiome and potentially metabolite profiles can be modulated to induce targeted effects on host function and health.

82-7 SEARS, MW*; NUSSEAR, KE; SIMANDLE, ET; Clemson University, University of Nevada, Reno; *thermalecology@gmail.com*
Biophysical ecology and the evolution of methods: are they deleterious mutations?
Ever since Cowles and Bogert demonstrated that reptiles could thermoregulate using behavior, investigators have developed various methods to show that these temperatures were not simply a passive response to the environment. Initially, sophisticated mathematical models calculated the energy balance of an animal at a specific point in time. Operative temperatures (T_es) from these calculations describe the instantaneous temperature for an animal given absorptive and convective properties, but with no heat capacitance. State of the art techniques were then developed, using hollow metallic replicas of animals, to approximate the T_es of individuals measured in real environments. When sampled over an environment, T_es can be used to benchmark thermoregulatory performance. Further, T_es can be used to calculate the body temperatures (T_bs) of individuals in a transient environment if additional information regarding thermal time constants are known. For various reasons, many biologists have substituted hollow metallic replicas with other types of inanimate objects, sometimes adding thermal mass to approximate a T_b rather than an T_e. In doing so, investigators have introduced errors into their work as their models have a substantial time lag, and are no longer taking direct measurements of T_e that could be used to examine thermal forcing in a changing environment or microhabitat (e.g. when thermoregulating). Here, we review the recent literature to 1) highlight the inappropriate measurement of T_es and its consequences, 2) suggest methodologies that might be able to correct some of these poor measurements, and 3) connect measurements of T_es back to the original underlying theory. Our hope is to clear up some fundamental misunderstandings of what T_es provide and to suggest future directions whereby correct measurements can advance our understandings of thermal biology.

49-6 SECOR, SM; University of Alabama; *ssecor@ua.edu*
Underlying Mechanisms that Drive an Adaptive Interplay in Digestive Physiology
Bill Karasov and Jared Diamond's 1988 article ‘Adaptive interplay between physiology and ecology in digestion' laid the foundation for my exploration in the adaptive interplay between feeding habits and the regulation of digestive performance. This work, largely undertaken with snakes, has identified an adaptive dichotomy for which frequently-feeding species narrowly regulate intestinal function with feeding, whereas species that naturally experience long periods between meals, due to an infrequent feeding behavior or dormancy, up and down regulate intestinal form and function with the start and finish of each meal. Proposed for why such a dichotomy exists resides in the energetic benefits of each mode as a function of feeding frequency. The cellular mechanisms underlying this dichotomy is apparently morphological, dictated by whether luminal surface area does not change with feeding or fasting (due to no change in microvillus length) as exhibited by frequent-feeders, or changes dramatically due to the postprandial lengthening of the microvilli and subsequent shortening following digestion as experienced by infrequent-feeders. Taking advantage of this dichotomy, our comparative approach is allowing us to identified specific gene 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. Given the convergent evolution of modes of regulatory responses among snakes, we are asking whether the underlying molecular programs of a common phenotypic response (i.e., microvillus lengthening) are conserved or have evolve independently, and thus are unique.

108-5 SEGRE, PS*; GOLDBOGEN, JA; Stanford University; *psegre@stanford.edu*
A computational framework for quantifying the maneuvering performance of free-swimming rorqual whales
Maneuverability, defined generally as the ability to change speed and direction, is critical to survival. Rorqual whales, the world's largest vertebrates, survive by catching much smaller and more maneuverable prey. They do so by using a series of surprisingly acrobatic maneuvers to approach schools of small fish or krill, accelerating, and engulfing large mouthfuls of prey-laden water. It has been thought that organisms that use lift based propulsion are constrained by the differential scaling of lift producing surfaces and body volume, but this has not been comprehensively tested in free-swimming animals. Rorqual whales exhibit a large range of sizes and have substantial differences in the morphology of body shape and propulsive surfaces, which makes them excellent subjects for studying the scaling of maneuvering performance at the upper extremes of body size. Using a collection of data from suction-cup attached, bio-logging tags equipped with a suite of inertial sensors (6 species, 384 deployments), we developed a framework to comprehensively quantify and compare the maneuvering performance of free-swimming whales. We identified five simple rotational and translational maneuvers (rolls, upward pitch changes, downward pitch changes, yawing turns, accelerations) that are effected by different hydrodynamic controls and can be sequentially pieced together to build complex trajectories used for capturing prey. Each type of maneuver is stereotypical, repeatable, and used thousands of times during the course of a multi-hour deployment, and thus can be automatically detected using a targeted search sequence. Taken together, an analysis of the performance limits of these five simple maneuvers and an analysis of how simple maneuvers are sequentially used to perform complex behaviors will allow us to quantify the overall maneuvering performance within and across species of rorqual whales.

P1-200 SEKITS, NF*; TUNNELL WILSON, WT; JACKSON, K; Whitman College; *sekitsnf@whitman.edu*
The Striped Beaked Snake really is a Skaapsteker adapted for digging: Evidence from cranial morphology
The genus *Rhamphiophis*, known as Beaked Snakes, are large, diurnal snakes with reinforced snouts adapted for digging. The genus *Psammophylax* is comprised of generalist, terrestrial snakes known as Skaapstekers. Both genera belong to the primarily African lamprophiid subfamily, Psammophiinae. The Striped Beaked snake (*Rhamphiophis acutus*) was originally considered a member of the genus *Rhamphiophis*. However, molecular evidence places *R. acutus* within the genus *Psammophylax*. If this phylogenetic placement is correct, the "beak" of *R. acutus* must have evolved independently of that seen in the "true" beaked snakes, genus *Rhamphiophis*. We undertook a detailed study of the cranial morphology of *R. acutus* in addition to representative species of both *Psammophylax* and *Rhamphiophis* for comparison. Our goal was to understand the overall structure of the nasal region of the skull in *Psammophylax* and in *Rhamphiophis*, to understand the cranial morphology underlying the "beak" of Beaked Snakes, and to look for any difference in the structure of the "beak" in *R. acutus* relative to that of other *Rhamphiophis* which might be attributable to convergence. We used micro-computed tomography (micro-CT) scanning and digital imaging to identify defining cranial characters of both genera. We found that, despite its striking adaptations to fossorial life, *R. acutus* still retains key features that reveal its true origin; its evolutionary history can be told not only by its genes, but by its morphology as well.

P2-184 SELEB, B*; THATCHER, M; LIEB, J; NOEL, A; SELEB, Ben; Georgia Institute of Technology, Georgia Institute of Technology , Georgia Tech Research Institute ; *bseleb3@gatech.edu*
Sure-Footed in Slippery Situations: Underwater Grip with Otter Paws
The North American river otter must traverse slippery, bio-fouled rocks in rivers and streams as it travels and hunts for food. Many aquatic organisms have developed grip mechanisms to combat these slippery bio-fouled surfaces, such as hooks, hairs, and adhesives. Qualitative observations have shown unique callous-like pads on the rear paws of the river otter. In this experimental study, we investigate the use of these pads and surrounding soft tissue for enhancing underwater grip. The composition and material properties of the paw pad tissue were determined using histology and nanoindentation, while the paw surface texture was characterized using microscopy and profilometry. The friction between the paw pad and various wet and dry surfaces was measured using a rheometer with tribological attachment. Field experiments were conducted concurrently with a live river otter. Field experiments included a locomotion analysis, friction testing with a custom adjustable ramp, and testing of an original paw scanning device using frustrated total internal reflection. Preliminary results indicate that the paw pad maximizes contact area between substrate and tissue through highly deformable tissue and tire-tread-like patterns on the epidermis. The results of this project may provide unique grip solutions for multi-terrain robots, tires, or even human apparel like boots or gloves.

50-2 SELLERS, KC*; MIDDLETON, KM; HOLLIDAY, CM; University of Missouri; *kcsty5@mail.missouri.edu*

Joint Loading and Transformation in Suchian Evolution

Modern crocodylians employ immense forces during feeding. Many characters that enable crocodylians to generate and resist these forces are not found in their ancestors, and thus the evolution of crocodylians involved a substantial reorganization of the feeding apparatus. Once this suite of changes was in place, crocodyliforms radiated into forms with derived diets and craniodental modifications. To assess the biomechanical effects of changing configurations of muscles and cranial joints, we used CT data to create 3D models of extant and fossil suchians that demonstrate the evolution of the crocodylian skull, using osteological correlates to reconstruct muscles. Muscle forces were distributed with the computational package Boneload and used as input for finite element analysis and 3D lever analyses. We found that jaw muscles expanded and shifted attachments throughout suchian evolution: muscle orientations became more mediolateral as the skull flattened, the pterygoideus ventralis muscle began inserting on the lateral mandible, and the depressor mandibulae muscle expanded its attachment on the enlarged retroarticular process. Changes to cranial joints accompanied muscular changes: the pterygoid buttress expanded, the articular surfaces of the jaw joint changed, and the quadrate and palate sutured to the braincase. Our results showed that joint force orientation tracks with articular surface metrics. We found that as bite location moves caudally, working side joint force decreases in magnitude; it is likely that in feeding events such as shaking bites or death roll, the jaw joint is loaded in tension. This study depicts a feeding apparatus that defies traditional understanding. The combination of dual craniomandibular joints and jaw joints loaded in tension is unknown from the rest of tetrapods.

P1-150 SEMANCHIK, P*; BERGEY, L; LABAR, J; RITCHIE, L; HORVATH, T; Centenary University, Centenary University ; *pier.semanchik@centenaryuniversity.edu*

Comparison of Parasite Occurrence Between Three Native and one Non-native Palaemon Species of Grass Shrimp

The presence of parasites in four species of Palaemon grass shrimp were investigated from four collections sites along the New Jersey coast. One of the four species, Palaemon macrodactylus, is an invasive species originating from Japan. The goal of this study was to compare parasite load and composition as well as damage to the exoskeleton between the native species and the nonnative species. Water samples were collected and analyzed for the presence of ammonia, nitrates, orthophosphate, coliform bacteria, temperature, salinity, pH, conductivity, dissolved oxygen, and total dissolved solids to determine if there is a correlation between parasite load and water quality. Data analysis showed the invasive species had significantly less parasites and damage to the exoskeleton when compared to the native conspecifics. This could lead to a competitive advantage and an increase in the invasive population numbers.

P1-253 SEMEL, MA*; RATOVOSON, JC; MOORE, IT; Virginia Tech, University of Antananarivo ; *merak91@vt.edu*

Impact of habitat type and disturbance level on golden-crowned sifaka (Propithecus tattersalli) fecal glucocorticoid metabolite levels

Madagascar is one of the world's "richest" biodiversity hotspots with many endemic and threatened species and yet the island is threatened by widespread habitat degradation. Little is known about how habitat degradation is affecting the endemic animal species. Golden-crowned sifakas (*Propithecus tattersalli*), listed as critically endangered on the IUCN red list, are folivorous, group living primates endemic to forests of the Daraina region of Madagascar. Their range encompasses a unique biogeographical transition zone from Daraina's northern and western dry deciduous forests to southern humid forests. This unique spectrum of forests across a limited geographical range allows for a natural study of how golden-crowned sifaka are influenced by landscape type and varying degrees of habitat fragmentation. To understand the effects of environment on glucocorticoid hormone activity, we completed full-day behavioral follows for nine groups of golden-crowned sifakas in an array of forest fragments (August 2018-July 2019). Fecal samples were collected daily from individually identified lemurs and fecal glucocorticoid levels were analyzed by radioimmunoassay. By understanding how degree of habitat fragmentation and degradation, as well as habitat type influence *P. tattersalli* glucocorticoid hormone levels, we start to understand how habitat quality influences physiological state and work towards ensuring that their territory is maintained at the level necessary for their sustained health.

P1-240 SEMRO, MR*; NEBHUT, AN; CARROLL, KR; SHINKLE, JR; Trinity University, San Antonio; *msemro@trinity.edu*

Stress then Acclimation: Effect of UV Radiation on Kale Growth, Pigmentation, and Antioxidant Content

Kale (*Brassica oleracea var. sabellica*) is a popular and nutritious vegetable in part because of its high antioxidant content. However, kale is often grown in greenhouses or indoor hydroponic farms using light sources containing no UV radiation despite the fact that UVR stimulates antioxidant production as part of stress and developmental responses which include changes in pigmentation, leaf anatomy, and biomass. The effects of UV supplementation were tested on two varieties of kale to assess the potential benefits and drawbacks of UV treatment on greenhouse-grown kale. After three days of UV-treatment, one of the varieties showed a 29% increase in antioxidant content while the other showed no significant difference. After seven and fourteen days of UV treatment, the UV stress response was characterized through biomass, UV absorbance spectra, UV reflectance spectra, and leaf chlorophyll and flavonoid content. Both varieties of kale displayed a pattern of short-term stress and long-term acclimation: at seven days, UV-treated plants were smaller than untreated plants, had lower UV absorbance and reflectance, and had higher chlorophyll and UVA-absorbing-flavonoid content. At fourteen days, most of these differences were smaller or insignificant. For example, after seven days of UV exposure, the UV-treated Premier kale was 21% smaller than its untreated counterparts, but after fourteen days of exposure, there was no significant difference between the two groups. Therefore, while UV-supplemented plants are initially smaller but more nutritious than unsupplemented plants, these effects lessen after two weeks of consecutive treatment as plants acclimate to UV exposure.

27-8 SENEVIRATHNE, G*; BAUMGART, S; SHUBIN, N; HANKEN, J; SHUBIN, NH; University of Chicago, Chicago, Laboratory Schools, Chicago, Museum of Comparative Zoology and Harvard University, Cambridge; *gsenevirathne@uchicago.edu*

Ontogeny of the anuran urostyle: the developmental context of evolutionary novelty

Unique developmental novelties often mark evolutionary origins of metazoan structures. The anuran urostyle is one such structure. It forms during metamorphosis, as the tail regresses and locomotion changes from an axial-driven mode in larvae to a limb-driven one in adult frogs. Histologically, the urostyle comprises of a mesoderm-derived coccyx and an endoderm-derived hypochord. The coccyx is formed by the fusion of rudimentary caudal vertebrae. Across vertebrates, coccygeal fusions have repeatedly evolved with the loss of the tail. However, the contribution of an endoderm-derived ossifying hypochord to the coccyx in anurans is unique among vertebrates and remains a developmental enigma. Here, we focus on the developmental changes across ontogeny, leading to the anuran urostyle with an emphasis on the ossifying hypochord. We found that thyroid hormone directly affects hypochord formation but not the coccyx. The coccyx development is initiated before the metamorphic climax and depicts an endochondral ossification pattern, whereas the ossifying hypochord undergoes rapid ossification at metamorphic climax and shows hypertrophy. The embryonic hypochord is known to play a significant role in the positioning of the dorsal aorta (DA), but the reason to form an ossifying hypochord during metamorphosis has remained obscure. Interestingly, our results suggest that the ossifying hypochord also plays a role in re-arrangement of the DA in the newly forming adult body by partially occluding the DA in the tail, which subsequently regresses. We propose that the ossifying hypochord induced loss of tail during metamorphosis enabled the evolution of the unique anuran *bauplan*.

P3-163 SENTHIVASAN, S*; ALTSHULER, DL; University of British Columbia; *shreeram@zoology.ubc.ca*

Automated kinematic tracking using inertial sensor arrays

Recording kinematics with high precision and time resolution is a problem common to nearly all studies of animal locomotion. However, current optical methods depend on expensive high-speed camera arrays, are difficult to set up outside of laboratory conditions, and often have limited effective measurement volumes due to occlusion of marked points. Recent advances in microelectronics and the rising popularity of small-batch circuit assembly provide a cheap and accessible way of designing project-specific animal-mountable data loggers on the order of 2-4 grams. Further, Monte Carlo state space modelling methods provide a robust way of inferring kinematics from raw magnetic, angular rate, and gravity (MARG) sensor data. In the present work, we use one such logger to track the flight kinematics of pigeons (*Columba livia*) flown in flight chambers. To test the accuracy of this method, we compare the results with tracking data collected from an optical motion capture system. Animal-mounted MARG sensor arrays could provide a minimally invasive and automated means of recording animal kinematics at sampling rates comparable to that achieved by high-speed video. The low cost and portability may also facilitate field studies of animal locomotion.

P1-101 SERBA, KM*; FASICK, JI; ALGRAIN, H; ROBINSON, PR; University of Tampa, University of Maryland Baltimore County, University of Maryland Baltimore County; *katherine.serba@spartans.ut.edu*

The Retinal Pigments of Filter-feeding Sharks and their Role in Visual Foraging Ecology

The spectral tuning properties of the whale shark (*Rhincodon typus*), basking shark (*Cetorhinus maximus*), and megamouth shark (*Megachasma pelagios*) rod (Rh1) and long-wavelength sensitive (LWS) cone visual pigments were examined to determine whether these retinal pigments have adapted to the broadband light spectrum available for surface foraging, or to the narrowband blue-shifted light spectrum available at depth. Recently published whale shark Rh1 and LWS cone opsin genes were used to design primers for amplification and sequencing of the opsin proteins from basking and megamouth sharks. Basking and megamouth shark Rh1 and LWS cone coding sequences were PCR amplified and sequenced to identify amino acid residues critical for spectral tuning. The predicted absorbance maxima (λ_{max}) for the whale, basking, and megamouth shark Rh1 visual pigments were 496 nm, 496 nm, and 486 nm, respectively. The deduced amino acid sequence for both the whale and basking shark LWS cone opsins resulted in predicted λ_{max} values near 500 nm. Although Rh1 λ_{max} values near 500 nm are typical of terrestrial vertebrates and surface foraging fish, it is uncommon for vertebrate LWS cone pigments to be so greatly blue-shifted. We propose that the spectral tuning properties of the Rh1 and LWS cone pigments in whale and basking sharks are most likely an adaptation to the broadband light spectrum available at the surface, while the megamouth shark Rh1 pigment is most likely an adaptation to the narrowband light spectrum available in deeper waters.

P2-85 SERMERSHEIM, LO*; WOODRUFF, MJ; ROSVALL, KA; Center for Integrative Study of Animal Behavior, Indiana University, Biology, Indiana University; *lsermers@iu.edu*

Behavioral responses to acute and persistent heat stress in nestling tree swallows (Tachycineta bicolor)

Rising global temperatures are generating new thermal challenges for animals across the tree of life. However, for endotherms, the sub-lethal behavioral effects of heat are poorly understood. Heat may be particularly inescapable in cavity-nesting birds, which are restricted to an enclosed area during a protracted but critical period of postnatal development. Here, we explore the behavioral effects of heat in nestling birds and test the hypothesis that nestlings behaviorally acclimate to heat. We experimentally simulated a 6-day heat wave inside the nest boxes of free-living tree swallows (*Tachycineta bicolor*) using air-activated shipping warmers that increased nest temperatures by >2°C. By measuring behavior only 4 hours after heat began and again 3 days later, we assessed the effects of both acute and persistent heat exposure. Sampling occurred when chicks were 6 and 9 days old, respectively, during the period of exponential growth. We quantified thermoregulatory behaviors that serve to expel heat, including the rate of panting and degree of clumping. In addition, we measured how heat exposure affects other fitness-related behaviors, namely, the frequency and intensity of begging. For both sets of behaviors, we assessed whether chicks acclimated to heat over time. Initial analyses show behavioral shifts in heated nests that may facilitate thermal tolerance, but treatments did not differ in nestling growth rates or survival to fledging. This study provides insight on how chicks behaviorally respond to thermal challenges and is an initial step in understanding how animals may cope with the increasing temperatures of climate change.

135-3 SEROY, SK*; GRUNBAUM, D; PADILLA, DK; University of Washington, Stony Brook University; *sseroy@uw.edu*
Inducible morphology reveals adult dispersal between habitats
The marine snail, *Lacuna vincta*, is an ecologically dominant grazer in kelp and eelgrass habitats. *L. vincta* exhibits inducible radula morphology dependent on current habitat, producing pointed teeth in kelp beds and blunt teeth in eelgrass beds. *L. vincta* adults disperse between these habitats via drifting on currents to avoid predation and to exploit seasonal shifts in resources. But dispersal behavior can result in arrival in a habitat that does not match a snail's radula morphology. Therefore, because this inducible morphology records individuals' histories of dispersal between these two habitat types, we used the interaction between individual-level plasticity and migratory behaviors to determine population-level characteristics of this important grazer in seasonal habitats. We surveyed two eelgrass and two kelp sites around San Juan Island, WA to assess radula mismatch and characterized flow regimes as a possible control on dispersal using novel micropython-based current speed sensors. Snails were collected during low tides from June to August 2019, dissected to extract the radula, and classified as matched, transitioning or mismatched to their current habitat. In eelgrass beds, proportions of matched snails increased over the summer, potentially reflecting the seasonal availability of eelgrass epiphytes and suggesting snail retention at these sites. In kelp beds, proportions of matched snails decreased over the summer, indicating potential high migration to and from these sites. Kelp sites had slower flow regimes than eelgrass sites. Preliminary analysis suggests a positive relationship between flow speed and radula mismatch at kelp sites, with a weaker effect at eelgrass sites. Our work shows how inducible traits can be used to quantify interactions between organism- and habitat-level ecological mechanisms in marine environments.

P2-84 SERRANO-ROJAS, S*; JUNG, J; WARKENTIN, KM; Glasgow University, Boston University, Smithsonian Tropical Research Institute; *shirley.serrano25@gmail.com*
Multimodal mechanosensing for escape-hatching decisions of red-eyed treefrogs
Agalychnis callidryas embryos hatch prematurely to escape predation, cued by physical disturbance in snake attacks. This response appears strongly mediated by otoconial organs in the developing vestibular system, but some mechanosensory-cued hatching (MCH) occurs before these sensors function. We tested if lateral line mechanoreceptors contribute to MCH by blocking neuromast function with gentamicin then exposing embryos to hatching cues at 3 developmental stages: just before and after the onset of vestibular function and closer to spontaneous hatching. To assess vestibular function, we measured the vestibulo-ocular reflex (VOR); it was unaffected by gentamicin. We confirmed lateral line blocking with DiAsp staining. We used egg-jiggling and vibration playbacks to test for MCH. Just prior to vestibular function, at age 4.2 d, gentamicin reduced the hatching response to jiggling from 22% to 1%, revealing a lateral line contribution to risk assessment. After vestibular function, MCH increased substantially. At 4.8 d, the lateral line still contributed, as gentamicin reduced hatching from 72% to 40%. By 5.4 d all jiggled embryos hatched, regardless of neuromast function, and their response to vibration playbacks (ca. 80%) was indistinguishable, suggesting redundancy of mechanosensory modalities. *A. callidryas* embryos clearly use lateral line mechanoreceptors, as well as otoconial organs, to sense mechanosensory risk cues, and their relative importance changes developmentally. The occurrence of MCH in a few embryos lacking both vestibular and lateral line function suggests cutaneous mechanoreceptors may also contribute to risk assessment. *A. callidryas* embryos appear to use all available sensors to assess mechanosensory risk cues for escape-hatching decisions.

65-7 SETH, D; Villanova University; *deeksha.seth@villanova.edu*
Development of an Interactive Model of a Snake Jaw for Natural and Applied Science Education
Multi-disciplinary education has become a critical part of formal and informal curricula to teach students how different disciplines work in harmony and to provide an exciting experience that can encourage the students to pursue education and careers in the science, technology, engineering and mathematics (STEM) fields. Due to the popularity of biomimicry, the integration of biology and applied sciences is becoming increasingly visible in curricula throughout the country, especially in museums where animal-related behaviors are popular. Recognizing the need for interactive tools that can make the integrated STEM education fun and effective, the objective of this work was to develop a biologically accurate model of a snake jaw that can demonstrate the function of the quadrate bone and how the unique physiology contributes to the large range of motion in the jaw. The goal of this model was also to teach other integrated STEM topics, such as mathematics. The robotic snake jaw was developed at Villanova University as a part of the undergraduate capstone program. The model uses servo motors that are individually controlled using an Arduino board. The frame and exterior skull of the device was modeled using SolidWorks and 3D printed. The device consists of movable inner and outer, lower and upper mandibles of the jaw as well the unique quadrate bone. Lastly, the device has a pre-programmed motion to simulate a human jaw movement to show the audience the effect of the quadrate bone on the range of motion. The device also enables teaching simple algebraic relations and advanced geometric and trigonometric relations for an interactive mathematics session. The device is currently housed at The Academy of Natural Sciences of Drexel University. In the upcoming months the device will be assessed.

62-1 SETH, D*; LAUDER, GV; FLAMMANG, BE; TANGORRA, JL; Villanova University, Harvard University, New Jersey Institute of Technology, Drexel University; *deeksha.seth@villanova.edu*
Fish Fin Compliance: A Perturbation Technique to Determine Compliance During Free Swimming
Despite significant importance, compliance of fish fins has not yet been investigated with live, freely-swimming fish. This is partly due to the challenges of interrogating a live fish during free swimming and the lack of adequate experimental devices and methodologies to measure the stiffness of the fin. The objective of this work was to validate a perturbation technique by predicting a known change in the stiffness of a physical system. A physical model of known stiffness was built and perturbed with a vortex ring, and its response was measured using high speed video. A second-order model was used to predict how the response of the system changes with compliance and those changes were compared to those observed experimentally. Comparison of the predicted and measured responses suggested that the displacement and the rate of displacement from unperturbed state can be enough to assess the compliance change. For the technique to be applicable to a fish, changes in displacement in the initial 20 – 100 ms due to a change in compliance were compared. This was done to ensure that the technique can work on the live fish by only looking at the passive response in the fin. The proposed technique of applying a known force to the fin and predicting compliance changes by looking at the displacement in the fin, was successful in estimating a known compliance change in a physical system. As the stiffness increases, the displacement at a given time can be expected to decrease and the rate of change from unperturbed state to that displacement at a given time can be also be expected to decrease. These trends hold true within 20 – 100 ms. Future work will involve studying the interaction of the vortex ring with flexible structures under water, so the force estimate of the vortex ring can be better validated for the biological studies.

46-3 SETTON, EVW*; SHARMA, PP; University of Wisconsin - Madison; *setton@wisc.edu*

The fly cannot save us: Using developmental transcriptomes to probe the genetic architecture of spider spinnerets

The phylum Arthropoda is a formidable system for understanding the developmental genetics of novel structures, with an abundance of structural innovations across the diversity of this group. Candidate gene approaches, grounded in established insect models like the fruit fly *Drosophila melanogaster*, have helped answer questions about some novelties, such as insect wings. This approach, however, is not suitable for study of evolutionary novelties that are restricted to distantly related lineages and is thus inadequate for probing the genetic architecture of structures not found in *D. melanogaster* or its close relatives. One such structure is the web-weaving organ of spiders, the spinnerets. Here we offer an alternative to the insect-based candidate gene approach toward a more comprehensive understanding of spinneret genetic architecture. We utilized appendage-specific transcriptomes of nascent spinnerets in the tarantula *Aphonopelma hentzi* and applied differential gene expression (DGE) analyses to derive a list of candidate genes specific to spinneret primordia. Here we share preliminary data for genes identified as highly differentially expressed in the developing spinnerets compared to primordial legs. We also examine leg and spinneret genes' ages using a phylostratigraphic approach as a test of evolvability. More broadly, our novel application of transcriptomic data and DGE analyses opens the door to identifying genes putatively important in the specification of other appendages types found exclusively in lineages distantly related to insects.

55-1 SEWALL, KB*; DAVIES, S; BECK, ML; Virginia Tech, Quinnipiac University, Rivier University; *ksewall@vt.edu*

Relationships Among Neuropeptides, Territorial Aggression, and Urbanization in Male Song Sparrows

Urbanization is a critical form of environmental change that can affect the physiology and behavior of wild animals and, notably, birds. One behavioral difference between birds living in urban and rural habitats is that urban males show elevated territorial aggression in response to simulated social challenge. This pattern has been described in several populations of song sparrow, *Melospiza melodia*. Such behavioral differences must be underpinned by differences in the brain, yet little work has explored how urbanization and neural function may be interrelated. Our previous work compared a marker of neural activation in response to song playback (the immediate early gene FOS) and expression of a neuropeptide involved in territorial aggression, arginine vasotocin (AVT), within nodes of the brain social behavior network of urban and rural male song sparrows. This initial work implicated both FOS expression and AVT in mediating behavioral adjustments to urbanization in male song sparrows. However, we were unable to correlate these brain measures with birds' territorial responses. In the present study we again compared FOS and AVT immunoreactivity within nodes of the social behavior network from urban and rural males but also correlated these measures of male territorial aggression and quantified co-localized protein expression. This approach allowed us to determine if neuropeptide expressing neurons were activated during elevated aggressive responses. Our findings implicate neural activation of neuropeptide-expression cells within the social behavior network of the brain in regulating the well-established differences in territorial behavior among song sparrows living in rural and urban habitats. We discuss how changes in neuropeptide systems could underpin both facultative and evolutionary adaptation to urban habitats.

P2-153 SHAH, A/A*; WOODS, H/A; University of Montana; *alishas0624@gmail.com*

Who can take the heat? Microclimates mediate heat tolerance in wasp-caterpillar interactions

A primary goal in ecophysiology is to understand how temperature influences physiological traits, behavior, and species distributions. Although many studies focus on thermal performance of single species, determining responses to climate change will depend on understanding how temperature affects interactions among species. Small ectotherms, which make up the majority of Earth's biomass, are an experimentally tractable group of organisms in which to examine the temperature-dependence of species interactions. Here, we take an insect's-eye-view of temperature to understand i) how micro-scale temperature is related to insect thermal tolerance and ii) how thermal tolerance differs between a parasitoid wasp and its caterpillar prey. We used the aspen leaf miner-parasitoid wasp system, an emerging model for investigating the thermal ecology of parasites and hosts. We predicted that leaf miners and wasps raised on leaves exposed to the sun would have higher heat tolerance than those from shaded leaves. We also predicted that the sedentary leaf miners, which are unable to thermoregulate using behavior, would have higher heat tolerance than their free-flying predators. We tested this prediction by measuring upper lethal limits in wild-caught leaf miners and adult wasps from ‘sunny' and ‘shaded' aspen leaves. Our results revealed no effect of sun versus shade, but caterpillars had higher heat tolerance than their predators. We discuss these results in the context of ecological theory about predator-prey interactions and response to climate change.

26-4 SHANKAR, A*; MCCAHON, S; CALLEGARI, K; SEITZ, T; DROWN, D; WILLIAMS, CT; University of Alaska Fairbanks; *nushiamme@gmail.com*

SAD rats: Effects of short photoperiod on sleep disruption, the gut microbiome, and carbohydrate consumption in diurnal grass rats

Seasonal affective disorder (SAD) is a recurrent depression triggered by short photoperiod exposure. In addition to being a major mental health issue, SAD has been linked to circadian dysfunction and weight gain, both of which have important implications for susceptibility to cardiovascular disease, type II diabetes, and metabolic syndrome. We use a diurnal rodent model, the Nile grass rat (*Arvicanthis niloticus*), to examine the effect of photoperiod (short 4:20 LD vs. neutral 12:12 LD) on sleep and activity patterns, sucrose consumption, and gut microbiome changes. We tracked individual sleep patterns in 45 grass rats and assessed reward-seeking behavior by measuring their consumption of high-concentration (8%) sucrose (HCS) solution. We collected liver (to diagnose fatty liver disease), cecum, large intestine, and periodic fecal samples (to characterize the diversity and functional profile of the gut microbiome). We found that animals on short photoperiods showed disrupted activity and sleep patterns, but maintained strong diurnal rhythms and similar subjective day lengths. We found no effect of photoperiod on sucrose consumption, but short photoperiod individuals had marginally higher liver fat content, and those with access to high sucrose had higher liver fat across both photoperiod treatments. Our study highlights the potential for metabolic effects of exposure to short photoperiods. Completion of sequencing will allow us to assess whether these effects are associated with shifts in the gut microbiome diversity or functional profile.

P2-160 SHANNON, ES*; POWERS, DR; George Fox University; *eshannon17@georgefox.edu*

Heat Dissipation by Hummingbirds during Perching Following a Hovering Bout

The low mechanical efficiency of hummingbird flight muscles results in the production of large amounts of endogenous heat during hovering. Dissipation of this extra heat is necessary to avoid hyperthermia but is confined to specific heat dissipation areas (HDAs) around the eyes, legs/feet, and the axial region due to insulation by the body contour feathers. However, when ambient temperature (T_a) is warm hummingbirds appear unable to sufficiently increase evaporation to compensate for the loss of passive heat dissipation. Thus, it is likely that when T_a is warm hummingbirds depend on intermittent behavioral thermoregulation while perching to manage body temperature. In this study we used infrared thermography and standard video recordings to examine heat dissipation in perching hummingbirds following hovering bouts. We also offered hummingbirds a choice between warm (T_a =20-37°C) and artificially cooled perches to see if microclimate was important for perch selection. Data were collected on 3 hummingbird species (*Archilochus alexandri*, *Eugenes fulgens*, and *Lampornis clemenciae*) ranging in mass from 2.8-9.6 g. As T_a increased breast surface temperature (T_s) exceeded mean total body T_s across all T_a values suggesting some accumulated heat is escaping through breast plumage. At the warmest T_a (37°C) breast Ts could be up to 42°C. Interestingly even at our warmest T_a mean head T_s never exceeded 40°C even when the T_s of other body surfaces was higher perhaps to protect the brain. Both the bill and feet were important means of heat dissipation. When at T_a >34°C heat was actively delivered to both bill and feet, and at the warmest T_a their T_s could be as high as 42°C perhaps suggesting slight hyperthermia during hovering. Our data suggest that these physiological mechanisms for dissipating heat are more important than microclimate selection.

P2-242 SHANNON, RP*; NADEN, L; BOLEK, MG; Oklahoma State University; *shannrp@okstate.edu*

Distribution of Oocysts of Two Neogregarines (Mattesia sp. and Ophryocystis elektroscirrha), which Infect the Hypodermis of Fire Ants, Solenopsidini, and Milkweed Butterflies, Danaini

Protozoa in the order Neogregarinorida (Gregarinea: Apicomplexa) infect the fat body, hypodermis, intestine or Malpighian tubules of insect hosts. All known *Mattesia* species infect the fat body or Malpighian tubules of beetles, moths, and fleas, with the exception of two species, which develop in the hypodermis of ants. Additionally, all species of *Ophryocystis* infect the Malpighian tubules of beetles, except for *O. elektroscirrha*, which develops in the hypodermis of Danaid butterflies. Using histological techniques and SEM, we examined the distribution of oocysts and their associated pathology of an undescribed *Mattesia* sp., in adult red imported fire ants, *Solenopsis invicta* and *O. elektroscirrha* in adult monarch, *Danaus plexippus* and queen, *Danaus gilippus*, butterflies. Our results indicate that oocysts of the *Mattesia* sp. were always located within the hemocoel of their ant hosts. Oocysts were distributed throughout the head, thorax and abdomen, and thousands of oocysts were observed surrounding the brain of infected ants. In contrast, oocysts of *O. elektroscirrha* were distributed on the surface of the abdomen, inside the aedeagus of male and within the vulva, ductus bursary and ovipore of female monarch and queen butterflies. Importantly, no oocysts were ever embedded in the cuticle of queen butterflies, however oocysts were commonly embedded in the cuticle of female monarch butterflies. These observations may be important as previous studies indicate that female monarchs lose weight at a faster rate than uninfected monarchs; suggesting *O. elektroscirrha* infections may increase the rate of water loss through the cuticle. It is currently unclear what effects, if any, the occurrence of *Mattesia* sp. oocysts surrounding the brain of infected fire ants may have on ant fitness or behavior.

S7-6 SHARBROUGH, J*; MONTOOTH, K; NEIMAN, M; Colorado State University, University of Nebraska, University of Iowa; *jsharbro@colostate.edu*

Phenotypic Variation in Mitochondrial Function across New Zealand Snail Populations

Mitochondrial function is critical for energy homeostasis and should thus shape how genetic variation in metabolism is transmitted through levels of biological organization to generate stability in organismal performance. Mitochondrial function is encoded by genes in two distinct and separately inherited genomes, and selection to maintain mitonuclear interactions is often intense. The frequently observed high levels of polymorphism in genes involved in mitonuclear interactions and variation for mitochondrial function is thus surprising and demands explanation. *Potamopyrgus antipodarum*, a New Zealand snail with coexisting sexual and asexual individuals and, accordingly, contrasting systems of separate vs. co-inheritance of nuclear and mitochondrial genomes, provides a powerful means to dissect the evolutionary and functional consequences of mitonuclear variation. The lakes inhabited by *P. antipodarum* span wide environmental gradients, with substantial across-lake genetic structure and mitonuclear discordance. We can therefore make comparisons across reproductive modes and lakes to partition variation in cellular respiration across genetic and environmental axes. Here, we integrated cellular, physiological, and behavioral approaches to quantify variation in mitochondrial function across wild P. antipodarum lineages. We found extensive across-lake variation in organismal oxygen consumption and behavioral response to heat stress, coupled with elevated mitochondrial membrane potential in males. These data set the stage for applying this important model system for sex and polyploidy to dissect the relationship between mitonuclear variation, performance, plasticity, and fitness in natural populations.

P1-102 SHARKEY, CR*; LEIBOWITZ, M; PINTO BENITO, D; WARDILL, TJ; University of Minnesota, Cambridge University, Autonomous University of Madrid; *camilla.r.sharkey@gmail.com*

In vivo spectral sensitivity of Drosophila photoreceptors

Fruit flies have tiny colour receptors, which are stochastically distributed across the retina. Sharp-electrode electrophysiology from these cells is therefore unfeasible and *Drosophila* visual pigments have yet to be fully characterised *in vivo*. Previous findings suggest that fly inner and outer photoreceptors are involved in both colour discrimination and achromatic motion detection. Furthermore, colour-opponent processing has been demonstrated between inner R7-R8 photoreceptor pairs (UV-blue/ UV-green). In this study, we first characterised the spectral sensitivity of *D. melanogaster* photoreceptors *in vivo*. We used the electroretinogram (ERG) method on blind norpA mutants with selectively recovered photoreceptor activity and tested the effect of screening pigment and dietary carotenoids on photoreceptor response. We report that the peak sensitivity of Rh6 is shifted by 90 nm from green (510 nm) to red (600 nm) when measured in its native receptor and with wild-type screening pigment. Our findings can be explained by both a blue-absorbing filter and long wavelength light leakage through the screening pigment. Secondly, we measured to what extent spectral sensitivity is refined by opponent processing, by recovering activity in photoreceptor pairs. We saw no evidence of opponent processing between R7 and R8 photoreceptor pairs at the level of the photoreceptors. However, between inner and outer receptors we observed a signal boost, suggesting a feedback mechanism in the medulla. The neural route for this signal boost will be the focus of ongoing experiments.

64-3 SHARMA, VP*; SPONBERG, SN; Georgia Institute of Technology; *vsharma98@gatech.edu*
Context Dependent Sensing and Robust Integration of Visual and Mechanosensory Stimuli in Hover-Feeding Hawk Moths
Insects exhibit robust goal-tracking behavior in a range of environmental conditions. In the presence of redundant, parallel sensory information, how does multimodal integration depend on environmental conditions, such as light-level? *Manduca sexta* (tobacco hawk moths) hover-feed under conditions ranging from moonlit nights (0.3 lux) to early twilight (300 lux). From earlier work on hover-feeding hawk moths at 0.3 lux, we know that mechanical and visual cues sum linearly in tracking, but mechanosensory gain is higher for slow movements and visual gain is higher for fast movements, an example of bandwidth separation. Visual processing delays depend on light level. Whether this bandwidth separation and linear integration remain true under high illuminance, or changes to accommodate the more salient visual inputs, was unknown. Hence, we studied hover-feeding behavior of *Manduca sexta* under high illuminance conditions (300 lux). Mechanical cues (to the proboscis) and visual cues (to the eyes) were provided, together and in conflict, using a two-part robotic flower. Frequency-domain system identification analysis showed that the high visual gain shifts the frequency crossover point between mechanical and visual modalities to lower frequencies. Nonetheless, the linear sum of the two conflict-responses matches the response to coherent flower motion. Hence, linearity is conserved irrespective of illuminance level, and the internal gain of visual cues is enhanced in the presence of a more salient visual environment. Parallel sensory inputs are modulated to achieve performance requirements, while maintaining linearity of the resulting behavior. This suggests that the underlying neural circuits are flexible, accommodating variable delays and sensitivity as light level changes, and robust in their integration.

59-8 SHARMA, PP*; ARANGO, CP; BALLESTEROS, JA; BRENNEIS, G; DILLY, GF; SETTON, EVW; WHEELER, WC; University of Wisconsin-Madison, Queensland Museum, University of Greifswald, California State University-Channel Islands, American Museum of Natural History; *prashant.sharma@wisc.edu*
Phylogenomic resolution of sea spider relationships via integration of phylogenetic data classes
Pycnogonida (sea spiders) is a fascinating group of marine arthropods renowned for their bizarre appearance and the widespread trait of exclusive paternal care of egg masses. The sister group to the remaining Chelicerata, the ca. 1350 known species of this lineage have an ancient origin, with crown-group body fossils present in the Silurian. However, higher-level phylogenetic relationships of sea spiders remain poorly understood, which has hindered inferences of morphological and developmental evolution, as well as estimation of divergence times. Previous efforts to infer the phylogenetic relationships of sea spiders have been hindered by the low informativeness of some Sanger-sequenced markers, the rarity of species in small-bodied families, and the pervasiveness of missing data in molecular phylogenetic matrices. To overcome these hurdles, we devised a phylogenomic approach to inferring sea spider relationships, capitalizing upon museum collections and sorted material from benthic surveys. Our sequencing strategy aimed to integrate several data classes, namely, ultraconserved elements, targeted exons, and mitochondrial genomes. Here, we show that integration of these data classes results in a robustly resolved basal phylogeny of sea spiders, with high nodal support for interfamilial relationships. We infer the age of crown-group Pycnogonida for the first time using internal fossil calibrations in a Bayesian inference framework. Finally, upon this temporal context, we contrast the different data partitions to identify which are the most informative for resolving relationships of varying phylogenetic depths.

43-4 SHARPE, SL*; UNGERER, MC; NIPPERT, JB; Kansas State University; *sharpes@ksu.edu*
Effects of Abiotic Stress Across Population in Wild Foxtail Millet Setaria viridis
BACKGROUND/QUESTION/METHODS Abiotic sources of stress, including drought, cold, and salinity, can substantially affect plant fitness and survival. This poses a significant threat to conservation, economic activities, and agriculture as climate change increases the stochasticity of temperature, precipitation, and availability of fresh water. Stress tolerance can vary widely between species and across differently adapted populations within a species. Environmental stress can decrease photosynthesis, diminish vegetative growth, and reduce reproductive allocation, each of which has serious consequences for agricultural and bio-energy crops. This research examines physiological and transcriptomic responses to abiotic stress across populations in the wild foxtail millet, *Setaria viridis*, a close relative of the agriculturally important foxtail millet, *Setaria italica*. We assessed differences in response to cold, drought, and salinity stress between two populations of *S. viridis* (one from China and one from Chile) in controlled greenhouse and cold room environments. RESULTS/CONCLUSIONS Physiological responses to drought stress, measured by photosynthetic rate, differed significantly between populations. Preliminary results indicate that plant response to cold stress at -5 degrees Celsius did not differ based on prior cold acclimation or population. We are awaiting sequencing data which will allow us to compare transcriptomic and phenotypic responses by quantifying up and down regulation of genes across treatment and population. Gene ontology analyses will be used to determine the function of genes that are significantly up or down regulated between groups. Ultimately, this research will help elucidate effects of population adaptation on abiotic stress response in a close relative of an important agricultural crop.

16-7 SHARPE, SL; Kansas State University; *sharpes@ksu.edu*
Creating LGBTQIA+ Inclusive Biology Curricula and Classrooms
LGBTQIA+ students in college biology classes often find their identities and experiences ignored or stigmatized, which can alienate these students from continuing to study biology and reaffirm harmful misconceptions about sex, gender, and sexuality for both these students and their heterosexual, cisgender peers. On a political and cultural level, the stigmatization and invalidation of queer, transgender, and intersex identities is often justified by appeals to the supposed biological immutability of sex binaries and the utility of heterosexual reproductive pairings. As scientists and educators, we have the opportunity to increase the inclusivity of our research, classrooms, and curricula by challenging these misconceptions while incorporating and exploring the diversity and complexity of sex, gender, and sexuality in human biology and across taxa. By developing intentional and inclusive biology classrooms and curricula, we can instill in our students an understanding that biology can serve as a source of empowerment for, rather than invalidation of, queer, transgender, and intersex individuals. Such efforts can play a crucial role in increasing retention of LGBTQIA+ students in the sciences and encourage innovative research on sex, gender, and sexuality across taxa.

P1-217 SHEA-VANTINE, CS*; KAJIURA, SM; PORTER, ME; GALLOWAY, KA; Florida Atlantic University ; *csheavantine2017@fau.edu*

Puncture performance of the barbs from the Atlantic stingray, Hypanus sabinus and the Bluntnose stingray, Hypanus say

Many animals have venomous structures for defense against predators, such as bee stingers, male platypus spurs, and lionfish spines. A diagnostic characteristic of stingrays in the Family Dasyatidae is the presence of a barb located on the tail and used for defense. Stingray barbs are composed of mineralized collagen and are partially serrated. Barb cross-sectional shape, serrated length, and number of serrations vary across taxa and are correlated with ecology. The goal of this project was to determine the puncture performance of barbs from the Atlantic stingray, *Hypanus sabinus* and the Bluntnose stingray, *Hypanus say*. We used an Instron E1000 materials tester to quantify the puncture and withdraw forces from porcine skin, a common model for human skin. We hypothesized that withdraw force would be greater than puncture force for both species due to the presence of the recurved serrations. To quantify puncture forces (N), barbs were oriented orthogonal to the skin and advanced at 30 mm min^{-1} until 20% of the total barb length embedded in the tissue. The withdraw forces (N) were quantified by raising the barb at 30 mm min^{-1} until the tip was no longer embedded into the porcine skin. We also incorporated micro-CT scanning to quantify the morphology of the barb as well as mineralization density. Preliminary data suggest that forces required for withdraw are larger than those needed for puncture, supporting our hypothesis. By investigating the puncture and withdraw mechanics of stingray barbs from two common coastal species, we can quantify outcomes of an interaction between a stingrays and their accidental targets, humans.

P1-190 SHELBURNE, EC; Fort Hays State University, Hays, KS; *ecshelburne@mail.fhsu.edu*

Something's Fishy: A Comparative Structural Analysis of the Feeding Morphology of the Fish Xiphactinus audax and Megalops atlanticus Using 2D and 3D Morphometrics

Xiphactinus audax was a large, predatory ichthyodectid fish that lived during the Late Cretaceous, from approximately 120 – 66 million years ago. It inhabited the Western Interior Seaway (WIS) – an epicontinental sea that extended from the Arctic Ocean to the Gulf of Mexico – where this top predator reached lengths of 6.0 m. *Megalops atlanticus* is an extant megalopid fish that inhabits both Atlantic coasts and the Gulf of Mexico. While not as imposing, *M. atlanticus* is nonetheless a hefty predator, reaching lengths of 3.0 m. Despite their temporal and phylogenetic distance, both species have superficial morphological similarities – notably their body shape and strongly supraterminal mouths. These two species are often noted as examples of convergent evolution, with *M. atlanticus* cited as a modern analog for *X. audax*. This study sought to quantify differences in the shape of the mandibular elements of these two fish species using both 2D and 3D landmark-based geometric morphometrics (GM) in order to assess claims of convergence. Landmark-based GM compares shape by statistically analyzing landmarks placed on homologous points between objects. A number of statistical procedures were carried out comparing shape differences between both complete skulls and individual elements. Results indicate considerable difference between the shape of both complete skulls and individual elements, suggesting differences in the feeding biomechanics between *X. audax* and *M. atlanticus*. These results also suggest a lack of convergence on a functional phenotype, indicating a re-assessment of what constitutes convergence and how it is detected – particularly in the fossil record – may be necessary.

44-1 SHIELDS-ESTRADA, AK*; CANNATELLA, DC; University of Texas at Austin; *ashieldsestrada@utexas.edu*

Near Infrared Reflectance & Thermoregulation in Epipedobates Poison Frogs

Adaptive variation in color reflects a suite of organismal specific traits and behaviors, ranging from warning signaling to thermoregulation. However, how this variation is partitioned within the spectrum of solar radiation (300-2500nm) and why, remains unknown. The near-infrared reflectance (NIR) spectrum (700-2500nm) compromises 55% of all solar irradiance, yet spectral reflectance is rarely measured outside of the UV or visible spectra. Furthermore, extensive animal insensitivity to near-infrared wavelengths, makes this spectrum an ideal candidate for understanding the role spectral reflectance plays in ectotherm thermal physiology. The NIR spectrum may be less constrained by selection for warning signaling, camouflage, and sexual signaling, and may instead largely reflect thermoregulatory requirements. Our work examines the relationship between NIR, visible spectral reflectance, and thermoregulation, in a clade of Epipedobates poison frogs exhibiting a diverse range of color variation and thermal habitat regimes. We measured spectral reflectance of cryptic and conspicuous species throughout western Ecuador across elevational and temperature gradients in both the visible and NIR spectra (400-1100nm), and measured critical thermal maxima & minima (CTmax & CTmin), desiccation rate, and body temperature of each individual. Our results show statistically significant differences between total reflectance in the NIR spectrum and the visible spectrum, indicating the possibility of different selective pressures on each spectrum, and emphasizing the need to consider multiple spectra when studying adaptive variation in color. Furthermore, we found inter-populational variation in CTmax, CTmin, desiccation rate, and body temperature that may illuminate NIR's role in thermoregulation.

P3-235 SHIIKI, NJ*; POWERS, DR; George Fox University; *nshiiki16@georgefox.edu*

Do Hummingbirds Select Perch Microclimates to Maximize Their Ability to Dissipate Heat?

During hovering hummingbirds generate large amounts of heat that must be dissipated to maintain normal body temperature. Hummingbirds have two physiological methods of dissipating heat, evaporative and passive heat loss. These methods appear to be insufficient when hummingbirds hover at ambient temperatures >35 °C likely requiring behavioral cooling while perching between hovering bouts. We predict that during warm parts of the day hummingbirds will select perching locations in cooler microclimates that 1) provide thermal gradients suitable for passive heat loss and 2) are relatively close to a food source to minimize hovering distance. We conducted this study in the Chiricahua Mountains of SE Arizona during summer 2019. We recorded perching locations, frequency of perch use and feeding, and feeding bout duration in black-chinned (*Archilocus alexandri*) and Rivoli's (*Eugenes fulgens*) hummingbirds, and blue-throated mountain-gems (*Lampornis clemenciae*). Ambient and operative temperatures of the study site as well as ambient temperature of common perching microclimates were recorded to characterize potential thermal gradients. Daytime operative temperatures ranged from 16°-46°C, which includes extended periods where passive heat dissipation is not possible. Hummingbirds used perches where ambient temperature was <35°C 2X more frequently than perches with higher ambient temperatures throughout the day. Perches in close proximity (within 2 m) to feeders were used frequently in the morning, but often experienced midday ambient temperatures >35 °C at which point they were largely abandoned. These data are consistent with the notion that hummingbirds select perches that support passive thermoregulation. Both perch microclimate and location appear important, but microclimate appears most important when operative temperature is >35°C.

68-5 SHORE, A*; SANDERS, K; CONETTA, D; CORREA, AMS; Rice University; *ashore@rice.edu*
Hypoxia and coral microbiomes: Linking field and experimental data
Reduction of dissolved oxygen (DO) in ocean surface waters is a consequence of both local (eutrophication) and global (ocean warming) stressors. Recently, acute conditions of low DO have been linked to mass mortality events on coral reefs. Few studies have investigated the impact of low DO events on coral microbiomes, which are important in coral health and tolerance to environmental stress. We present one of the first studies to examine coral microbiome responses to low DO, coupling field and lab results. In July 2016, benthic organisms on reefs at the Flower Garden Banks National Marine Sanctuary (FGBNMS, northwest Gulf of Mexico) experienced a Localized Mortality Event (LME), which was linked to encroachment of storm-generated floodwaters, up-welling, and low DO. We collected healthy and dying corals (*Orbicella faveolata*) and other dying organisms at the FGBNMS during the LME and during the next corresponding season with ‘normal' conditions (approximately two years after the LME). Many abiotic and biotic factors change when floodwaters interact with reef environments, making it difficult to disentangle the effects of low DO from co-occurring stressors. To further examine the immediate responses of *O. faveolata* to low DO in the absence of other stressors, we experimentally reduced DO directly (bubbling with N_2 gas) and indirectly (limiting gas exchange with the atmosphere). We then characterized coral-associated bacterial communities from field and experimental samples, and compared the long-term response of corals collected from the FGBNMS to the short-term response seen in experiments. A better understanding of the resiliency of reef-building corals to low DO is important given the significant threat of ocean deoxygenation.

94-3 SHORT, RA*; LAWING, AM; Texas A&M University, College Station; *rachel.a.short@tamu.edu*
Locomotor morphology of ungulate communities as an environmental predictor
Ecometric methods capture functional trait-environment relationships at the community-level and can be applied to fossil and future assemblages to understand change through time. We developed an ecometric model using the calcaneal gear ratio of ungulates across the globe. The gear ratio is a measurement of the overall length of the calcaneum divided by the length of the in-lever, i.e. calcaneal tuber. A low gear ratio indicates a long in-lever and a more plantigrade stance, e.g. pygmy hippo, whereas a high gear ratio indicates a short in-lever and a more unguligrade stance, e.g. steenbok. We tested the hypothesis that communities exhibiting higher gear ratios tend to occur in hot, dry, open habitats, whereas communities exhibiting lower gear ratios occur in cool, wet, closed habitats. We sampled ungulate species composition, mean and standard deviation of gear ratio, and environmental variables, including temperature, precipitation, and vegetation cover, at 50 km equidistant points across the globe (180 species and 53922 points). To discern relationships between morphology and environment, we calculated the most likely environment given community values of gear ratio. Anomalies between the observed and estimated values were used to evaluate ecometric models. For logged precipitation, anomalies ranged between 3.98 and -5.39 mm. With this ecometric framework, fossils of ungulate postcrania can be used to interpret paleoenvironment for a more comprehensive understanding of the past. These relationships between community morphology and environment will enable better models of biotic responses for conservation under changing environments.

P3-200 SHRESTHA, S*; TUNG, J; GRINSHPON, RD; SWARTZ, P; HAMILTON, PT; MYDLARZ, L; CLARK, AC; University of Texas at Arlington, Arlington, TX, North Carolina State University, Raleigh, NC, North Carolina State University, Raleigh, NC; *suman.shrestha2@uta.edu*
Caspases from Scleractinian Coral Show Unique Regulatory Features
Coral undergo bleaching when polyps expel endosymbionts as a response to stress, which is usually followed by cell death. Cnidaria contain complex apoptotic signaling pathways, but the mechanisms leading to cell death are largely unexplored. We examined two caspases each from *Orbicella faveolata* (OfCasp3a and OfCasp3b), a disease-sensitive stony coral, and from *Porites astreoides* (PaCasp7a and PaCasp3), a disease-resistance stony coral. The four caspases are predicted homologs of human caspases-3 and -7, but OfCasp3a and PaCasp7a also contain an N-terminal caspase activation and recruitment domain (CARD) similar to those of human initiator caspases. Using substrate-phage display assays, we show that OfCasp3a and PaCasp7a are DxxDases, like human caspases-3 and -7. In contrast, OfCasp3b and PaCasp3 are more similar to human caspase-6, with VxxDase activity. Our biochemical analyses suggest a unique mechanism in coral in which the CARD-caspase-7 may be activated on death platforms in response to stress, and that the protease then directly activates the VxxDase. We also report the first X-ray crystal structure of a coral caspase that of PaCasp7a determined at 1.57Å resolution. The structure reveals the overall conservation of the caspase-hemoglobinase fold in coral as well as an N-terminal peptide bound near the active site that may serve as a regulatory exosite. The exosite has been observed in initiator caspases of other species, suggesting mechanisms for the evolution of substrate selection while maintaining common activation mechanisms of CARD-mediated dimerization.

76-6 SIDDALL, RJD*; JUSUFI, A; Max Planck Institute for Intelligent Systems; *rob@is.mpg.de*
Modulation of Cranio-Caudal mass distribution facilitates obstacle traversal in a cursorial biorobotic model
From the long necks of giraffes and hyenas, to the large tails of crocodilians, terrestrial animals display a broad diversity of body plans. Additionally, ecological situations such as the carrying of prey, caudal autotomy, offspring, undigested food, or pregnancy will each affect the distribution of mass. We seek to gain insight into how animals may use cranio-caudal mass redistribution to reject disturbances as they navigate uneven terrain. To do so, we have performed experiments using a robophysical model with adjustable mass distribution. In our biorobotic experiment, weights equal to 10% total mass are placed on elastic suspensions at varying distances, simulating the effect of ‘head' or ‘tail'-biased mass distribution. The performance of the robot traversing an obstacle is then recorded in a variety of configurations, including both legged locomotion with compliant whegs, highly damped airless tires, and wheels. The accumulated results of 126 trials indicate that massive passive tails (without ground contact) can have a destabilizing effect, while head mass enhances traction and suppresses perturbation in many cases. Based on this, the experiment is being expanded to appendages with an active response, moving mass and increasing inertia in response to sensing. Preliminary results from the pilot study suggest active modulation in anticipation of an obstacle, such as a hurdle, will control body attitude, resulting in reduction of undesired oscillations with respect to the cranio-caudal axis (body pitch). This study shows the advantages of mass redistribution in dynamic locomotion, and offers insight into the diversity of evolved body plans, and the use of robophysical models as instruments of discovery.

P2-1 SIDEBOTTOM, RB*; MARTIN, GG; Occidental College, Los Angeles, CA; *rsidebottom@oxy.edu*

Is That a Basal Lamina Lining the Open Circulatory System of a Shrimp?

Arthropods are most notably differentiated by their open circulatory system, where vessels extend from the heart but eventually end, allowing hemolymph to flow into sinuses. The organs in the body of arthropods are directly bathed with hemolymph until the fluid returns to the heart. In crustaceans, the lining of the vessels and hemal spaces is often coined a basal lamina, despite obvious differences from the acellular layers more thoroughly studied in vertebrate systems. In the latter, the basal lamina lies beneath the epithelium and is composed of type IV collagen and a collection of proteoglycans such as laminin. Exposure of the basal lamina is one trigger for blood coagulation. Previous studies have demonstrated fibrillin in the acellular layer lining major vessels in the lobster and have begun to address the extracellular matrix in several invertebrates. Our study has used electron microscopy to characterize the basal lamina of large and small vessels as well as the lining of hemal spaces within and on the outside of the heart, muscles, and gut of the shrimp *Sicyonia ingentis* and a variety of other crustaceans. Immunofluorescent staining of these areas with antibodies to type IV collagen and fibrillin identified the materials "seen" by circulating hemocytes and show that exposure to the "basal lamina" is an important step in identifying what these organisms consider self vs non-self.

P3-174 SIEBER, KR*; ZLOTNIK, S; MILLER, CW; University of Florida; *krsieber@gmail.com*

Feeding Facilitation and its Impacts on Mouthpart Development in the Leaf-Footed Bug, Narnia femorata

Animals are often less successful in acquiring food resources as juveniles than as adults even though nutrition plays a critical role in juvenile development and survival. Juveniles without fully developed mouthparts or other feeding morphology may thus suffer nutritional limitations that can only be overcome when an adult is present in the local environment. Here we examine the morphological development of juvenile leaf-footed cactus bugs, *Narnia femorata* (Hemiptera: Coreidae), in environments with and without adults present. This species does not exhibit parental care, yet juveniles may experience a feeding trait limitation as their piercing-sucking mouthparts are much smaller than those of adults. We hypothesize that juveniles benefit from the presence of adult conspecifics by reusing the semi-permanent "feeding holes" the adults create, thus overcoming their own limited ability to pierce fruit. These nutritional resources may also impact the morphological development of juvenile mouthparts, which are known to be highly plastic. To investigate this hypothesis, we raised juvenile leaf-footed bugs in groups containing either an unrelated adult or no adult. We monitored the survival rates of each group and took body and mouthpart measurements after the juveniles became adults. Our study aids in our understanding of the impacts of social factors on animal development and the strategies juvenile animals use to overcome environmental challenges.

P3-12 SILVA, MA*; CHO, A; IBARRA, JN; NAQUIN, TE; TEEPLE, JB; WHITTEMORE, KS; HOESE, WJ; BURNAFORD, JL; CARRILLO, A; LEIGH, S; California State University Fullerton, CSU Fullerton, Cabrillo Marine Aquarium; *Mayrasilva22212@csu.fullerton.edu*

Bust A Move: Movement of Microplastics Through Open Water Marine Trophic Levels

In the oceans, plastic waste breaks down into microplastics (<5mm diameter) that may be ingested by prey organisms and transferred up trophic levels to their predators, disrupting food webs. We hypothesized that microplastics consumed by brine shrimp, *Artemia salina*, could move up the food web to the predatory moon jelly, *Aurelia aurita*. We compared ingestion and gut progression of 90um diameter polypropylene pieces and fish flakes in *Artemia* over 120 minutes and found no significant differences in the consumption or the rate of progression through the gut. To determine whether jellies themselves consume plastics, we compared ingestion of microplastics in four suspension feeding treatments: (plastic alone, *Artemia*, *Artemia* + plastic, plastic-fed *Artemia*) and two gavage treatments (plastic alone, plastic-fed *Artemia*). Jellies did not eat plastic alone but after two hours we did observe plastic in 100% of jellies in the *Artemia* + plastic treatment. While we observed plastic in 75% of gavage-fed jellies after two hours, after four hours jellies had cleared their guts of plastic. In contrast, after four hours 100% of gavage-fed jellies in the plastic-fed *Artemia* treatment still contained plastic. Plastic can move across trophic levels from brine shrimp to jellies and has the potential to move further up trophic levels in ocean systems.

P1-3 SILVA, MAP*; NAKANISHI, N; University of Arkansas; *magostin@uark.edu*

Assessing the Function of the POU-Domain Transcription Factor Pit-1 During Development of the Cnidarian Nematostella vectensis

The class I POU-domain transcription factor, POU-I (Pit-1), has an ancient evolutionary origin at the base of animals, but was later lost in protostome bilaterian lineages (e.g. *Drosophila* and *C. elegans*). Pit-1 plays an essential role in the development of the vertebrate anterior pituitary gland by regulating differentiation of peptide-hormone-producing cell types, but its ancestral function basal to vertebrates is poorly understood. In amphioxus, Pit-1 is expressed in the pre-oral organ which is believed to be a chemosensory and neurosecretory organ homologous to the adenohypophysis, and in the scyphozoan cnidarian, *Aurelia sp.1*, Pit-1 is expressed in a subset of sensory cells in the ectoderm of rhopalia (sensory organs). These comparative gene expression data raise the possibility that Pit-1 directed differentiation of sensory cells in the last common ancestor of Cnidaria and Bilateria. To further examine this hypothesis, we are analyzing the developmental expression pattern and function of Pit-1 in the anthozoan cnidarian *Nematostella vectensis*, by using in-situ hybridization, immunohistochemistry and CRISPR-Cas9-mediated targeted mutagenesis. We find that during the planula stage Pit-1 is expressed throughout the endoderm, and, at tentacle-bud and polyp stages its expression becomes restricted to ectodermal sensory cells in the tentacles. These data are consistent with Pit-1 having a role in differentiation of sensory cell types. We are currently characterizing the subpopulations of Pit-1 positive cells and generating knockout animals to test whether Pit-1 is necessary to regulate the differentiation of sensory cells in anthozoans. Further investigation is required to clarify if Pit-1^+ cells of *Nematostella vectensis* produce growth-related hormones and neuropeptides as seen in chordates.

P3-226 SILVERTHORN, DU; SILVERTHORN, Dee; University of Texas at Austin; *silverthorn@utexas.edu*

Teaching Epithelial Transport as a Core Concept in Physiology

Epithelial transport is an ideal subject for teaching basic biological concepts, including homeostasis, compartmentation, cell membrane transport, cell-cell communication, flow down gradients, and energy use. Teaching the principles of epithelial transport can also help correct common misconceptions, such as the idea that only nerve and muscle generate electrical potentials. Too often students learning the physiology of osmoregulatory and digestive organs try to memorize each cell as if it were a separate entity, when there are recurring patterns of gradients and transporters found in diverse tissues. This presentation will discuss how to teach epithelial transport as a core concept rather than a series of unrelated cells in various organ systems. Using compartmental models, transcellular and paracellular pathways, and various combinations of membrane transporters requires students to think about energy, flow, and gradients and challenges them to apply their understanding of basic transport principles.

S2-6 SILVESTRE, F*; CARION, A; CHAPELLE, V; VOISIN, A-S; FELLOUS, A; SUAREZ-ULLOA, V; MARKAY, A; HETRU, J; GOUJON, V; WAUTHIER, E; CHATTERJEE, A; EARLEY, RL; University of Namur, Belgium, University of Otago, Dunedin, New Zealand, University of Alabama, Tuscaloosa, USA; *frederic.silvestre@unamur.be*

The Self-Fertilizing Mangrove Rivulus as a Model Species in Environmental Epigenetics

There is an increasing body of evidence that epigenetic variation can contribute to phenotypic changes in a population. A deeper understanding of the roles of epigenetics in phenotypic diversity and in organism adaptation and evolution can only be achieved in individuals that are genetically identical but naturally exhibit a range of heritable phenotypes. For that purpose, the mangrove rivulus, *Kryptolebias marmoratus*, is a precious model. Closely associated with red mangroves from Florida to South America, it shows numerous adaptations that facilitate survival in environments with considerable variability. Its main biological particularity is its mixed-mating reproductive system wherein hermaphrodites can either fertilize their own eggs or mate with males. Depending on the geographical region, the ratio between hermaphrodites and males varies alongside selfing rates, which directly affects genetic diversity. Here, we characterized DNA methylation in adults and during embryogenesis. Differentially methylated fragments were associated with specific behavioral traits such as boldness and aggressiveness. Effects of exposure to different environmental contaminants, such as neurotoxic compounds or endocrine disrupting chemicals were assessed to investigate relationships between DNA methylation and phenotypic variation. Collectively, our research has demonstrated extensive opportunity for epigenetic change during early life, which might underlie the diversity of phenotypes exhibited both within and among genotypes.

P2-45 SIMMONS, J*; FARINA, S; Howard University; *simmonsjam@icloud.com*

Mapping the Evolution of the Urohyal and Gill Chambers in Flatfishes Using Micro-CT

Background: Flatfish (Pleuronectiformes) are characterized by asymmetry of the skull, with both eyes on one side of the head. Flatfish lay with their ‘blind' side facing the sediment and ‘eyed' side facing upward, using the pigmented, eyed side to blend into the sediment of the ocean floor beneath them. The urohyal is an ossified tendon of the sternohyoideus muscle, which attaches anteriorly to the hyoid. In ray-finned fish, this bone plays a large role in the mechanism responsible for the opening of the mouth. In flatfish, this bone also forms a channel between the left and right gill chambers, with branchiostegals on either side, allowing for water to pass between the chambers. Micro-CT scans of flatfish species were analyzed to collect data on the morphological variation of the urohyal, including whether or not it is attached to the hyoid, the number of branchiostegal rays surrounding the structure, size of the opercular bones, and the size and shape of the dorsal and ventral forks of the urohyal. We mapped these traits onto the Fish Tree of Life phylogeny to understand the evolution of traits and describe patterns based on burying behavior, habitat, and diet.

105-3 SIMON, MN*; BRANDT, R; KOHLSDORF, T; MARROIG, G; University of Sao Paulo; *monique.simon@usp.br*

Linking Phenotypic Modularity to Directional Selection on Multiple Functional Performances

A better comprehension of the evolution of complex multivariate phenotypes can be achieved by unravelling the factors that shape trait correlations and modularity. An underexplored question is how directional selection on multiple functions contributes to phenotypic modularity. We hypothesized that combinations of traits describing the pattern of trait modularity would be under directional selection associated with performance, reflecting potential functional trade-offs. We tested this hypothesis using the lizard *Tropidurus catalanensis*, for which four locomotor performances were measured - climbing, grasping, sprinting and exertion - and a trade-off between grasping and exertion was found. We estimated selection as linear performance gradients of hindlimb traits (bones and muscles) on the four performances, using original traits and eigenvectors of the phenotypic correlation matrix (P-matrix). We expected the same eigenvector to show significant performance gradients for grasping and exertion, but with opposing signs. We found that two eigenvectors of the P-matrix, allometric size and a contrast involving the thigh muscle, are under significant directional selection associated with grasping, sprinting and exertion. Also, allometric size shows opposing signs of performance gradient associated with grasping and exertion, indicating conflicting selection. However, the most apparent modular signal (bone x muscle contrast) was not under significant directional selection, but instead seems to match developmental processes. Our results indicate that directional selection on different performances can reduce or increase phenotypic modularity depending on which combinations of traits affects each performance.

113-6 SIMONITIS, LE*; MARSHALL, CD; Texas A&M University at Galveston, Texas A&M University at Galveston, Texas A&M University; *laureneve@tamu.edu*

A Natural Occurring Shark Repellent: Ink has a Negative Effect on Shark Swimming Behavior

Inking is an antipredator defense system which affects predators visually (as a smoke screen) and chemically (as a deterrent). As a chemical deterrent, ink is thought to either disrupt the reception of chemicals or act aversively to a predator's chemosensory systems. The use of ink as a defense is known for a variety of animals such as sea hares, cephalopods, and even whales. We hypothesized that ink acts as a chemical deterrent, negatively impacting the normal swimming behavior of bonnethead sharks. 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*). Sharks (n=7) were individually placed in a circular mesocosm with a GoPro camera mounted overhead. Locomotory kinematic variables (e.g. angular velocity, angle of deviation, seconds to max deviation, distance of max deviation, etc.) were recorded in response to each of the experimental treatments: the three inks, food odor (to test for a positive response), food coloring (to control for color), and sea water (to control for mechanosensory stimulation). Food odor provoked a significantly positive effect while all three inks elicited significant negative responses in at least one of the kinematic variables. These data confirm that ink negatively impacts shark swimming behavior. Future studies will address the ability of ink to deter a predation event, the chemical makeup of the ink, and the electrophysiological reaction of shark olfactory systems to ink.

36-6 SIMPSON, DY*; TELEMECO, R; LANGKILDE, T; SCHWARTZ, TS; Auburn University , California State University, Fresno, Pennsylvania State University; *dys0004@tigermail.auburn.edu*

Differential Gene Expression to heat or fire ant envenomation in Sceloporus undulatus

Environmental stressors 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 ecology, and life history evolution. We have developed a high-quality reference genome that furthers the 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.

P2-234 SINGH, K*; HIDALGO, F; BERG, O; LAW, D; MüLLER, UK ; California State University, Fresno, University of California, Berkley; *krizmasingh@mail.fresnostate.edu*

Building a mechanical model of a tiny suction feeder to explore its performance landscape

Bladderworts, aquatic carnivorous plants, use specialized traps (with a mouth opening of about 0.2mm in diameter) to complete their feeding strike in less than a millisecond after the prey triggers it. Suction feeding is well understood in animals with sizes greater than 1 centimeter and the little we know about small suction feeders from larval fish suggests that small suction feeders are not effective. Yet bladderworts have strong suction performances despite having the same mouth size as that of fish larvae. Previous studies of bladderwort suction feeding have focused on the trap door mechanics rather than the mechanics of fluid flow. As bladderwort suction flows are difficult to study due to the traps' small size and fast prey capture feeding strike, we use a dynamically scaled mechanical model of the bladderwort trap. This model allows us to study hydrodynamic performance in greater detail by generating suction flows with a higher temporal and spatial resolution. The mechanical 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 (PIV) to quantify flow and pressure fields by filming the flows with high-speed cameras. We simulate strike kinematics of actual traps as well as counterfactual scenarios of traps that are smaller and slower than real traps to explore how peak pressure and time to peak pressure affect suction performance. Our findings largely agree with theoretical models of suction flows, which show that pressure has a strong effect on flow speed. This dynamically scaled mechanical model is a valuable tool to address bio fluid-dynamic questions as it allows us to tease apart the role of pressure and time to peak pressure in generating fast, high pressure-gradient flows.

S4-4 SIROT, L.K.; The College of Wooster; *lsirot@wooster.edu*

Opportunities for Female Modulation of Seminal Fluid Molecules

In many animal species, seminal fluid molecules (SFMs) influence female post-mating processes that affect reproductive success. SFMs have been most thoroughly studied in insects in which the affected processes include: egg development, sperm use, mating behavior, attractiveness, and lifespan. The magnitude of the effects of SFMs can be quite variable, even within inbred strains. This variation is important because it could impact post-copulatory reproductive outcomes. One likely cause of this variation is modulation by males or females of the quantities or qualities (e.g., stability or activity state) of SFMs, or, in the case of females, of their sensitivity to SFMs. Here, I review opportunities for SFM modulation by males and females, with a special emphasis on providing a framework for understanding the stages at which there is evidence for female control of the effects of SFMs. These stages occur during, after, and in between copulations and include behavioral, physiological, and biochemical mechanisms. I propose that these processes could provide mechanisms by which information received before and during copulation influences post-copulatory reproductive success and suggest ideas for future research in this area.

43-1 SIROVY, KA*; KELLY, MW; JOHNSON, KM; 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.

P2-172 SKELTON, ZR*; WEGNER, NC; PRINZING, TS; HASTINGS, PA; University of California, San Diego, Southwest Fisheries Science Center, NOAA Fisheries , Simon Fraser University, University of California, San Diego; *zskelton@ucsd.edu*

Comparison of Temperature Preference and Q_{10} Between Two Juvenile Shark Species

Many ectotherms, including sharks, behaviorally thermoregulate to optimize physiological processes. Juvenile sharks often utilize estuaries as nursery grounds, that, among other benefits, provide warm water temperatures that increase metabolism and facilitate growth. Discerning how temperature influences the behavior and physiology at the juvenile life stage is important in understanding how environmental changes (e.g. human encroachment and climate change) may affect the distribution and movement of local species. Here we compare two abundant coastal species that possess contrasting activity levels: the benthic horn shark (*Heterodontus francisci*) and the demersal leopard shark (*Triakis semifasciata*). The aim of this study was to isolate temperature as a single variable to investigate the relationship of behavioral thermoregulation and metabolism. The objectives were threefold: 1) identify the temperatures juveniles prefer and avoid, 2) assess how temperature affects metabolism (Q_{10}) via measurements of oxygen consumption, and 3) compare between sexes and species. Both species exhibited increasing metabolic rates with increasing temperatures. Leopard sharks exhibited higher metabolic rates than horn sharks across all temperatures. However, horn sharks exhibited a higher overall Q_{10} suggesting they may experience greater metabolic stress traveling across thermal regimes. Our results suggest horn sharks are more likely to target environments closer to their preferred temperature than leopard sharks. Ultimately, this baseline assessment should be paired with future *in situ* tracking to elucidate the role of these parameters on habitat selection in juvenile sharks.

P1-203 SKONIECZNY, KL*; D'EMIC, MD; BURK, C; HOFFMANN, S; NYIT College of Osteopathic Medicine, Old Westbury, Adelphi University, Garden City , Northport High School, Northport; *kskoniec@nyit.edu*

Cementum Analysis for Age Estimation in Fossil Mammals: Micro-CT vs Histological Thin Sections

Cementum is a continuously growing tissue that anchors the periodontal ligament to the root surface. It is deposited annually and aside from age of the individual, has the potential to record life history parameters such as age at sexual maturity and nursing cycles. The fine increments of cementum are usually visualized through destructive histological sectioning. Here we explore the utility of micro-CT scanning in detecting cementum in fossils and compare it to traditional histologically thin sections. We sampled 7 teeth (1 incisor, 5 canines, and 1 premolar) of 6 individuals of the 55-million-year old mammal *Coryphodon* from the Bighorn Basin of Wyoming. Histological thin sections were sampled around the apical one third of the root and standard petrographic techniques were used to create ground thin sections. Specimens were micro-CT scanned either before or after thin sectioning on a Bruker SkyScan 1173 at 0.015-0.020 mm voxel resolution. Cementum lines were traced in Adobe illustrator (histological thin sections) or Amira (micro-CT data). Our results indicate that micro-CT is capable of detecting cementum growth lines in fossils. Preliminary data reveal one specimen with consistent cementum line numbers using both methodologies, while the remaining samples varied in clarity and number. This indicates that there may be a preservation bias in cases in which histology out performs micro-CT scans and vice versa. Sub-micron level resolution may be necessary to provide detail regarding the organization of cementum. Exploring the use of micro-CT technology is of great value due to its non-destructive nature and allowance for visualization in multiple planes.

24-5 SLAMA, SL*; SANDMEIER, FC; SHEEDY, MD; PAINTER, MN; Colorado State University Pueblo; *sadelbush@gmail.com*

Quantifying Phagocytic Activity of Lymphocytes in Ectotherms

We used blood samples from Mojave desert tortoises (*Gopherus agassizii*) to show that phagocytosis by lymphocytes occurs at a high but variable rate among individuals and can be quantified with and without species-specific reagents. Thus, this is an important new measure to add to the toolbox of ecological immunologists who are working with species of ectothermic vertebrates. Phagocytosis is an important aspect of innate immunity in which foreign elements are recognized by immune cells via receptors and are internalized, thereby clearing the body of potentially harmful pathogens. While lymphocytes are known to serve key functions within adaptive immunity, these cells have been previously shown to perform the innate immune function of phagocytosis in a wide variety of ectothermic vertebrates. These past studies have all relied on both expensive machinery and species-specific reagents. We optimized phagocytic assays for use in desert tortoises, using published protocols, species-specific reagents, fluorescent and confocal microscopy, and flow cytometry to verify and distinguish between innate binding of beads and true phagocytosis. However, we also show that simple Wright-Giemsa staining can be used to quantify binding and phagocytosis. Therefore, we show that this technique is widely applicable, with the recognition that some optimization-steps will need to be adjusted for use in different taxa. We offer suggestions for trouble-shooting optimization steps and hope to establish this technique as a common tool to assess immune function across species of ectothermic vertebrates.

P1-156 SLATTERY, JD*; RODRIGUEZ, IM; BILOTTA, AJ; WACKER, DW; University of Washington Bothell; *slattj@uw.edu*

Caw and Response: Context-Dependent Group Calling In American Crows

Research on cawing in American crows (*Corvus brachyrhynchos*) has often assessed the acoustic variation of isolated caw syllables emitted by individual crows. However, crows often emit syllables in bursts (i.e., multisyllabic calls) and sometimes call collectively in groups. How collective cawing may vary by context has not been well explored. In this study, we 1) examined the context-dependency of group calling in two aggregation types – mobbing and pre-roosting aggregations and 2) used playback of natural sounding crow call sequences to examine the function of pauses (i.e., the silence between successive calls) in crow vocal communication. We observed that, while controlling for the number of calls, average pause durations were significantly shorter during mobbing vs. in pre-roosting aggregations. Based on this finding, we combined recorded calls to create three different playback files where pause durations were randomized, accelerated, or decelerated, and played these files to crows on diurnal foraging areas. Decelerated playback led to significantly fewer movements towards the playback speaker and fewer crows within 30 m of the speaker compared to the randomized playback. Crows also did not as closely approach the speaker in response to decelerated vs. randomized playback. Post hoc tests did not reveal behavioral differences in response to accelerated vs. randomized or decelerated playbacks. These findings suggest that crows both alter collective calling across different contexts and use collective cues when responding to group calling.

14-5 SLEBODA, DA*; WOLD, ES; ROBERTS, TJ; Brown University, Providence, RI; *david_sleboda@brown.edu*

The Hydrostatic Skeleton of Muscle

Fluid accounts for over 70% of muscle mass, filling intracellular, extracellular, and capillary spaces. During normal physiological activity intramuscular fluid pressures develop as muscle exerts a portion of its developed force internally. These pressures, typically ranging between 10 and 250 mmHg, have the potential to influence force and work produced during contraction. Classic Hill-type models of muscle rarely incorporate fluid into their designs. Here we test a model of muscle structure in which intramuscular pressure directly influences muscle mechanics. Using a pneumatic cuff, we pressurized isolated bullfrog muscle mid-contraction at 5 psi (~260 mmHg) and measured the effect on isometric force. We compared the response of muscle to that of a simple physical model of muscle fiber and extracellular matrix morphology. Experimentally pressurizing isolated bullfrog muscle reduced isometric force at short muscle lengths (e.g. -11.87% of P_0 at 0.9 L_0), increased force at long lengths (e.g. +3.08% of P_0 at 1.25 L_0) but had no effect at intermediate lengths ~1.10-1.15 L_0. Our physical model qualitatively mimics this variable response, displaying negative, positive, or neutral responses to pressurization depending on the orientation of reinforcing fibers representing extracellular matrix collagen. Our findings show that pressurization can have immediate, significant effects on muscle contractile force and suggest that forces transmitted to the extracellular matrix via pressurized fluid may be important, but largely unacknowledged, determinants of muscle performance *in vivo*. The work draws parallels between muscle and the hydrostatic skeletons typical of soft-bodied animals and plants, and exemplifies the importance of emergent, multiscale mechanics in biological systems.

8-7 SLEVIN, MC*; FRESIN, W; CANNATARO, G; ANDERSON, RC; Florida Atlantic University; *mslevin2018@fau.edu*

Smarts and Symbiosis: Elucidating the Relationship between the Microbiome and Cognitive Performance in Birds

Recent years have seen a surge of research on the link between an individual's cognitive ability and its gut microbiome. With recent advances in understanding avian cognition, songbirds are an ideal system for investigating this relationship. In a captive Zebra Finch (*Taeniopygia guttata*) population of 42 adults, I quantified individual variation in performance on cognitive tasks (novel foraging, color association, and color reversal) that measure motor learning and memory, recording the number of trials needed to pass each task and error rate per trial. I sampled the gut microbiome via cloacal swab immediately prior to testing, sequenced the bacterial taxa present, and assessed diversity and relative abundance in each sample using Qiime2. There was high individual variation in cognitive performance, ranging from 22 to 80 trials needed to complete all three tasks (mean = 15.1 ± 1.4 trials for novel foraging, 9.4 ± 0.8 for color association, and 16.2 ± 0.9 for color reversal), with no sex difference for any task (all $P > 0.18$). Color association and reversal performance were correlated ($r = 0.3$, $P = 0.03$), but neither task was correlated with novel foraging performance ($r = -0.02$, $P = 0.9$). Finally, the slope of the per-trial error rate over the course of each color task was significantly correlated with the number of trials needed to complete the task ($r = 0.4$, $P = 0.003$). I will relate each bird's cognitive performance to its microbiome characteristics to test for evidence of a gut-brain axis. Our results from this model songbird species will build a foundation for future research, including understanding the microbiome during critical developmental stages (e.g., song learning) and in wild populations.

17-4 SMEDLEY, GD*; SERB, JM; Iowa State University; *gdsmedley13@gmail.com*

Molluscan Transcriptomes Suggest a More Complex Visual Cycle Homologous to Vertebrates

Photoreceptive organs have evolved as many as 65 times over the course of evolutionary history. Interestingly, nearly all light sensitive structures function via the same pathway of phototransduction. Phototransduction is a two step process which causes a conformational change of the photopigment upon light absorption and then requires resetting by reuptake or recycling of the bound retinal isomer. The latter half of the phototransductive pathway is known as the retinoid visual cycle. The molluscan visual cycle functions via retinochrome which photoisomerizes all-*trans* to 11-*cis* retinal by absorbing a photon and a shuttle protein transports the retinal isomers between the photoisomerase and the opsin. In vertebrates, retinal is recycled using shuttle proteins to transport the retinal between cell lines and through a well-characterized complex of enzymes for phototransduction or storage. Insects possess bistable opsins allowing retinal recycling within the opsin; however, recent studies have shown the enzymes of insects are homologous to those found in the vertebrate visual cycle. Changes in the understanding of the insect visual cycle and lack of a described non-light dependent molluscan visual cycle leads one to challenge the current simplicity of the molluscan visual cycle. To investigate this pathway in molluscs, published transcriptomes were searched for proteins involved in vertebrate or insect visual cycles. The results show the presence of RPE65, CRALBP, RDH5, and RDH12, in molluscan species, suggesting 1) molluscs possess a more complex visual cycle and 2) the origin of the retinoid visual cycle is before the protostome-deuterostome split.

122-3 SMITH, MG*; WESTGATE, AJ; KOOPMAN, HN; Harvard University, UNC Wilmington; *mollygablersmith@gmail.com*

Adipose tissue in diving animals: measuring the potential for gas exchange

Diving tetrapods are a biologically diverse group; however, they are all under similar constraints: oxygen limitation and increased hydrostatic pressure at depth. Adipose tissue is an interesting tissue to study, due to its physiologically important roles (e.g. metabolic energy storage, regulation of energy balance and thermoregulation) and because nitrogen (N_2) is 5 times more soluble in fat than in blood, creating a potential N_2 sink in animals consistently diving to depth. We examined the adipose tissue of diving tetrapods (3 species of seabirds, 3 sp. of sea turtles, 3 sp. of pinnipeds and 10 sp. of cetaceans), focusing on how adipose tissue structure allows these animals to cope with the physiological demands of diving. Adipose tissue microvessel density and diffusion distance were used to evaluate the comparative potential for aerobic activity (i.e. O_2 delivery). Long duration divers (i.e. beaked whales, > 120 min.) had relatively lower microvessel density (2.6 ± 0.5%) and greater diffusion distances (44.0 ± 13 µm), compared to short duration divers (e.g. eider ducks, < 2 min.; 4.4 ± 1.7% and 24.7 ± 9.9 µm). We hypothesize that beaked whale adipose tissue characteristics may function to minimize energetic costs during diving. Previous research indicates that lipid composition (lipid classes and short chained fatty acids [FA]) in some whales is an important factor determining N_2 solubility. However, there was no relationship between FA profile and N_2 solubility in the animals studied; species with similar FA profiles had different N_2 solubility values. The 3D structure of intact lipid molecules may elucidate the complex interactions between O_2, N_2 and lipid. Future studies should consider these interactions to better understand the physiological adaptations in diving animals.

P3-46 SMITH, JJ*; BALENGER, SL; University of Mississippi; *jjsmith5@go.olemiss.edu*

Costs of Immunity vs. Costs of Infection: Is the Relationship Between Humoral Immunity and Corticosterone Context Dependent?

Glucocorticoids (GC) exhibit varying effects on the immune system at different stages of infection. The relationship appears to be complex, with GCs having both stimulating and inhibitory effects. Numerous studies have found relationships between corticosterone and the immune system's ability to fight disease. The pathogenic bacterium *Mycoplasma gallisepticum* (MG) elicits an adaptive immune response in birds, in which B cells produce MG-specific antibodies to fight the infection and prevent reoccurrence. Previously, we found Eastern Bluebirds that produce the most antibodies in response to MG infection also have the highest corticosterone levels. This finding led us to ask whether corticosterone typically stimulates production of antibodies in response to any immune challenge, or if the nature and virulence of the challenge will influence the relationship between corticosterone production and humoral immunity. Here we examine the effects of corticosterone supplementation on Eastern Bluebirds following vaccination against MG. This experiment consisted of a control group that received neither a corticosterone supplement nor a vaccine, and three experimental groups that were either supplemented with corticosterone, injected with the killed vaccine, or given both treatments. We compare results from the current study utilizing a vaccine challenge with those of the previous study where birds were infected with the live pathogen. If both studies generate the same positive relationship, this suggests that corticosterone is stimulating the humoral immune system; if antibody production and corticosterone are negatively related in response to vaccination, this suggests that the nature of the relationship is dependent on factors associated with pathogen virulence.

84-4 SMITH, SM*; ANGIELCZYK, KD; KERBIS PETERHANS, JC; Field Museum of Natural History, Chicago, IL; *smsmith@fieldmuseum.org*

Vertebral number and spinal regionalization in large shrews (Soricidae)

In addition to having unique extra articulations on its vertebrae, the hero shrew (*Scutisorex*) is unusual in having almost twice as many lumbar vertebrae as other shrews of its size. Other than being noted in descriptive literature, this increase in vertebral number has received little attention; there has been no investigation of how it might reflect the elusive function of the highly modified *Scutisorex* spine. Comparisons of individual vertebrae and whole-column characteristics between *Scutisorex* and other large shrews are also lacking, despite the fact that such studies could give insight into i) function of particular vertebral regions in shrews with and without external vertebral modifications, and ii) developmental patterns driving regional proportions. We collected µCT scans and linear measurements of cervical, thoracic, and lumbar vertebrae in two species of *Scutisorex* and three other species of large shrews. We compared a variety of linear vertebra measurements, and trabecular bone characteristics of each centrum, across species. Further, using this combined suite of measurements, we executed principal coordinates analysis and segmented regression to detect unique vertebral regions in each taxon. Our results show that relative to other large shrews, *Scutisorex* has a shorter thoracic region and longer lumbar region, and, despite having more dorsal vertebrae than other species, does not have a proportionally longer body length. Regionalization signals vary within and across the five species, but generally suggest that functional regions may not correspond exactly with traditionally recognized anatomical regions of the column, and that the extended lumbar region in *Scutisorex* may afford it an additional functional region.

P3-122 SMITH, HJ; GOUGH, WT*; SAVOCA, MS; CZAPANSKIY, MF; FISH, FE; POTVIN, J; CADE, DE; BIERLICH, KC; KENNEDY, J; GOLDBOGEN, JA; Southwestern University, Stanford University, West Chester University, Saint Louis University, University of California, Santa Cruz, Duke University; *wgough@stanford.edu*

The Physics of Whale Movement: Drag and Thrust Production to Measure Whale Propulsive Efficiency

The group of whales known as the rorquals contains some of the largest animals that have ever lived. As a result, this group presents an interesting case study for examining how morphology at the extremes of body size can affect aspects of behavior such as locomotion as well as bioenergetics. Here, we explore how body size effects hydrodynamic factors such as thrust power and propulsive efficiency. The current study uses data from inertial whale-borne sensors to calculate kinematic parameters during normal and maximum effort swimming. By combining these data with morphometric measurements (i.e., total length, fluke area) taken from aerial drone footage, we have produced some of the first estimates of thrust power derived from direct kinematics measures. Absolute thrust power (watts) predictably increases with body size while our results for mass-specific thrust power per flukebeat during normal effort swimming showed no significant change between the smallest species in our dataset (minke; ~8m) and the largest (blue; ~25m). Maximum effort swimming, on the other hand, resulted in higher mass-specific thrust power for humpback whales than for blue whales. We also found that propulsive efficiency decreases slightly with increasing body size from humpback whales to blue whales. These results suggest that the unique morphology of the humpback whale (larger tail and flippers, a less streamlined body shape) impacts the thrust generation and overall performance of the species and could explain their more generalist foraging habits and highly maneuverable lifestyle.

P3-8 SMITH, TR*; MOORE, IT; HERNANDEZ, J; Virginia Tech, Blacksburg, VA; *taryn97@vt.edu*

Using buccal cells to estimate DNA damage associated with urbanization

Micronuclei are pieces of chromosomes that separate atypically from the group of chromosomes that aggregate in the nucleus during cell division. These micronuclei can be used as a measure of environmental damage to DNA experienced by the organism. We worked to develop an immunohistochemistry protocol to fluorescently tag micronuclei within buccal cells. Buccal cells divide rapidly, and thus are a good candidate for investigating cellular responses to environmental challenges. Buccal swabs were collected from adult Tree Swallows (*Tachycineta bicolor*) during the breeding season in western Virginia. A method was developed to optimize the concentration of cells that were transferred and fixed onto slides. These slides were then used to adapt the immunohistochemistry protocol for buccal cells. We will utilize immunohistochemistry moving forward to look at DNA damage, in the form of micronuclei, to provide a way to compare environmental effects on birds across different habitat types. The results of these future studies will add to our understanding of urbanization effects and highlight the importance of management systems to protect a variety of species.

P1-186 SMITH, SK*; HAKANSSON, J; FRAZEL, PW; LONG, MA; ELEMANS, CPH; PHELPS, SM; University of Texas Austin, University of Southern Denmark, NYU Langone; *samksmith@utexas.edu*

An Intralaryngeal Whistle Using an Elaborated Structure Enables Song in Alston's Singing Mouse

Most mammals produce sound via vocal fold vibration, in accordance with the myoelastic-aerodynamic theory. However, when lab mice produce ultrasonic vocalizations (USVs), they do not use vocal fold vibration, but instead produce self-sustained whistles where a glottal air jet impinges on an intralaryngeal structure. The tones are produced by a feedback loop between flow structures traveling downstream and acoustic waves traveling upstream in the flow. We examined sound production in Alston's singing mouse, *Scotinomys teguina*. This murid rodent produces a highly elaborate, stereotyped song consisting of rapidly-repeated, frequency-modulated notes that span from 43 to 10 kHz. We analyzed sound production in excised larynges that combined airflow modulation with sound recording and high-speed imaging. In a series of experimental manipulations, we identified the anatomical structures essential to sound production and manipulated laryngeal cartilages to imitate muscle action and identify how frequency is modulated. Along with *in vitro* manipulations, we used histology and µCT for morphometric analysis. We found that singing mice sing by producing a jet that impinges on the alar cartilage. However, unlike lab mice, singing mice require the inflation of a hypertrophied ventral pouch. *In vitro* manipulations show that frequency is set predominantly by jet speed, which can be modulated by changes in air flow and glottal area. Thus, the fine interplay of action of respiratory and laryngeal muscles, such as the cricothyroid, and thyroarytenoid, combine to control frequency.

3-4 SMITH, NM*; DICKERSON, AK; University of Central Florida; *smithni@knights.ucf.edu*

Mosquitoes use multiple bounces to engage landing zones

In this experimental study we film the landings of *Aedes aegypti* mosquitoes to characterize landing strategies and kinetics, limitations, and the passive physiological mechanics they employ to engage a surface. A typical landing on a vertical surface involves 1-2 bounces before the mosquito firmly affixes to a surface, which act to reduce inbound momentum by more than half. Mosquitoes initially approach landing surfaces at 0.2 - 0.6 m/s, decelerating to zero velocity in approximately 3 ms at accelerations as high as 13 gravities. Impacts are damped by deforming forelimbs and buckling of the proboscis, which also serves to distribute the impact force, lessening the potential of detection by a mammalian host. The incoming threshold velocity which produces rebound too vigorous for tarsal attachment was observed to be approximately 1.35 mph, indicating host motion is an effective deterrent against mosquito bites.

P1-163 SMITH, C*; REICHERT , M; Oklahoma State University ; *cheyenne.e.smith@okstate.edu*

Chemical Commuication and the effect of Calling Behavior in Hyla chrysoscelis

Multimodal communication is where an animal signals through more than one sensory channel. In most anurans, acoustic signals are the primary modality for reproductive communication. However, most anurans' displays are not only acoustic but in fact are multimodal (e.g. visual and acoustic). One modality that has received little attention is the chemical modality. Calling anurans are most likely exposed to chemical cues, but the relationship between chemicals and calling behavior is poorly known. Our goal with this experiment was to establish whether advertising male gray treefrogs (*Hyla chrysoscelis*) can sense chemical cues released from conspecifics in water and adjust their mating calls. In order to test this, we caught male *H. chrysoscelis* and put them into cages. We proceeded to spray them with water that either a male (male cue treatment) or female (female cue treatment) conspecific had been soaking in, or a distilled water control, while recording their calls. We have a total of 67 recordings between our 3 treatment groups. The chemical did not affect the likelihood that males continued to call (male cue: 20/21 called; female cue 17/20 called; control 22/26 called). We also tested whether our treatments had an effect on the males' call characteristics.

P1-105 SOLIE, SE*; JOHNSEN, S; Duke University;
sarah.solie@duke.edu

Contrast Sensitivity and Spatial Resolution in the Trinidadian Guppy (Poecilia reticulata)

Female Trinidadian guppies (*Poecilia reticulata*) are known to assess male sexual signals on the basis of pattern elements that vary in color, size, and contrast. While color vision in guppies has long been a subject of intense investigation, much less is known about their spatial resolution and contrast threshold. Here we present the results of optomotor experiments that exposed guppies to a large rotating visual field. Stimuli were comprised of alternating dark and light vertical bars that varied in spatial frequency (i.e. stripe width) as well as contrast. Optomotor performance was scored across five different spatial frequencies, each presented at seven different Michelson contrast values. Our results are presented as a contrast sensitivity function (CSF), which represents guppy contrast sensitivity as a function of spatial frequency. The CSF allows for an estimation of visual acuity and identifies the spatial frequencies to which a given visual system is maximally sensitive. Because spatial resolution and contrast sensitivity limit the details which can be resolved within a given scene, the CSF contributes to our understanding of the pattern elements which may be most salient within a visual signal. As such, our results are interpreted within the context of sexual signaling and pattern evolution in *Poecilia reticulata*.

P3-61 SOLIS, GM*; HUSAK, JF; University of St. Thomas;
soli8428@stthomas.edu

The Role of Aromatization in Male Brown Anole Sexual Behavior

Brown anole lizards pose a perplexing example of neural steroid regulation in reproductive behavior. While testosterone is perceived to be the crucial steroid in male aggression, the low baseline levels of testosterone in brown anoles are mismatched with their high levels of reproductive behaviors. Previous steroid manipulations in brown anoles generally showed variability in changes to behavior but suggested that an increase in testosterone did not directly increase aggression. This contributes to the question of how brown anoles support high aggression with low testosterone. Past studies with aromatization inhibitors were equivocal, making the role of estrogens in male sexual behavior unclear. Given that androgen levels are typically lower, it is feasible to consider estrogens as being the primary mediator in sexual behavior as in some other vertebrates. The process of aromatization converts androgens into estrogens, and the low levels of testosterone may suggest that estrogens play a larger role. To further understand the mechanism of reproductive behaviors in A. *sagrei*, experimentation with the factors of the aromatization process was conducted. We exposed 40 male lizards to either flutamide (anti-androgen), estradiol, fadrozole (aromatase inhibitor) or control treatments (10 in each group) for 5 days. We then conducted behavioral trials through 20-minute side-by-side introductions of both an intruding male for aggression and (separately) a female for courtship stimulus. We expected that flutamide and fadrozole would decrease reproductive behaviors. We describe how each treatment helps understand the role of androgens and estrogens in regulating male aggression and courtship behavior in brown anoles.

125-3 SOLLA, AL*; O'ROURKE, C; ANDERSON, A; RENN, SCP; Reed College; *solla.auror@reed.edu*

Secret's in the Sauce: Hormones and Behavior in Julidochromis marlieri

Julidochromis marlieri, a socially plastic African cichlid, naturally establishes pair bonds between relatively larger and more aggressive dominant females and smaller subordinate males in both the wild and in the lab. However, these fish will also form pairs with a relatively larger male and a smaller female, and exhibit a reversal of their natural sex-biased behaviors. Here we investigate the hormonal profiles associated this plastic switch in social behavior. We collected gonadal hormones and behavioral measurements from male and female *J. marlieri* in both dominant and subordinate conditions over several weeks. Analysis of three sex hormones—17β-estradiol, testosterone, and 11-keto testosterone—showed that 11-keto testosterone concentration correlated positively with increased dominance and aggression in both males and females, with no significant correlation found between dominance and testosterone or 17β-estradiol in either sex. This further expands the importance of 11-keto testosterone in teleost social behavior, and illuminates the appropriate hormone for further manipulation and functional analysis in *J. marlieri*.

84-1 SOMBKE, A*; MUELLER, CHG; University of Vienna, Department of Integrative Zoology, University of Greifswald, Zoological Institute and Museum ; *andy.sombke@univie.ac.at*

Evolutionary transformations of centipede ultimate legs

In comparison to locomotory legs, the last pair of legs in Chilopoda – the ultimate legs – is particularly unique as no other legs in centipedes show a comparable functional, morphological, and behavioral diversity. These evolutionary transformed appendages are never or only rarely used for locomotion and can exhibit different morphologies associated with different functions. Sexual dimorphic characteristics suggest that ultimate legs play a pivotal role in intraspecific communication, mate finding and courtship behavior. Thus, centipede ultimate legs provide an excellent opportunity to explore diverse pathways of leg transformations. Ultimate legs in Scutigeromorpha (house centipedes) are extremely elongated and resemble antennae. The diversity, abundance and distribution of sensory structures, their association with elaborated primary processing centers in the nervous system, as well as electrophysiological experiments strongly suggest that these multi-annulated legs function as sensory appendages at the posterior end of the body. In Geophilomorpha (soil centipedes), ultimate legs may be sexually dimorphic and frequently covered with thousands of cuticular structures. However, these hairs do not resemble sensilla, but shafts of glandular structures. Thus, geophilomorph ultimate legs evolved a secretory function of yet unknown relevance. We show that centipede ultimate leg transformations are by no means restricted to external morphology, but that this particular centipede character was subjected to a cascade of adaptations.

13-1 SOMJEE, U*; ANZALDO, S; MARTING, PM; PAINTING, CJ; POWELL, E; HICKEY, T; Smithsonian Tropical Research Institute, Panama, Arizona State University, USA, University of Auckland, New Zealand, University of Waikato, New Zealand; *ummat.s@gmail.com*

Extreme size variation in an armed weevil sheds light on the relationship between body mass and metabolic rate

The relatively low metabolic rates of larger organisms compared to small organisms is among the most pervasive trends in biology. Yet, most studies that examine the relationship between body mass and metabolic rate are conducted across species. Here we examine resting and recovery metabolic rates in a species of brentine weevil that vary more than an order of magnitude in size among adults. These weevils also exhibit extreme positive allometry of their sexually selected rostra, used as weapons during male-male contests; larger male carry proportionally larger weapons for their body size. We find resting metabolic rates scales with a similar slope as those found across species, consistent with low metabolic scaling. Metabolic rates after sustained activity were higher in all individuals yet scaled with the same hypo-allometric relationship with body size as during rest. Further, cuticle tissue of the weapon scales in direct proportion to mass of the weapon, while soft tissue within the weapon scales with low allometry. These results suggest that as these weapons get larger in size they are comprised of a proportionally higher mass of metabolically inactive structural tissue and proportionally less active metabolic tissue. Our findings reveal the low scaling of metabolic rate in a single species is consistent with across species trends, and that larger individuals carry disproportionally larger weapons but likely at a reduced metabolic cost per gram of tissue.

13-3 SORLIN , MV*; MARKS, JR; JOHNSON, MA; HUSAK, JF; LAILVAUX, SP; University of New Orleans, LA, Trinity University, San Antonio, TX, University of Saint Thomas, Saint Paul, MN ; *mvsorlin@uno.edu*

Effect of Exercise Training on Brain Allometry and Cognitive Abilities in Anolis carolinensis

Brain size is highly variable across the animal kingdom. Multiple studies investigating this variation point at a correlation between cognitive abilities, brain mass and performance enhancement. For instance, performance enhancement lead to the general increase in brain volume in humans and hippocampal neurogenesis in mice. However, vertebrates outside of the mammalian clade have received very little attention, making it difficult to distinguish general evolutionary patterns across taxa. In order to address this gap, we investigated the effect of training exercise on cognitive abilities and brain allometry in a species of lizard (*Anolis carolinensis*). Individuals were trained for both endurance and sprint for an extended period of time. Following this treatment, they were subjected to a cognitive test using spatial recognition. We hypothesize that trained individuals will demonstrate higher navigational skills than untrained lizards as well as potentially exhibit an increase in brain size compare to individuals from the control group.

139-2 SOTO, D*; GOLDMAN, DI; Georgia Institute of Technology; *dsoto7@gatech.edu*

Improving performance of a legged robot on bumpy ground via gentle tail taps

Robot locomotion on uneven terrain is typically assumed to require complex sensing, control and planning. However, discoveries of the role of mechanics and nonlinear dynamics in running animals and legged robots indicate that stabilization and performance increases can be facilitated via leveraging of non-locomotor structures. Here we examine how an open-loop controlled tail affects performance of a legged robot on uneven terrain. We constructed a RHex-type quadruped robot (L=27cm, m=2.8kg) with compliant C-legs (d=8cm) and a tail (L=20cm, m=0.4kg). Each leg was controlled via a cascaded PID position-velocity control system, with setpoints determined by the duty factor and phase lag of a chosen gait. A landscape consisting of a Gaussian height distribution of 128 blocks (h=0-10cm, w=5cm) generated failures in no-tail robot by either catching a leg or trapping the robot on its belly. We first tested two tail behaviors which we hypothesized would improve performance. The first maintained a constant angle with the body, essentially adding a fifth point of support, and the second oscillated the tail periodically, resulting in intermittent ground contact. In all tests, stability (the average summed roll and pitch of the robot), energy cost (average current draw), and success probability (full transit across the testbed) were measured. In 106 total trials, both tail strategies improved the success probability from 60% (no tail) to 90-100%. Constant angle led to stable locomotion (average of 5.5°) but with high energy cost (0.7A), whereas tapping displayed higher instability (9°) but lower energy costs (0.5A). A "gentle tap" strategy which combined both behaviors demonstrated high success probability (100%), good stability (5.7°), and low energy cost (0.35A), thereby improving locomotor performance with minimal control additions.

34-1 SPAGNA, JC*; ESPINOSA, AJ; CREWS, SC; William Paterson University, California Academy of Sciences; *spagnaj@wpunj.edu*

Grass Spiders of North America and Europe: A Long-Distance Relationship Lasting 50 Million Years

The grass spider subfamily Ageleninae (Araneae: Agelenidae) is distributed throughout North America. However, in the western part of the distribution, they are incredibly species rich with 129 species in 10 genera endemic to the region. However, other North American agelenine taxa with widespread and Gulf/Caribbean distributions (3 genera, 28 species) are clearly diverged morphologically from the Western taxa, based on spinneret shape and male genitalia. The affinities of the North American taxa with worldwide Agelenidae, particularly the Eurasian taxa, have been difficult to decipher. Here we attempt to test both the monophyly of the North American taxa and their relationships to worldwide taxa. To answer these two questions we analyzed genetic data from targeted genes using Bayesian likelihood to construct a phylogenetic hypothesis. A monophyletic relationship between the western and eastern North American groups was not recovered, and the eastern North American group is more closely related to the Eurasian taxa. Additional analyses using molecular clock estimates for the age of the subfamily (~50 MY) disallow an obvious vicariant event induced from the opening of the Atlantic at 66 MYA, leaving trans-oceanic dispersal as a potential cause for the surprising sister relationship.

115-3 SPIERER, AN*; MOSSMAN, JA; RAND, DM; Brown University, Providence, RI; *adam_spierer@brown.edu*
Dissecting the genetic modifiers of flight performance using the Drosophila Genetic Reference Panel
Insect flight is a complex and polygenic trait requiring the coordination of many genes across disparate systems throughout ontogeny. Identifying loci that contribute to complex traits is exceptionally challenging because traditional Genome Wide Association Study (GWAS) methods are best for identifying fewer loci with larger effect sizes. However, most complex traits and behaviors are comprised of many loci with small effect sizes. Recently developed tools for GWAS analysis are revolutionizing the field of quantitative genetics, better enabling us to map more subtle genetic underpinnings of complex traits. Accordingly, our study aimed to leverage these newer methodologies in a powerful Drosophila genetic model to identify genetic modifiers of flight performance. Using the Drosophila Genetic Reference Panel, a set of nearly 200 isogenic *Drosophila melanogaster* lines representing a snapshot of natural variation, we were able to begin mapping genotype to phenotype. Using a combination of traditional methods and methods recently developed for human GWAS--never before applied to a Drosophila model--we were able to identify a number of significant SNPs (individual and epistatic), genes, and pathways that broadly mapped to neuron and muscle function and development, regulators of gene expression, and previously undescribed functions. These results aim to expand our understanding of the genetic basis of aerial locomotor performance, unravel patterns of complexity underlying polygenic phenotypes, and facilitate research in other model organisms surrounding the genetics of insect flight. Future directions are underway to investigate the genetic modifiers for robustness of the flight performance phenotype, which preliminary evidence suggests is strongly tied to loci modifying gene expression.

P1-26 SPILLANE, JL*; LAPOLICE, TM; MACMANES, MD; PLACHETZKI, DC; University of New Hampshire; *jlh1023@wildcats.unh.edu*
Transcriptome assembly quality affects phylogenomic inference
Building accurate phylogenies is the first step in understanding the evolution of complexity and novelty. Genome-scale datasets leverage great power to test phylogenetic hypotheses, but questions remain about best practices, particularly when it comes to using whole transcriptome assemblies derived from heterogeneous sources. While some aspects of whole transcriptome sequencing and assembly have been empirically evaluated (e.g. depth of sequencing, trimming of reads), there are no current data on how user defined aspects of the assembly process can influence phylogenetically relevant factors including orthogroup composition, branch length estimation and topology. Here we construct comprehensive phylogenomic datasets derived from transcriptomes assembled using the Oyster River Protocol, a multi-assembler/kmer approach. This method allows us to create datasets of both good and poor quality and use them to test the effects of assembly quality on phylogenomic reconstruction. We find that good quality transcriptomes produce richer phylogenomic datasets with many more viable partitions than poor quality transcriptome assemblies. This difference in data richness produces pronounced topological artifacts in the poor vs. good datasets and has the potential to affect any downstream analyses or inferences based on the tree itself. Our findings demonstrate the importance of sound transcriptome assembly techniques in phylogenomic analyses, and suggest best practices for building accurate phylogenies.

P2-23 SPINELLI, JMC*; HUYNH, AV; RICE, AM; Lehigh University; *jcs518@lehigh.edu*
Vocal Learning in Hybrids: How Does Hybridization Affect Call Learning and Learning Biases in Chickadees?
Avian song can have important impacts on speciation, through its contributions to premating reproductive isolation. However, to my knowledge, the potential effects of avian calls on species barriers have not been as widely studied. Depending on the functions of calls in a species, and how they contribute to fitness, calls could be an important factor in reproductive isolation. An individual's ability to learn calls and discriminate between con- and heterospecific calls can affect multiple aspects of fitness. These could include mating success, resource acquisition, and territorial defense. Here, we tested two hypotheses about call learning in the black-capped and Carolina chickadee, and their naturally occurring hybrids. The black-capped and Carolina chickadee species distributions overlap, forming a narrow hybrid zone. The two parent species have slightly different versions of the well-known "chick-a-dee” call, which is used throughout the year by both sexes. Evidence suggests the chick-a-dee call has a variety of uses, including recognition on both the individual and species levels. We hypothesized that each species would be biased towards learning conspecific calls; and that hybrids would exhibit reduced ability to learn either parental species' calls. We hand reared wild-collected chickadee nestlings from hybrid zone populations in a controlled environment. We exposed all birds to playbacks of Carolina and black-capped calls for two months, and then recorded samples of each bird's calls. To test for learning ability, we compared similarity of each bird's call to the playbacks. We also measured frequency of species-specific notes in all recorded samples to analyze for any biases towards learning a single specie's call. Results from this project will provide further insight into the possible effects of avian calls and call learning on pre- and post-zygotic reproductive isolation.

103-2 SPRAYBERRY, JDH; Muhlenberg College; *jordannasprayberry@muhlenberg.edu*
Compounds without borders: a novel paradigm for quantifying complex odors and responses to scent-pollution in bumblebees
Bumblebees are critical pollinators whose populations have been declining over the past several decades. Successful foraging improves colony fitness, thus understanding how anthropogenic influences modulate foraging behavior may aid conservation efforts. Odor pollution can have negative impacts on bumble- and honey-bees foraging behavior. However, given the vast array of potential scent contaminants, individually testing pollutants is an ineffective approach. The ability to quantitatively measure how much scent-pollution of a floral-odor bumblebees can tolerate would represent a paradigm shift in odor-pollution studies. Current statistical methods derive the dimensions of an ‘odor-space' from the odorants within a dataset; therefore, when the dataset is modified the odor-space itself is reconstructed. In this way statistical methods such as principle components analysis (PCA) or non-metric multidimensional scaling (NMDS) have excellent descriptive power, but are less effective at prediction This study presents an alternative method of analyzing complex odor blends based on the encoding properties of insect olfactory systems. This "Compounds Without Borders” (CWB) method represents odors as a vector in a multidimensional space representing the functional group and carbon characteristics of their component odorants. The dimensions of this space are independent of the data described within it. These vectors allow the angular distance between any two odors to be calculated – including a learned odor and its polluted counterpart. Data presented here indicate that CWB-angles are capable of both describing and predicting bumblebee odor-discrimination behavior: odor pairs with angular distances in the 20-29° range are generalized, while odor pairs over 30 degrees are differentiated.

35-8 SQUARE, TA; University of California, Berkeley; *square@colorado.edu*

Stem Cell Markers Reveal Conservation of Tooth and Hair Regeneration

Vertebrates interact directly with their environment largely through their epithelia. To enhance these interactions, most vertebrates deploy various accessory structures in these high-contact regions of their bodies, called epithelial appendages. These include scales, hair, feathers, teeth, and many other organs. Despite their vastly different shapes and compositions as mature organs and structures, epithelial appendages begin development by relying on a surprisingly conserved set of signals and cell-cell interactions, and exhibit curiously similar histogeneses. Another character shared by most epithelial appendages is their capacity to regenerate. In most cases, this process is undergone constantly throughout the life of an organism, either in a facultative or obligate manner (i.e. prompted by damage or constant renewal). Given the recently published evidence for the conservation, and perhaps homology, of epithelial appendage development, we hypothesized that the regenerative process would also be conserved between disparate organs such as teeth and hair, namely that the stem cells contributing to this process would be marked by similar sets of gene expression. Using previously published information on gene expression during mammalian hair regeneration, we assayed the expression of stem cell markers during tooth replacement in two fish species: zebrafish (*Danio rerio*) and the threespine stickleback (*Gasterosteus aculeatus*). We find expression overlap consistent with a conserved regeneration process in these distantly-related epithelial appendages.

74-3 SRYGLEY, RB; USDA-Agricultural Research Service; *robert.srygley@ars.usda.gov*

Diapause plasticity allows insects to cope with drought at high and low elevations

Semi-arid rangelands of the western US are sensitive to climate change, with droughts projected to increase in frequency and duration in the latter half of the 21st century. These extreme events also impact many insect populations. We hypothesized that if drought could prolong diapause of Mormon cricket eggs, it might synchronize embryonic development and hatching after moisture is restored. We compared a high elevation WY population with two (OR and ID) at lower, drier elevations where we predicted the eggs would be more tolerant of desiccation. We predict that eggs will show the least development in drought during the first growing season, but the undeveloped eggs in the driest treatments will show the greatest development following restoration of moisture and a second growing season. For WY, the two drier treatments had significantly more eggs prolonging development until after the first warm period than the two wetter treatments. Whether those eggs in prolonged diapause developed in the second or subsequent warm periods did not differ among moisture treatments. Significantly fewer OR embryos developed at the driest treatment compared to the others, and almost all of the ID eggs developed irrespective of the moisture treatment. In conclusion, Mormon crickets can delay embryonic development to avoid drought until favorable conditions for growth and hatching are restored. Because undeveloped eggs lose less water than developed embryos, plasticity of WY mitigates the drought effect on egg viability. Eggs from high elevation were the most tolerant due to their capacity to postpone development to any one of several more favorable growing seasons. OR also reduced egg loss by prolonging diapause relative to ID that developed in even the driest condition. Although drought did not result in a concentration of development, diapause plasticity allowed the katydids to await more favorable conditions.

129-2 ST. JOHN, ME*; MARTIN, CH; University of California - Berkeley; *stjohn3@berkeley.edu*

A tale of scales and snails: behaviorally mediated traits drive the evolution of novelty in a radiation of Cyprinodon pupfishes

Understanding how organisms adapt to novel ecological niches is an outstanding question in evolutionary biology. Adaptation often includes shifts in foraging preferences, kinematics, and trophic morphology. Here we investigated behavioral, kinematic, and morphological adaptations to the novel ecological niches of of scale- and snail-eating in a recent radiation of *Cyprinodon* pupfishes endemic to San Salvador Island, Bahamas. Scale-eating and snail-eating pupfish both arose from an algae eating ancestor 10 kya, but display unique adaptations which allow them to occupy novel niches. First, we compared the feeding kinematics across pupfish species and their F1 hybrids during scale-biting and suction-feeding in the lab. We found that scale-eaters had peak gapes that were twice as large as other groups, but simultaneously had gape angles that were 32% smaller—which appears to be behaviorally mediated. We also found that the scale-eater's unique kinematic profile resides on a performance peak. Second, we investigated whether the novel nasal protrusion of the snail-eating pupfish is adapted for the novel behavior of ‘shelling' (i.e. removing snails from their shells). We measured snail-shelling preferences across pupfish species and F1 and F2 hybrids using behavioral assays and their nasal protrusion distance. We found that snail-eaters and snail-eating hybrids consumed more snails than other groups, but that nasal protrusion distance did not affect an individual's ability to consume more or larger snails in the F2 hybrids. Similar to scale-eating, this suggests that a shift in feeding behavior, such as foraging preference, is driving the evolution of the snail-eating specialist. Ultimately, we found evidence for the importance of behaviorally-mediated traits during adaptation to novel trophic niches.

83-3 STADTMAUER, DJ*; CHAVAN, AR; WAGNER, GP; Yale University; *daniel.stadtmauer@yale.edu*

Baby Light My Fire: "Cooperative Inflammation" in Marsupial Pregnancy

Marsupials and placental mammals have diverged substantially in life history: marsupials produce highly altricial young which complete development attached to the mother's nipple, whereas placental mammals have evolved the potential for extended pregnancy. The traditional explanation for this pattern is that marsupials are constrained by a rejection-like immune response upon contact of fetal and maternal tissues that is incompatible with prolonged gestation. Indeed, transcriptomic and histological studies of the opossum *Monodelphis domestica* have shown that an inflammatory phase of pregnancy begins after intrauterine hatching from the shell coat and progresses until birth. However, it has remained unclear whether this phenomenon is defensive inflammation, a tissue damage response, or a modified pregnancy-specific derivative of inflammation. If the constraint model for marsupial pregnancy is accurate, we would expect that inflammation proceeds as in a normal defensive immune response of host to pathogen, and that the fetus is expelled because it is not masked from the maternal immune system. Predictions of this model were tested by identifying the cellular origin of inflammatory signals in opossum pregnancy using immunohistochemistry and *in situ* hybridization. In at least two key pathways, prostaglandin synthesis and the cytokine interleukin-17, pro-inflammatory signals were found to originate from both the fetus and the mother, rather than the mother alone. We therefore reject that opossum parturition is a maternal attack upon the fetus, and instead propose that inflammation has been evolutionarily stabilized in this marsupial, potentially as a way for the fetus to effect its own birth. We name this new model *cooperative inflammation* and shall discuss its implications for the evolutionary narrative of mammalian viviparity.

100-5 STAGER, M*; SENNER, NR; TOBALSKE, BW; CHEVIRON, ZA; University of Montana, University of South Carolina; *maria.stager@umontana.edu*

What makes the Snow Bird fit for winter? The mechanisms underlying seasonal physiological flexibility

Organisms maintain dynamic regulatory systems that can confer the flexibility to reversibly match their phenotype(s) to fluctuating environmental conditions. This process often involves the dramatic modification of 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 avian body temperature regulation in the cold by combining assays of gene expression, tissue-level- and whole-animal physiology of Dark-eyed Juncos (*Junco hyemalis*) exposed to controlled temperatures. This work indicates that organismal performance is disproportionally influenced by a few subordinate traits and reveals an undocumented mechanism of avian thermoregulation. We then ask—Do populations within this geographically widespread species vary in their degree of flexibility? To address this, we replicated this approach across five additional *Junco* populations that vary in the natural thermal regimes they experience and interpret these patterns in light of historical demographic processes. Our results shed light on the mechanisms underlying avian body temperature regulation and the ability of natural populations to respond to seasonal environmental fluctuations.

P2-54 STAPP, C*; STANKOWICH, T; PAIG-TRAN, M; CSU Long Beach, CSU Fullerton; *caitlin.stapp@student.csulb.edu*

Investigating How Ecological Traits Influence the Evolution and Diversity of Armadillo Armor

Various selective pressures have undoubtedly influenced the adaptive radiation of defense mechanisms across taxa. While the correlates that favor the evolution of morphological defenses such as noxious sprays, spines, quills, and dermal armor are well studied, we know far less about the factors that contribute to variation in these defenses within a single taxon. Dermal armor is energetically costly and, in the case of cingulates, the multiple selective pressures that drive the maintenance and diversity of their heavily armored carapaces are largely unknown. In this study, we use CT scans and Amira imaging software to quantify and compare the relative thickness, surface area, and volume of armor from 13 armadillo species. Using these data, we plan to further investigate the potential correlates of dermal armor such as climate, habitat type and usage, intraspecies interactions, and predation using phylogenetic generalizes least squares analyses. Early results show dermal armor of armadillos appears to vary in these measures among species. Ongoing work indicates species that are larger in size and more exposed to predation have more armored carapaces. We hope to disentangle the selective pressures that play a role in the evolution of armadillo carapaces and build a theoretical framework by which to help predict the adaptive radiation of body armor in extinct and extant mammals.

14-7 STARK, AY; Villanova University; *alyssa.stark@villanova.edu*

Tenacious Toes and Fastening Feet: Biological Adhesive Systems in Complex Environments

Organisms that temporarily attach in order to move within their environment face potential failure with every step and release cycle. This potential for failure prompts unique morphological, biomechanical, and behavioral attachment structures and strategies that are likely tuned to current spatial and temporal conditions. Rather than studying the success of these systems in pristine laboratory conditions, I study failure in natural and semi-natural conditions to better understand the functional morphology of temporary adhesion. My observational and experimental work shows that biological attachment systems fail, sometimes spectacularly, but often remain successful in the conditions that matter. The focus of my research program is to understand the conditions that matter and how biological adhesive systems maintain high performance and versatility when it counts. Currently I use three biological adhesive systems to explore adhesive performance in challenging conditions: geckos, ants, and sea urchins. Each system offers a unique mechanism and set of challenges that must be overcome. For instance, geckos from the tropics must adhere in hot, humid, and wet conditions, tropical arboreal ants must adhere to superheated substrates, and sea urchins in the intertidal must adhere to rocky substrates while resisting intense wave forces. In all instances, failure is rare when the adhesive system is matched with common environmental conditions. When the biological adhesive system is not matched with common environmental conditions adhesive performance may be too low or too high to be biologically functional. By exploring the successes and failures of biological adhesive systems in complex environments, we improve our understanding of the functional morphology of these systems, providing valuable insight into the ecology and evolutionary development of adhesion and potential for bio-inspired synthetic design.

S5-3 STARK, A Y*; YANOVIAK, S P; Villanova University, University of Louisville and Smithsonian Tropical Research Institute ; *alyssa.stark@villanova.edu*

Adhesive Performance of Tropical Arboreal Ants on Canopy Substrates

The surface characteristics of forest canopy substrates are highly variable over relatively small temporal and spatial scales. Substrates often differ in roughness, surface wettability, temperature, moisture level, and inclination over minutes and millimeters. This extreme variation favors the evolution of adhesive and attachment mechanisms in ants and other cursorial, arboreal organisms. Ants use soft pads coated with an adhesion-mediating fluid and claws to prevent falling. Our observational and experimental work suggests three patterns. First, ant adhesive performance and running speed varies as a function of substrate type and condition. Second, ant adhesive performance and running speed are not consistently correlated across a range of substrate conditions. Third, adhesive performance and morphology vary with body size and phylogeny. Understanding the functional morphology of ant adhesion is fundamental to understanding ecological relationships in the highly competitive and dynamic canopy environment.

P2-76 STARKEY, J.M*; WHITE, K.J; PRADHAN, D.S; Idaho State University; *starjer2@isu.edu*
Androgen levels in sexually dimorphic musculature of a sex changing fish, Lythrypnus dalli
In vertebrates, androgen biosynthesis and signaling through receptor binding are critical regulators of physiological and morphological processes for male-typical reproductive behavior. Muscles essential for courtship behavior and copulation are highly sensitive to androgens, and the amount of androgen available locally within specific tissues may be important for maintaining dimorphic musculature. *Lythrypnus dalli*, a bidirectionally hermaphroditic fish, exhibits complex and sexually dimorphic reproductive behaviors. For example, males perform courtship displays, characterized by rapid jerky movements towards a female or around the nest, during which the first set of dorsal fins are erect. Dorsal fin movement might be controlled by the supracarinalis muscle that runs the length of the fish between two sets of dorsal fins and the spinal cord. Levels of androgen receptors are higher in males compared to females and are associated with the rates of jerk movements. Here, we found sex differences in the length of the dorsal fin, such that males have longer dorsal fins compared to females. In addition, we measured 11-ketotestosterone (KT), a potent androgen in Teleosts in two regions of the supracarinalis muscle, attached to the first and second set of the dorsal fins. We found that both juveniles with undetermined sex and adult males have higher levels of KT in both regions of the supracarinalis muscle compared to females. In another experiment, we formed social groups that consisted of three females, and induced a social context for protogynous sex change, within which the most dominant female-initiated transition to male behavioral phenotype by establishing her nesting territory and displaying parenting. We will measure KT in the supracarinalis muscles of these fish that have completed 5 d and 10 d towards protogynous sex change.

121-3 STARLING, JA*; GUATAM, S; HOWARD, LJ; MADSEN, SS; TIPSMARK, CK; UNIVERSITY OF ARKANSAS, FAYETTEVILLE, AR, UNIVERSITY OF SOUTHERN DENMARK, ODENSE, DENMARK; *jastanle@uark.edu*
Salinity effects on water and salt transport components in the intestine of Atlantic killifish (Fundulus heteroclitus)
Atlantic killifish is a hardy euryhaline teleost that thrives in both fresh water (FW) and seawater (SW). Compensatory salt transport in teleost fish is mainly branchial while volume regulation is renal in FW and intestinal in SW. Intestinal handling of imbibed SW must involve aquaporins, ion transporters and claudins. In this study of killifish, we analyzed salinity effects on the transcriptional, protein and morphological level to better identify the role of the intestine during the rapid salinity fluctuations experienced by an estuarine species. An organ distribution experiment was performed to analyze mRNA expression of known membrane proteins involved in water and ion transport. Aquaporin paralogs (aqp1, aqp8, aqp10a), two ion transporters (nka1a, nkcc2) and three claudin paralogs (cldn15a, cldn15b, cldn15like) were all expressed in both anterior and posterior intestine of all salinities but with segmental differences. Some genes showed elevated expression in SW compared to FW acclimated killifish (nkcc2, aqp1, aqp2), suggesting increased capacity for transcellular ion and water transport. Remarkably, cldn15b had 100-fold higher expression in posterior intestine only in FW acclimated fish. The minor or absent salinity regulation of many ion and water transport genes suggests partial maintenance of intestinal water handling capacity. However, some adjustment occurs and the dramatic elevated expression of cldn15b suggests a specific role of this paralog in the posterior intestinal segment but only in FW. Confocal microscopy revealed brush border localization of Aqp1 and significant morphological differences between anterior and posterior intestine supporting functional specialization.

37-7 STAYTON, CT*; PRICE, SA; WAINWRIGHT, PC; FRIEDMAN, ST; Bucknell University, Clemson University, UC Davis, UC Davis; *tstayton@bucknell.edu*
What does it take to make an eel? Convergence and adaptation in the evolution of an eel-like body plan
True eels (Anguilliformes) are characterized by a distinctive elongate morphology. Ichthyologists have informally, by utilizing the term "eel" in common names, identified a number of additional lineages with this morphology (e.g., "electric eels", "swamp eel"). The apparent ubiquity of the "eel morphotype" has led researchers to search for common selective pressures towards elongation. However, a quantitative study of the degree to which this frequency requires adaptive explanations has never been conducted. Here we use a multi-dimensional database of body shape in teleost fishes to address the following questions: besides elongation, are there other distinctive morphological characteristics of true eels? Do other "eel-like" fishes occupy the same region of shape space as true eels? How many times have lineages invaded this region of shape space, and is this greater than expected without adaptive evolution? Besides being relatively long, true eels are also characterized by flat heads, narrow mouths, and tall caudal peduncles (relative to the rest of the fish). Few "eel-like" lineages occur within the region of shape space defined by true eels, but many are close to this region. Overall, 23 lineages have invaded the "true eel region" of shape space; this is not significantly greater than the number expected under a non-adaptive BM model. Thus the eel body plan, while distinctive, appears fairly easy to access. Although the various lineages which have adopted this form have probably done so for adaptive reasons, our results provide no evidence that a single explanation (e.g., evolution towards a single adaptive peak) is necessary to account for the diversity of "eel-like" teleosts.

112-6 STEELE, AN*; MOORE, PA; Bowling Green St Univ, Univ of Michigan Biological Station; *ansteel@bgsu.edu*
Behavioral consequences of per- and poly-fluorinated alkyl substances (PFAS) exposure on Northern Michigan crayfish species
The need for bioindicator species to aid the assessment of anthropogenic impacts on aquatic ecosystems is currently rising due to the continued degradation of environments. Several characteristics of crayfish make them suitable candidates as bioindicators: global distribution, high population densities, low migratory rate, sensitive physiology and behaviors. The demonstrated sensitivity of crayfish as an established bioindicator for an array of anthropogenic toxicants raises interest in the sensitivity of crayfish to emerging contaminants. The emergent contaminant family, per- and poly-fluorinated alky substances (PFAS) has gained research attention due their widespread detection and stability within the environment. Previous research has demonstrated PFAS causes negative effects on the reproductive, endocrine, immune and nervous systems of experimental organisms, however, behavioral effects have not been well documented. The aim of this study was to investigate the behavioral consequences of PFAS exposure on crayfish species and the utility of these organisms as a bioindicator model for PFAS contamination. Differences in the foraging and antipredator response of crayfish were compared between animals collected from various polluted locations in Northern Michigan. Water chemistry sampling provided verification of PFAS concentrations at crayfish sampling sites and was used to determine the relationship between behavioral deficits and PFAS exposure. Analysis resulted in differences in two ecologically relevant bioassays. Due to the prevalence and uptake of PFAS compounds by aquatic organisms, a suitable bioindicator species and further study on fitness related behaviors that may be affected by PFAS are critical.

71-5 STEELE, TJ*; BARKAN, CL; BAAS-THOMAS, N; ZORNIK, E; Reed College; *thesteel@reed.edu*

Investigating the neuronal basis of sex-specific vocal behavior

Sexually dimorphic behaviors are useful systems in which to study the role of hormones in generating behavioral diversity within a species. The mating calls of *Xenopus laevis* are sexually distinct; female calls are slow and monophasic, while male calls are faster and biphasic. The circuit that produces these vocalizations is a central pattern generator consisting of androgen sensitive premotor and motor nuclei. The production of male song requires circulating androgens; gonadectomized male song degrades, while androgen-treated females (T-females) develop the ability to produce male-like calls. We used whole-cell electrophysiology to investigate the vocal circuit changes underlying the masculinization of T-female vocal behavior. We identified premotor neurons in T-females with vocal activity during song resembling that of male premotor vocal cells. These cells increased in size over the course of testosterone treatment, reaching male-like values after 8 weeks of androgen exposure; they also possessed the hyperpolarization activated cation current, I_H, and displayed NMDA receptor-dependent oscillations, both of which are characteristic of male premotor cells. In males, vocal cells in the premotor nucleus can be categorized into two groups based on differences in activity during song. T-female vocal neurons also separated into these two groups when compared with male cells. Both cell types were found throughout the course of androgen treatment. Our findings suggest that the masculinization of vocal behavior involves changes to cell morphology and intrinsic currents in the premotor nucleus, and involves both premotor cell types.

82-2 STEELE CABRERA, S*; HUNT, TS; HADDAD, NM; LUCKY, A; DANIELS, JC; University of Florida, Gainesville, FL, Michigan State University, East Lansing, MI; *ssteelecabrera@flmnh.ufl.edu*

Measuring the Outcome of Reintroduction Efforts for an Endangered Butterfly

Reintroduction of imperiled species has become a popular conservation strategy; rigorous monitoring of reintroduced organism is vital to assessing the outcomes of these efforts. The Miami blue butterfly (*Cyclargus thomasi bethunebakeri*), a federally endangered Lycaenid endemic to Florida, is the focus of an ongoing captive breeding and reintroduction project. Captively reared pupae and adult butterflies were released into large in-situ enclosures at two sites in the Florida Keys. Released individuals were monitored in order to estimate pupal survival, adult butterfly longevity, fecundity, and egg survival. In addition, a variety of environmental factors were measured at each site, including precipitation and vegetative characteristics. Successful establishment of reintroduced butterflies occurred quickly at one site, where individuals went through multiple generations without further intervention by researchers, while establishment did not occur at the second reintroduction site. Release of adult butterflies was associated with greater fecundity than for pupal reintroductions, likely due to mortality of pupae in the field. Adult butterfly longevity as well as fecundity were higher in field enclosures with greater cover of one larval host plant but not a second larval host plant, as well as higher overall plant cover. These results indicate that Miami blue butterfly may experience higher survivorship on one larval host plant versus the other, though a lab experiment indicated that larval survival was not significantly different between the two host plants. These results indicate that conservation efforts should include habitat restoration with larval host plants.

53-5 STEFFENSON, M*; GARCIA, M; VALENTINI, A; VARGAS, R; St. Edward's University; *msteffen@stedwards.edu*

The Effect of Elevated Temperature on Basal Immunological Activity in The Wolf Spider Tigrosa helluo

Climate changes models predict that Earth will continue to see increasing temperatures over the coming decades. However, the effect that such elevated temperatures will have on organisms is in many cases hypothetical. The impact of increased temperatures on ectotherms is even more critical to understand as they cannot regulate their own body temperatures. Because of these reasons, understanding how future climate change affects the ability of organisms to alter their energy budgets is critically important. This study aims to determine the effect of elevated temperatures on the basal immunological activity of the wolf spider, *Tigrosa helluo*. Female spiders with all eight legs intact were collected at night from the St. Edward's University campus. Specimens were massed and stored overnight in plastic crispers at room temperature. The following morning, spiders were transferred to environmental chambers that were either at ambient temperature (36 degrees Celsius) or an elevated temperature (42 degrees Celsius). Spiders were offered one cricket on day three in the incubators and had water provided ad libitum. After five days in the appropriate incubator, spiders were massed again and had their hemolymph extracted for immunological assessment. Preliminary data indicates that spiders in the elevated temperature gained weight from consuming prey, as did the ambient temperature spiders, but elevated temperature specimens then lost weight by the end of the experiment. Anecdotally protein concentration appears to be lower in spiders held at an elevated temperature. Data collection is ongoing and future assays will include prophenoloxidase activity (a protein commonly associated with immune activity among invertebrates) and peroxidase activity (an antioxidant).

128-3 STEIN, LR*; HOKE, KL; University of Oklahoma, Colorado State University; *laura.stein@ou.edu*

Parental and personal experience with predation risk interact in shaping phenotypes in a sex-specific manner

Evolutionary history, parental experience, and personal experience provide distinct avenues by which organisms adjust phenotypes based on environment, yet the mechanisms mediating phenotypic variation on these time scales may interact. Here we examine how population history, parental environment and juvenile experience interact to modify offspring phenotypes in the Trinidadian guppy (*Poecilia reticulata*). Parents from across four populations (two high-predation and two low-predation) were raised in the lab either with or without predator cues, and offspring were split and raised either with or without predator cues. We found that parental effects impacted both offspring size and multiple behaviors. For most phenotypes, male and female offspring differed in consequences of parental and personal experience. Indeed, sex was a stronger predictor of the interaction between parental and personal experience than population history. Altogether, our results suggest that parental effects and offspring experience are weighted differently in males and females, and highlight the complex interactions between transgenerational and developmental plasticity during development.

S1-5 STEINBERG, DK*; CONROY, JA; THIBODEAU, PS; Virginia Institute of Marine Science, College of William & Mary; *debbies@vims.edu*

New Insights Into Patterns of Zooplankton Abundance Along the Rapidly Changing Western Antarctic Peninsula

During the last two decades the rapid regional warming and sea ice decline in the western Antarctic Peninsula (WAP) region observed since the mid-twentieth century has plateaued. While the long-term trend in warming and sea ice loss is still significant, there has been a notable increase in sea ice extent and duration, and its interannual variability, since the late 2000s in the coastal WAP. The Palmer, Antarctica Long-Term Ecological Research (PAL LTER) program is investigating marine ecosystem response to both long-term regional warming and shorter-term reversals along the peninsula's marine continental shelf. Changes in the distribution and relative abundance of Antarctic krill (*Euphausia superba*) and other zooplankton that play a central role in the food web in many cases can be tied to warming and sea ice trends, and to the atmospheric circulation patterns that underlie these trends. For example, episodic recruitment sustains the Antarctic krill population along the WAP, and strong recruitment since 2011 is coincident with enhanced phytoplankton productivity and recent sea ice increases. A long-term increase in another krill species in the southern part of the study region is also attributed to increased phytoplankton production or more favorable timing of ice-retreat leading to subsequent blooms. Abundance of gelatinous salps and pteropods (pelagic snails) were significantly affected by sub-decadal climate oscillations (e.g., El Niño Southern Oscillation). We discuss the importance, and challenges, of understanding the effects of this environmental variability on the WAP food web, and some potential effects on regional carbon cycling.

27-4 STEINWORTH, BM*; MARTINDALE, MQ; RYAN, JF; University of Florida Whitney Laboratory; *bsteinworth@ufl.edu*

The evolution of cnidarian and bilaterian Hox genes

Hox genes control patterning of body regions along the bilaterian anterior-posterior axis and are found in cnidarians, making them good targets for better understanding evolution of axial patterning in animals. The relationships between cnidarian and bilaterian Hox genes remain unclear, possibly because previous research has focused on limited cnidarian taxa Here, we present a phylogeny of Hox and related homeobox genes using the broadest cnidarian sampling to date, including representatives from Octocorallia and Hexacorallia as well as all four medusozoan groups, Hydrozoa, Scyphozoa, Staurozoa, and Cubozoa. One notable result is the phylogenetic placement of genes known in the anthozoan Nematostella vectensis to be involved in specifying the directive axis, a secondary body axis perpendicular to the primary cnidarian oral-aboral axis. Phylogenetic placement suggests the directive axis genes were lost in medusozoans, potentially as an adaptation to pelagic open-ocean life. Overall, our results are consistent with a scenario of significant Hox gene loss in both cnidarians and bilaterians.

P3-104 STEPHENS, ER*; HARRIS, BN; PRATER, CM; SOTO, PL; CARR, JA; Texas Tech University, Lubbock, TX, Louisiana State University, Baton Rouge, LA; *emily.r.stephens@ttu.edu*

Testicular histopathology in an Alzheimer's disease model

Plaques in the brain formed through the accumulation of amyloid beta (Aβ) peptide are a characteristic symptom of Alzheimer's disease (AD). Aβ originates within the brain and peripheral tissues and contributes to pathologies in each. The blood-brain barrier (BBB) regulates Aβ influx from peripheral sources, and the membrane proteins responsible for Aβ clearance lose their function as AD progresses. We examined the testes which have a blood-tissue barrier (BTB) that is similar to the BBB and are thus potentially susceptible to similar Aβ accumulation and subsequent cell damage. We expected that the process of spermatogenesis in transgenic (Tg) APPswe/PS1dE9 mice would be altered relative to non-transgenic (non-Tg) mice and that human Aβ would be present in testicular tissue of Tg but not non-Tg mice. Testes from adult male mice were stained with H&E, and cells from each stage of spermatogenesis were recorded. We then used immunohistochemistry to determine the cellular location of Aβ-immunoreactivity (ir) in testicular tissue. We found that spermatogenesis does not differ between genotypes despite the presence of Aβ-ir within the seminiferous tubules of Tg mice. Aβ-ir was blocked by preadsorption with human Aβ 1-40 but not mouse Aβ 1-40. Current work is focused on analytical determination of the Aβ form present in the testes of Tg mice and its potential colocalization with Sertoli cells. Since the testes possess a BTB similar to the BBB, this research will elucidate details about the integrity of the body's BTBs in AD. Furthermore, our research will add to our understanding of Alzheimer's pathology in peripheral tissues. Partially funded by NIH 1R15AG048447.

11-2 STEVENS II, DR*; GRAHAM, MA; BADJIS, CB; MASON, JN; BAKER, JA; FOSTER, SA; Clark University; *dalstevens@clarku.edu*

Differences in behavioral plasticity among populations of threespine stickleback experiencing a novel predation threat.

Rapid, novel changes to an organism's environment due to invasive species are a global threat to biodiversity. Behavioral shifts are often the first phenotypic response to such changes, particularly when the invasive species poses a predatory threat. The high level of plasticity inherent to most behavior may potentially permit population survival until adaptive changes can occur, and the initial behavioral plasticity itself may even facilitate adaptation. Thus, in order to fully understand how behavioral responses are shaped by novel environments created by invasive predators, it is important to consider both the behavioral responses and the degree of plasticity of that behavior. Northern pike, Esox lucius, is an invasive species in Southcentral Alaska, where it constitutes a novel, intense predatory threat to threespine stickleback, Gasterosteus aculeatus. In this experiment, we asked how antipredator behavior differs among stickleback from pike-invaded and pike-free populations. We quantified stickleback behavior after a simulated attack when placed in one of four chemical cue conditions, thus creating environments differing in the degree of threat (e.g. control vs alarm/predator cues) and specificity of threat (general conspecific alarm cue vs specific predator cue). Populations differed in whether they had experienced the cues associated with the invasive predator within their recent evolutionary history. We show population differences in general antipredator behavior to a simulated attack (differences among individuals in the control condition), as well as population differences in behavioral plasticity, with population-specific responses to chemical cue treatments. We discuss these results here in a broader evolutionary context.

47-3 STEVENSON, TJ; University of Glasgow;
tyler.stevenson@glasgow.ac.uk
Rhythmic Epigenetics and the Neuroendocrine Regulation of Reproduction in a Seasonal Rodent.
The daily and yearly rotations of the Earth have provided a constantly changing environment that has driven the evolution of biological rhythms. The ability to adapt to future predictable climatic conditions is an ancient adaptation; therefore, it should not be surprising to observe biological rhythms at genomic, physiological, and behavioral levels across taxa. In this presentation, the conjecture that DNA methylation is an evolutionary ancient and essential component for the genomic regulation of biological rhythms will be outlined. The studies used male or female Siberian hamsters (*Phodopus sungorus*) to investigate the role of photoperiod, oestrous and hormonal regulation of DNA methylation and *de novo* DNA methyltransferase (*Dnmt3a/b*) expression in the hypothalamus and peripheral reproductive tissues (i.e. testis, uterus). Hypothalamic DNA methylation and *Dnmt3a/b* are elevated in long day (LD) summer-like breeding conditions. Short days (SD) and melatonin were sufficient to reduce hypothalamic DNA methylation and *Dnmt3a/b* expression. In females, hypothalamic *Dnmt3a* expression increased during the transition from proestrous to oestrous states. A single bolus injection of diethylstilbestrol (DES) and progesterone (E2P4) was sufficient to increase *Dnmt3a* cell numbers and *Dnmt3b* immunoreactive intensity in the suprachiasmatic nucleus (SCN). Upregulating DNA methylation *in vitro* reduced expression of vasoactive intestinal polypeptide, Vip, and the circadian clock gene, Bmal1. Conversely, SD increased global DNA methylation and *dnmt3a* expression in the testes and uterine tissue. Ovariectomy increased *Dnmt3a/b* uterine expression that was rapidly reduced after a single injection of E2P4. Altogether, the data reveal a dynamic and oscillatory role of DNA methylation for timing biological rhythms in reproduction.

87-8 STEVENSON, JPJ*; CHENEY, JA; DURSTON, NE; USHERWOOD, JR; WINDSOR, SP; BOMPHREY, RJ; University of Bristol, UK, Royal Veterinary College, Hatfield, UK;
jonathan.stevenson@bristol.ac.uk
Avian wing suspension for gust rejection
Amid the gusty conditions of the low atmosphere, birds routinely fly where air vehicles of the same scale would struggle severely or even fail. Crucially important to birds' control abilities are their compliant, articulated flight surfaces, which offer aerodynamic load alleviation to help stabilize the torso and head. To gain understanding on these control mechanisms, we flew a barn owl (*Tyto alba*) through variable upward gusts and derived its wing and tail kinematics from synchronized multi-angle high-speed video. In all flights, the wings rotate upwards about the shoulder, yet the torso remains exquisitely stable; under the same conditions, a simulated owl with rigid wings is driven vertically off course. We conclude that the basic requirement for the observed stabilization is a shoulder hinge, which acts as suspension to modulate the transmission of initial aerodynamic load to the torso. That the torso stays consistently still in all flights suggests that wing inertia is particularly well tuned – hinge forces (hence motion) are all but eliminated as the gust is encountered, in the same way that jarring at the hand is cancelled out when a ball is struck with the sweet spot of a bat. The mechanism is fast and should reduce the active burden on the flight control system. Once wing elevation saturates and the suspension effect subsides, the wings pitch down, dumping yet more aerodynamic load to provide sustained rejection of the gust.

P3-66 STEWART, KA*; MUTSUDDY, A; SEROY, SK; Heritage University, Toppenish, WA, Wheaton College, Norton, MA, University of Washington, Seattle, WA; *kimstewart023@gmail.com*
Effects of Warming Ocean Temperatures on Predation Rates on the Marine Snail Lacuna vincta
Warming ocean temperatures can present significant stress for coastal marine ecosystems. Understanding effects of warming temperatures on the ecological interactions within these ecosystems can help predict effects of climate change. The marine snail, *Lacuna vincta*, is an ecologically important herbivore in eelgrass and kelp habitats, which are vulnerable to warming ocean temperatures. *L. vincta* is consumed by two main predators, the kelp crab, *Pugettia gracilis*, and the sea star, *Leptasterias spp*. Our objective was to investigate how warming ocean temperatures affect predation rates of these two predators on *L. vincta*. Predation rates were measured in three different temperature treatments: 12°C, 16°C and 20°C. Predators had the opportunity to consume 10 snails each for two hours (*P. gracilis*) and three hours (*Leptasterias spp.*) We recorded the number and sizes of remaining snails after the feeding period. Our results showed that *P. gracilis* consumed more snails than *Leptasterias spp.* in all temperature treatments, and that temperature had no significant effect on predation rates for both predators. Additionally, there was no significant difference between the size of snails consumed by *P. gracilis* and *Leptasterias spp.* Our results suggest that the interactions between *L.vincta* and their predators could remain unaffected as ocean temperatures continue to rise.

P2-119 STEWART, H*; HAYES , D; O'BRIEN, S; Radford University; *hstewart7@radford.edu*
Exploring the Efficacy of Opiates on PTSD Through a Fish Model
Post-traumatic stress disorder (PTSD) is a mood disorder that occurs in individuals who have experienced a traumatic event such as an assault, war/combat, natural disaster, or other serious incident. Individuals who experience PTSD may have flashbacks to the event, feel angry, or display stress responses when reminded of the incident. Previous research has suggested that PTSD is an enhanced Pavlovian fear conditioning response that relies on an exaggerated amygdalar response altering how the memory in encoded (Pitman, 1989)). A study conducted with U.S. military personnel supported the use of an opioid regimen immediately following a traumatic event as a pharmacotherapy (Hollbrook et al., 2010). It is thought that the opioid exposure reduced the likelihood of developing PTSD, likely through neural modulation (Hollbrook et al., 2010). I hypothesize that the success of the opioid treatment is due to the drug's ability to suppress the amygdalar response following a traumatic experience. Therefore, the present study will use a total of 100 Zebrafish (Danio rerio) to investigate the differences between those treated with an opioid (morphine) and those without in a model of fear conditioning. Here we compare the behavioral and physiological response difference between those groups treated with an opioid drug and those who have not.

37-3 STEWART, TA*; LEMBERG, JB; SHUBIN, NH; The University of Chicago; *tomstewart@uchicago.edu*

The evolution of dermal rays in tetrapodomorph paired fins

Paleontological studies of the fin-to-limb transition have focused almost exclusively on endoskeletal evolution. However, comparative analyses of dermal fin rays can also inform the behavior, ecology, and developmental evolution of tetrapodomorph fishes. Here we use computed tomography to describe the dermal rays of the pectoral fins of three tetrapodomorph species: *Sauripterus taylori*, *Eusthenopteron foordi*, and *Tiktaalik roseae*. We find that in the lineage leading to crown group tetrapods, fin rays were simplified (segmentation and branching was lost), the fin web was reduced in size, and asymmetry evolved between dorsal and ventral hemitrichia. In tetrapodomorph pectoral fins, dorsal hemitrichia generally cover the endoskeleton to a greater degree than the ventral hemitrichia, indicative of dorsoventral asymmetries in the distribution of fin musculature. Notably, in *Tiktaalik*, dorsal hemitrichia cover the third and fourth mesomeres, while ventral hemitrichia are restricted distal to these elements, suggesting the presence of ventralized musculature at the fin tip, analogous to a fleshy palm. Additionally, in tetrapodomorph pectoral fins, dorsal and ventral hemitrichia differ in cross sectional area. *Eusthenopteron* dorsal hemitrichia are slightly larger than ventral hemitrichia, and the magnitude of difference is consistent between individuals of different sizes; while *Tiktaalik* dorsal hemitrichia are several times larger than ventral hemitrichia, and magnitude of asymmetry is greater in larger individuals. This indicates a transition from isometric to allometric scaling between the dorsal and ventral hemitrichia in elpistostegids. We argue that dermal fin ray evolution in tetrapodomorphs shows convergence with benthic actinopterygians and adaptation to substrate-based loading and prior to the origin of digits.

P2-46 STIEGLER, J*; MOORE, AJ; WANG, S; LEITE, JV; SCANNELLA, J; XU, X; CLARK, J; The George Washington University, Stony Brook University, Keck School of Medicine, University of Southern California, Natural History Museum, London, Museum of the Rockies, Montana State University, Institute of Vertebrate Paleontology and Paleoanthropology; *stiegler@email.gwu.edu*

Homology of an Ossified Metacarpal V in Extant Birds and Mesozoic Theropod Dinosaurs

Early dinosaur hands had three primary digits (I-III) and two vestigial digits (IV and V) in positions 1-5. However, embryological studies have concluded that avian manual digits with digit I-III phenotypes are derived from digit positions 2-4, while positions 1 and 5 retain only un-ossified vestiges. Hypotheses to resolve these conflicting digit reduction patterns include complete or partial homeoses of digits, among others, however there is uncertainty regarding the duration, phylogenetic position, and contributing mechanisms of this transformation. Here we show that a vestigial digit V is ossified in a phylogenetically disparate sample of extant and Mesozoic birds, having been overlooked by morphologists and all modern treatments of avian evolutionary development. Metacarpal V ossifies postnatally before fusing with metacarpal IV, and the homologues of muscles specific to digit V insert at the location of fusion. We use these data to constrain the phylogenetic location of digit I loss within Theropoda and hypothesize that following digit I loss, the remaining digits with phalanges (II-IV) are each homologous in part to multiple ancestral digits, the result of partial and gradual homeoses. The persistence of a small, lateroventrally positioned metacarpal V without phalanges from Triassic non-avian theropods through extant birds suggests that its range of phenotypes has not changed substantially for more than 220 Ma, and that only digit I has been permanently lost.

83-6 STILLER, AB*; STAUB, NL; Whitman College, Walla Walla, WA and Gonzaga Unviersity, Spokane, WA, Gonzaga University, Spokane, WA; *stilleab@whitman.edu*

Not a surprise: Female salamanders (plethodontid species Aneides ferreus) communicate to males during courtship as evidenced by courtship-like glands on their dorsum

The tail-straddling walk of plethodontid salamanders is a stereotypical courtship behavior to ensure spermatophore uptake by the female. With the recent description of the circular-tail-straddling walk in *Aneides ferreus*, it became clear that females are more actively participating in this courtship ritual than previously understood. We examined the tailbase region of both male and female *A. ferreus* for potential pheromone-producing glands (modified-granular glands) which have been described primarily in male salamanders. We identified these glands using histochemistry and morphology, in both males and females, on the dorsal and ventral surfaces of the tail. These glands are similar to the known pheromone-producing gland on the chin of males, the mental gland. They are positive for the periodic-acid Schiff test, have a granular secretory product, and have large secretory cells around the gland periphery. The presence of these modified granular glands is not sexually dimorphic, though not all females examined possessed them. The frequency is sexually dimorphic; males have more modified-granular glands on their dorsum than females do. No modified granular glands were identified on the dorsal tailbase region in females of the other species examined that perform the linear tail-straddling walk (*Aneides hardii*, *Aneides flavipunctatus*, and *Aneides lugubris*). The modified granular glands on the ventral tailbase region are thought to be involved in marking the substrate. Our results suggest that during the circular-tail-straddling-walk, the female is signaling to the male as well as vice-versa.

87-7 STINSON, HM*; MUKHERJEE, R; TYTELL, ED; SCHWALBE, MAB; Lake Forest College, Tufts University; *H.Stinson97@gmail.com*

Lateral line and visual systems in bluegill sunfish (Lepomis macrochirus) contribute to regaining stability in horizontal vortices

Fish encounter complex hydrodynamic environments while swimming and probably rely on multiple sensory systems to adjust their swimming and to remain stable in unsteady flows. It is unclear how the lateral line and vision contribute to a fish's ability to compensate for different types of unsteady flows, including horizontal vortices (like those shed by waterfalls, or over the top of rocks). Preliminary experiments showed that bluegill sunfish (*Lepomis macrochirus*) were stable in horizontal vortices with and without their lateral line and visual systems. Here, we challenged fish in a flow tank to more frequent horizontal vortices generated by a custom-made flapper and faster flow rates to continue testing the relative importance of these sensory systems in fish swimming. To test vision, fish were filmed under regular or infrared light and to test the lateral line system, fish were treated with cobalt chloride to deactivate this sensory modality. A fish was positioned behind the flapper (flapping frequency = 1, 2, or 3 Hz) while swimming at one of three speeds during each trial and recorded with three high-speed cameras to obtain the fish's position relative to the flapper over time. Overall, fish recovered quickly from the flapper action and differences in swimming movements were observed under the various flow and sensory conditions and will be discussed. Therefore, we continue to support that bluegill sunfish are relatively stable in horizontal vortices likely due to passive properties of their bodies, but sensory input from the lateral line and visual systems contribute to regaining stability after exposure to unsteady flows.

29-3 STINSON EASTERLING, CM*; SEIS, C; DEBAN, SM; Northwest University, University of South Florida; *charly.easterling@gmail.com*

Evidence of power amplification and thermal robustness in salamandrid feeding mechanisms

Tongue projection is often used by salamanders to feed on land. Many plethodontid salamanders are known for high-powered, thermally robust, ballistic tongue-projection; however, examples of similar feeding mechanisms in salamanders outside of the group are limited. Previously, we found that a distantly-related salamandrid, *Chioglossa lusitanica*, possesses a high-powered feeding mechanism with two distinct, ballistic movements. Here we continue our investigation into this highly specialized feeding mode by testing the thermal robustness of tongue projection in the salamandrids *Chioglossa* and *Salamandra salamandra*. High-speed imaging (3000 Hz) was used to capture feeding events over a 20-degree temperature range for both species. During both tongue projection and radial rotation (i.e. tongue pad flipping), *Chioglossa* continued to show evidence of an elastic mechanism, with tongue projection power exceeding 4000 W/kg, while radial rotation often reached over 2000 W/kg. High-powered projections were observed over the entire temperature range for *Chioglossa*. Projection performance decreased as temperature decreased, but was more thermally robust than retraction performance across all temperature ranges. Conversely, feeding performance in *Salamandra* was more strongly affected by low temperatures; tongue projection and retraction velocity, acceleration, and power were lower than those at higher temperature ranges. These results further support the hypothesis of convergent evolution elastically powered feeding mechanism in *Chioglossa* and plethodontid salamanders.

37-2 STOCKER, MR*; NESBITT, SJ; ANGIELCZYK, K; SIDOR, C; FORTNER, J; OLROYD, S; LUNGMUS, J; SMITH, R; Virginia Tech, Field Museum, University of Washington, Southern Methodist University, University of Chicago, University of the Witwatersrand; *stockerm@vt.edu*

A New, Small Arboreal Reptile from the Upper Permian of Tanzania

The Permo-Triassic mass extinction massively reorganized terrestrial tetrapod communities from the synapsid-dominated ecosystems of the late Permian to communities with more reptile diversity in the Early-Middle Triassic. The Ruhuhu Basin of Tanzania documents the latter part of this transition; however, only large pareiasaur parareptiles and a single specimen of the ?archosauromorph *Aenigmastropheus parringtoni* are the known reptiles from the upper Permian Usili Formation, despite decades of collecting. We report a new, unique reptile from the Usili Formation that may represent the oldest diapsid from Tanzania. CT data reveal densely packed and well-ossified, and apparently unduplicated bones, indicating that the specimen represents the remains of an individual likely preserved within a coprolite. This small specimen (estimated humeral length = 21 mm) includes articulated forelimbs and hindlimbs with a humerus with both ent- and ectepicondylar foramina and a distinct capitellum, elongated metapodials and phalanges, and curved and tapered unguals, suggesting an arboreal lifestyle. The combination of elongated caudal vertebrae, and morphology of the pes and the manus suggest that this amniote is likely a diapsid reptile; however, a diagnostic skull was not found in this specimen. Additionally, the articulated caudal vertebrae have elongated centra distinct from those of anomodont synapsids, such as the possibly arboreal Suminia from the late Permian of Russia, indicating an arboreal ecology for some small reptiles in the late Permian.

BART-1 STODDARD, MC; Princeton University; *mstoddard@princeton.edu*

Diversity of Form and Function in the Colorful World of Birds

Birds evolved about 150 million years ago, and today they are the most diverse and colorful land vertebrates. In my group, we are fascinated by the ecological and evolutionary processes that drive this variation. Much of our work investigates coloration and vision in birds. A fundamental challenge is that birds see differently from humans: they have tetrachromatic vision (four color cone-types) and ultraviolet sensitivity. To estimate a "bird's-eye view," we combine advanced imaging techniques with new computational methods. This has allowed us to test ideas about how birds use color to attract mates, avoid predators and deceive rivals. In the field, we are establishing a system for studying color perception in wild hummingbirds in the Rocky Mountains. These tiny iridescent birds lead colorful lives, performing spectacular courtship dives and pollinating diverse wildflowers. We also study the avian egg, a remarkable structure that is tough but breakable. The eggs laid by stealthy cuckoos and flightless emus offer insights into avian behavior and evolution. We apply a highly interdisciplinary approach, combining tools from mathematics, computer vision and bioengineering, to explore the avian world.

90-7 STORCH, JD*; HERNANDEZ, LP; The George Washington University, Washington, DC; *jdstorch@gwu.edu*

Constraining 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 premaxillary protrusion mediated by a sesamoid bone, 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. Does developmental integration across hard and soft tissue components of the protrusile mechanism constrain diversity of trophic morphology? We want to investigate the signal of constructional constraint on the pattern of morphological diversity of the A1 division of the adductor mandibula muscle in Cypriniformes. Here we present an experimental framework using modeling and simulation. Our interpretation of anatomical diversity in this element of the trophic apparatus through a functional lens informs a biomechanical model that can be parameterized to support simulation of linkages. Measuring the mechanical stress regime of a simulated linkage provides selection criteria that reflect the constraint of successful sesamoid bone formation. We use a novel extension of the phylomorphospace approach to calibrate these empirical estimates of theoretical morphospace. In this way we are able to test hypotheses of developmental constraint *in silico* that are less experimentally tractable *in situ*.

P3-253 STORCH, JD*; HERNANDEZ, LP; The George Washington University, Washington, DC; *jdstorch@gwu.edu*

Calibrating Empirical Estimates of Theoretical Morphospace: A Phylometricmorphospace Approach

Projections of phylogeny into morphospace i.e. phylomorphospace allow evolutionary relatedness and morphological diversity to be visualized. Positioning tree topologies within spaces produce estimates of branch length measured in units of morphospace distance. Evolutionary relatedness between observations is a source of distance information that is available to most of the biological systems we study. We can use this information to calibrate our perception of morphospace. Warping morphospace around an ultrametric phylogeny results in space that is increasingly traversable along phylogenetic lines of least resistance i.e. phylometricmorphospace. The phylometricmorphospace approach can improve empirical estimates of theoretical morphospace. Incorporating distance-based information about evolutionary relatedness into the construction of phylometricmorphospace increases the informativeness of distance measures within this space, amounting to a phylogenetic correction of regions between point estimates of morphospace occupancy. We explore the behavior of this method using simulation in order to characterize the sensitivity of phylometricmorphospace to misspecification of the tree topology. In this manner, we illuminate properties of the sampling distribution of morphospace occupancy within phylometricmorphospace as structured by the tree topology. We expect a calibrated empirical morphospace to better estimate the "spectrum of possible forms" (*sensu* Raup) when signals of e.g. convergence and constraint captured in the tree are attenuated by the noise of merely measurable forms in the uncalibrated condition.

P2-200 STOVER, KK*; ROBERTS, TJ; AZIZI, E; University of California, Irvine, Brown University; *stokris@gmail.com*

The shape of things to come: Age-related restriction in muscle shape change during shortening

Pennate skeletal muscles can operate with a range of gear ratios, i.e. the ratio of muscle shortening velocity to fiber shortening velocity, where a high gear favors speed and a low gear favors force. A previous study has shown that age-related increases in muscle stiffness result in a loss of variable gearing and compromised force production. Here we test the hypothesis that age-related changes in connective tissue result in restricted shape change during a contraction, leading to the loss of variable gearing and reduced force capacity. The dynamic 3D shape of the muscle belly and aponeurosis were tracked with a set of eight external markers during a series of isotonic contractions in young (n= 5, 6-8 months) and old rat (n=5, 30-32 months) lateral gastrocnemius muscles. We confirmed that the aged muscle lost variable gearing and produced less stress (aged= 15.6 ± 2.7 Ncm^{-2}, young= 24.0 ± 3.5 Ncm^{-2}, $P<0.01$). The fiber rotation, or degree of pennation angle change per mm fiber shortening, decreased with force in the young muscle, but in the aged muscle, rotation stayed elevated across all force levels (b= 2.73 ± 1.27 deg mm^{-1}). In young muscles, strain measured in aponeurosis width and muscle belly width decreased as force increased (P=0.0025 and 0.0001, respectively). In the aged muscle there was no change in width of the aponeurosis or muscle belly across force (P=0.99 and 0.72). Increased connective tissue within old muscles likely restricts the change in width during shortening, resulting in greater fiber rotation across all force levels. These results show that directional restriction of muscle shape leads to a fixed gear, and lower forces in aged muscle.

21-2 STRANG, CG*; BROWN, EK; SHERRY, DF; HAMPTON, RR; University of Western Ontario, Emory University; *cstrang@uwo.ca*

Memory systems in food-caching caching and non-caching birds

For birds that overwinter in north temperate zones, such as Black-capped Chickadees and Dark-eyed Juncos, keeping track of reliable long-term food resources is critical. Chickadees have an additional overwintering strategy of storing food in unique cache sites and locating them using memory. Animals and humans have multiple memory systems. While both chickadees and juncos are under selective pressure to remember reliable long-term spatial locations (habit memory), chickadees are under additional selective pressure for quickly forming and rapidly updating spatial memory for unique cache sites (one-trial memory). We conducted a series of touchscreen experiments to assess each species reliance on these two types of memory. Habit memories were experimentally established in trials in which photographic backgrounds were paired with spatial arrays in which the same location always rewarded. In other trials, birds were given one-trial memory tasks on different photographic backgrounds that required them to remember which location had been rewarded most recently. Both species showed high accuracy on these one-trial memory tests. On trials in which one-trial and habit memory were put in conflict, however, both species preferentially used habit memory. We hypothesized that photographic backgrounds provided a contextual cue that birds used to determine which memory system to use. In a further experiment, the same photographic backgrounds were used for both habit trials and one-trial memory trials, eliminating their utility as a contextual cue. This change in procedure increased the use of one-trial memory and decreased the use of habit memory on trials in which the two memory systems were in conflict. We discuss how ecology and context influence the use of memory systems in Black-capped Chickadees and Dark-eyed Juncos.

P3-59 STROM, MK*; MABRY, KE; New Mexico State University; *mkstrom@nmsu.edu*

The Influence of Habitat Type on the Reproductive Success of Brush Mice (Peromyscus boylii)

Population size and density are common metrics used to describe the population dynamics of a species. However, reproductive output and adult survival can be more informative. Further, individual reproductive success may vary between habitat types within one site, suggesting implications for the adaptive significance of dispersal and habitat selection. Here, we compare the reproductive output of brush mice (*Peromyscus boylii*) in two distinct, adjoining habitat types, chaparral and woodland, at 3 study sites in Napa, CA during 15 breeding seasons (2003-2017). Mice were genotyped at 12 polymorphic microsatellite loci and parentage assignment was conducted in CERVUS. We assigned 80/221 offspring (36%) to both parents. Preliminary analysis indicates that for adults that recruited at least one offspring into the trappable population, mean reproductive output was similar for individuals living in the chaparral (n=37) and woodland (n=40) habitat types, and for males (n=39) and females (n=38). Future analyses will compare the reproductive success and failure of individuals, as well as survival, between the two habitat types to gain further insight into factors influencing habitat selection.

62-4 STRUBLE, MK*; GARDNER, J; GIBB, AC; Northern Arizona University, Montana State University; *strublemikayla@gmail.com*
Grasping Behavior in Birds Drives Pedal Adaptations
Birds use their feet for a large range of functions including grasping behaviors. Many perching, raptorial, and vertically clinging birds show shortened proximal phalanges in their feet. To test the relationship between grasping behavior and phalangeal proportions, we conducted Bayesian phylogenetic comparative analysis on about 200 bird species using phylogenetic ANCOVA and compared alternative models using a Bayesian Information Criterion to select the most-fitting model while penalizing by the number of additional parameters. The most well-supported model in our analysis finds that the lengths of proximal phalanges in raptors are significantly shorter than other birds, suggesting extreme grasping strength in birds is related to shortened proximal phalanges. We then investigated the biomechanical mechanism for this phenomenon. The flexor complex of the avian foot acts as a series of complex pulleys and levers. Theoretical modeling of this system predicts the reduction in phalangeal length increases the mechanical advantage of each phalange, but to test this principle in such a complex system, we designed a series of physical models created from CT-scanned and 3D printed bird feet rearticulated into biomimetic robotic models. These models confirm that proximal phalangeal shortening does not directly increase the pressure exerted by the talons, it instead increases the pressure exerted by the interdigital pads. Our models showed that a 50% decrease in phalangeal length increases the interdigital pressure by over 160% with the same muscular effort. This suggests shortenings proximal phalanges increases the strength of the core of the foot rather than the pressure exerted by the tips of the talons.

87-2 SU, GT*; DUDLEY, R; PAN, TY; ZHENG, MZ; PENG, LS; LI, QS; Beihang University and University of California, Berkeley, University of California, Berkeley, Beihang University, Beihang University, Beihang University and Xihua University; *pantianyu@buaa.edu.cn*
Maximum Aerodynamic Force Production by the Wandering Glider Dragonfly (Pantala Flavescens, Libellulidae)
Maximum aerodynamic force production is a parameter critical to extreme performance in volant taxa, and which may also be relevant to optimization of force production in micro air vehicles. Here, we describe a new method for measuring maximum force production in free-flying animals, and present associated data for the wandering glider dragonfly. Flight trajectories were repeatedly acquired from pull-up responses by insects dropped in mid-air with submaximal loads attached to the center of body mass. Forces were estimated from calculations of the maximum time-averaged acceleration through time, and multiple estimates were obtained per individual so as to statistically facilitate approximation of their maximum capacity through use of the Weibull distribution. On a group level, wandering glider dragonflies are capable of producing total aerodynamic force equal to ~4.4 times their own body weight, a value which significantly exceeds earlier estimates made for load-lifting dragonflies, and for other volant taxa in sustained vertical load-lifting experiments. Allometric analysis further indicates that, among individuals, maximum force production declined systematically with increased body mass.

P1-202 SULLIVAN, SP*; MIDDLETON, KP; HOLLIDAY, CM; University of Missouri, Columbia; *spsullivan@mail.missouri.edu*
Morphology and Function of the Avian Furcula
The diversification of bird flight involved major changes to the pectoral girdle and musculature, including modification of the furcula. The furcula articulates with the scapulo-coracoid complex medially to the glenoid and is the rostral-most attachment of m. pectoralis, the primary downstroke muscle in flying birds. As a result, furcula morphology has been used to infer flight behavior in extinct avialans. However, furcula morphology only modestly correlates with flight style in extant birds, and some volant birds lack furculae. While furcular morphology has often been considered in isolation – under the assumption that the functional signal of the element resides in its gross shape – the bone's anatomical orientation, structural properties, and relation to adjacent pectoral muscles remain unexplored in most avians. We collected contrast imaging, dissection, and morphometric data of the musculoskeletal system from nine passerines (Passeriformes) and parrots (Psittaciformes), groups with disparate furcula morphology but similar flight styles. Generally, passerines possess more robust and rostrocaudally-curved furculae than do parrots, whose furculae are reduced to ligamentous bands in some taxa. We examined pectoral muscle architecture, muscle resultants, and mechanical properties of the furcula as correlates of flight style and furcular morphology. In volant parrots with reduced or absent furculae, modified pectoral muscle architecture and morphology may functionally replace a bony furcula. Whereas earlier studies found that lateral and anterior furcula shape may covary with flight style among all avians, we find that these trends may not hold at higher taxonomic resolution. Our data suggest that the question of furcula function, and thus of avian pectoral evolution, depends on taxonomic level.

134-7 SUMMERS, AP*; TRNSKI, T; HANNAM, S; CONWAY, KW; University of Washington, Auckland War Memorial Museum, Texas A and M; *fishguy@uw.edu*
A diversity of fishes that suck - New Zealand edition
Clingfish (Gobeisocidae) are small, shallow water fishes found in marine and freshwater environments. They are distinctive for having a suctorial disk on their belly made up of elements of the pectoral and pelvic girdles and fins. Work on one species, the Northern Clingfish (*Gobeisox maendricus*) has demonstrated the extreme tenacity of this disk on smooth and rough surfaces. Across the family this disk is variable in size and shape. There are double disks, disks with many papillae, and disks that appear small for the length of the fish. We report on the disk morphology and performance of 10 species of clingfish from New Zealand. Morphologically two groups stand out - rubble associated with relatively large disks and algae associated species with smaller disks. We tested fish on molds from six abrasive surfaces, from smooth to 120grit. The peak stress under the disk ranged from 50-100kpa. The theoretical maximum stress in our experimental design was 101kPa. It was possible to get performance data from fish as small as 70mg. Smaller fish could not stick to the roughest surfaces. The suctorial disk is a device that requires no living input. A dead fish will stick repeatedly with the same tenacity an arbitrary number of times. We made over 100 tests on one fish without degradation of attachment.

P1-206 SUMMERS, DA*; WAINWRIGHT, DK; Harvard University, Yale University; *dexter@mightycheese.com*

Crushers: When Lanternfish Develop Modified Pharyngeal Jaws

Lanternfish (Myctophidae) are a common and diverse group of small to medium sized deep-sea fish. They are an integral part of the vertical migration of deep-sea fish towards the surface each night, which in turn is vital for connecting the deep-sea with surface waters. This migration is where they consume a lot of their food, which generally consists of dominant meso-zooplankton groups such as copepods and amphipods. Past work suggests there may be little diet specialization in this group, although this may change in different locations and seasons. We sought out to study the pharyngeal jaws of lanternfishes to help us understand the evolution and morphological diversity of this group. Pharyngeal jaws are a second set of jaws located in the pharynx that aid with food processing. We CT-scanned almost a 100 lanternfish species and used software to isolate the pharyngeal jaw apparatus. Then we placed landmarks for geometric morphometrics, and made linear measurements. We found one clade of myctophids with highly modified pharyngeal jaws, adapted for processing hard-shelled prey. In this clade, the upper jaws are hypertrophied with molariform teeth, and the lower jaws are greatly reduced. This morphology suggests that the left and right upper jaws can push together and crush prey between them – a novel mechanism of jaw action for fishes. Relatives of this clade also have modified jaws with a similar potential for occlusion between left and right upper jaws. We further explore the diversity and evolution of pharyngeal jaw morphology in this group by studying pharyngeal jaw morphology across the entire family using modern comparative tools. This study highlights where in the Myctophid family these adaptations evolved and provides insight into the evolution of myctophid morphology and ecology.

104-6 SUMMERS, AP*; MULLER, U; UW -Friday Harbor Labs, CSUF; *fishguy@uw.edu*

Ideas and initiatives for the two SICB journals

The editors of Integrative Comparative Biology and Integrative Organismal Biology will continue a dialog with members on issues of transparency, inclusion, diversity, and accessibility. The aim of this time slot will be to solicit opinion and guidance from the membership on these issues as they relate to our society's journals.

66-6 SUN, B-J; HUEBNER, C; TREIDEL, LA; CLARK, R; ROBERTS, KT; WILLIAMS, CM*; Chinese Academy of Sciences, University of California, Berkeley, Sienna College; *cmw@berkeley.edu*

Integrated behavioral and physiological strategies allow Gryllus lineaticeps crickets to fly on cool nights

Dispersal flight is an important component of life history strategies for many animals. For insects, the only ectotherms to have evolved powered flight, dispersal at night may present a challenge because low temperatures can limit physiological functions. *Gryllus lineaticeps* crickets have a wing polymorphism consisting of flight-capable (long wing; LW) and -incapable (short wing, SW) morphs. In the field, temperatures during the active period are frequently below the threshold for flight initiation. We test four non-exclusive hypotheses to determine the strategies nocturnal insects use to achieve flight: 1) behavioral thermoregulation to increase Tb; 2) pre-flight warm-up using muscular contractions; 3) resistance to heat loss; 4) modification of thermal performance curves to permit flight at low body temperature. Experiments on wild and lab-reared crickets showed that LW crickets had higher thermal preferences and field body temperatures than SW crickets. They performed wing-shaking prior to flight initiation, which further raised their body temperatures until they reached the threshold temperature for flight initiation. LW crickets had higher mass-specific metabolic rates and a greater resistance to passive cooling compared to SW crickets. Thus, we found support for all four hypotheses and conclude that LW crickets use a combination of behavioral and physiological strategies to facilitate nocturnal flight. Our study highlights the complexity and diversity of responses to variable thermal environments in ectotherms.

P1-168 SUNG, JY*; MOREHOUSE, NI; University of Cincinnati, Cincinnati, OH; *sungyg@mail.uc.edu*

Selection for Distinctiveness in Chinese Opera Masks

Facial morphology and facial patterning often communicate important sources of information such as the age, sex, species identity, and individual identity of animals within ecological communities. Distinctiveness is often selected for under such contexts. This is particularly true in multispecies assemblages of phylogenetically related species, where there is strong selection to avoid heterospecific mating. Such character displacement of facial patterning has been observed in a variety of animal systems, yet we know little about whether similar selective pressures might shape the patterns of face ornamentation used in human art and culture. Chinese opera is an integrative performance artform that uses multimodal communication strategies to tell classic Chinese stories and myths. In these operas, male *Jìng* characters don elaborate, symbolic masks. The *Jìng* masks function within Chinese opera in ways similar to facial patterning in complex animal communities: they must correctly communicate the identity of specific *Jìng* characters to assist in rapid identification by the audience. We thus predicted that the facial ornamentation of *Jìng* characters has evolved under disruptive selection within each opera story (the cultural equivalent of a sympatric species assemblage) to reinforce character identity during audience recognition. Using a computer vision approach, we evaluated whether facial patterning has evolved for increased recognizability and disparity using a sample of *Jìng* masks from well-known traditional Chinese operas. We discuss our results in the context of similar patterns in non-human systems, such as the evolutionary divergence in facial patterning in guenon primates and *Habronattus* jumping spiders.

137-1 SUSTAITA, D*; FARABAUGH, S/M; BARTHMAN-THOMPSON, L; Department of Biological Sciences, California State University San Marcos, Institute for Conservation Research, San Diego Zoo Global, Suisun Marsh Unit, California Department of Fish and Wildlife, Stockton, CA 95206 USA; *dsustaita@csusm.edu*

Why morphology matters for management: the role of organismal form and function in wildlife conservation and management

Ecomorphologists and natural resource professionals often have different priorities, but share the common interest of advancing the state of understanding of the organisms they steward. Here we present snapshots of two case studies that illustrate the reciprocal benefits of in-depth morphofunctional analysis to address this joint cause. One study in collaboration with San Diego Zoo Global Institute for Conservation Research looks at the ontogeny of feeding performance in endangered San Clemente Loggerhead Shrikes. Here we address questions regarding how predatory proficiency relates to beak development, and when juveniles attain adult-levels of performance. This work is relevant to captive breeding efforts because it provides ways to quantify predatory performance, and an opportunity to assess whether juvenile feeding performance predicts post-release survival. A second case study in collaboration with the California Department of Fish and Wildlife examines the morphological basis to habitat use in the endangered salt marsh harvest mouse. Of particular interest is whether these mice possess specialized swimming and climbing capabilities that allow them to tolerate periods of tidal inundation. These data are useful for assessing the potential impacts of tidal restoration, because they shed light on how mice negotiate flooded habitats. Taken together, these studies provide new functional insights and metrics for species of conservation concern, which could ultimately aid in their preservation.

119-4 SWALLA, BJ*; FODOR, A; LOWE, EK; STOLFI, A; Friday Harbor Laboratories, University of Washington, Friday Harbor, WA 98250, Department of Biology, University of Washington, Seattle, WA 98125, School of Biological Sciences, Georgia Institute of Technology, Atlanta, GA, School of Biological Sciences, Georgia Institute of Technology, Atlanta, GA; *bjswalla@uw.edu*

Tailless Molgulid Ascidians express Larval Pseudogenes

Transcriptomic and genomic data offer exciting new approaches to examine the genetic networks underlying the origin and evolution of the chordate body plan. We study two closely related tunicate species with very divergent larval body plans—the tailed ascidian *Molgula oculata* and the tailless *M. occulta*. Tailed *M. oculata* embryos, like most solitary ascidians, have 40 notochord cells that are converged and extended in the center of the tail of the tadpole larvae. The larvae also have tail muscle cells flanking the notochord in the tail, and, in the head, an otolith, a gravity sensory organ with a single pigmented cell. The tailless *M. occulta* do not form a tail in their larval stage and lack the otolith, and the pigment cell associated with it. We have sequenced the genomes and analyzed developmental transcriptomes for both species and the hybrid embryos. Hybrid embryos made from the sperm of the tailed, *Molgula oculata* and the egg of the tailless *Molgula occulta* undergo convergence and extension of the notochord to form a short tail and, in some cases, also a pigmented otolith. We have shown that the muscle genes and tyrosinase pigment genes are pseudogenes in the tailless *M. occulta* species, but in some cases, the mutated transcripts are found in the transcriptome. We have also found examples where the tailless genes are intact, but show different expression levels in the hybrids, suggesting that there are changes in the cis regulation of the genes. We are continuing analyses of gene expression in the parental species and also in hybrid embryos in an effort to understand the evolution of the genetic networks necessary for tadpole larval development in ascidian embryos.

100-7 SWANSON, DL*; OBOIKOVITZ, P; University of South Dakota, Vermillion; *david.swanson@usd.edu*

Environmental Heterogeneity and Metabolic Flexibility in Horned Larks and House Sparrows: A Test of the Climatic Variability Hypothesis

The climatic variability hypothesis posits that physiological flexibility should be higher in organisms from more variable climates. Summit (Msum) and basal (BMR) metabolic rates are flexible traits and seasonal metabolic flexibility can be advantageous for small birds living in highly seasonal environments. Behavioral thermoregulation may reduce demand for seasonal metabolic flexibility, but favorable microclimates may be less available to some birds than others, depending on habitat. To investigate the relationship between seasonal variation in environmental temperatures and metabolic flexibility, we compared seasonal metabolic flexibility and microclimates (operative temperatures) of horned larks (*Eremophila alpestris*), which occupy open habitats, and house sparrows (*Passer domesticus*), which occupy more protected habitats, from South Dakota. We hypothesized greater seasonal variation in BMR, Msum, and operative temperatures for horned larks than for house sparrows. Winter daily average and minimum operative temperatures were similar for the two species' habitats, but including convection resulted in lower winter temperatures for lark habitats. Summer daily average and maximum operative temperatures were higher for lark habitats, even after incorporating convective heat loss. Both species demonstrated metabolic flexibility with higher Msum in winter and lower Msum in summer; however, the seasonal change for larks was 25% greater than in sparrows (39.4% vs. 31.4%). Significant seasonal variation in BMR occurred only for larks, with 92.5% higher BMR in winter than in summer. These results are consistent with the climatic variability hypothesis in that horned larks occupied habitats with more variable temperatures and showed greater seasonal metabolic flexibility.

118-4 SWIDERSKI, DL*; ZELDITCH, ML; University of Michigan, Ann Arbor; *dlswider@umich.edu*

An Incisor Runs Through It II. Evolutionary modularity of the squirrel mandible

If variational modularity explains how complex adaptations can evolve, it should predict the pattern of evolutionary modularity. The rodent mandible has long served as a classic example of variational modularity, but the prevailing hypothesis is of two "functional modules": the tooth-bearing front and muscle-bearing back. That is difficult to reconcile with the idea that the mammalian mandible can be modeled as a beam because a beam is not divisible into two functional complexes along its length. In addition, it raises the specter of functionally incompatible changes occurring in different regions. This hypothesis is even more difficult to reconcile with the rodent mandible because the incisor runs through the mandible, well past the boundary between the modules, and the masseteric muscle overlaps the border in the other direction. These anatomical relationships lead to the question: why would the front/back model fit so well, if it does? Analyses of mandibular shape changes in four major lineages of squirrels reveal evolutionary modularity in all clades consistent with the Front-Back model, which is consistently one of the best for variational modularity, although it missed the integration along the beam. For evolutionary modularity, models derived from mechanical principles, incorporating that integration of the beam and uniting muscle-bearing processes in a module consistent with their functional coupling, provide evidence of an even stronger modular signal, indicating they improve upon the Front-Back model. Thus, modular patterns of evolutionary change are partially aligned with the Front-Back model, but lineages differ in their deviations from it. Also, the most disparate are the least modular in their evolutionary changes.

P3-161 SWINSKY, CM*; JACKSON, BE; Longwood University; *jacksonbe3@longwood.edu*
(Don't) Shake a Tail Feather: Function of American Goldfinch Tails During Slow Flight
Previous studies have demonstrated that at medium and fast flight speeds, bird tails aid with maneuverability and drag reduction. However, little is known about tail function during slow flight in wild birds when display and locomotor demands may co-occur. Wild American Goldfinches (*Spinus tristis*) perform remarkable aerobatic maneuvers around bird feeders, particularly in the presence of conspecifics, and have striking black and white markings on their tail feathers. We hypothesized that goldfinches approaching the feeder use their tails for behavioral signaling, pitch maneuverability, and to increase drag, but the primary function varies based on the presence of other birds. For example, we predicted that finches approaching another finch would spread and depress their tails more than solo finches, even at very slow velocities when the tail has little aerodynamic effect. High speed cameras (250 frames per second) were used to record American Goldfinches during landing, takeoff, and slow flight around established feeders. We reconstructed the 3D kinematics of the body and tails using Argus, and calculated tail angle of attack, spread angle, and surface area. ANOVA analyses showed that tail angle of attack during takeoff was significantly lower than in landing or flight. However, the presence of other birds did not significantly affect either tail angle of attack or surface area. These results suggest that display is secondary to aerodynamic functions, even in slow flight.

7-7 SYKES, BE*; BALENGER, SL; University of Mississippi; *besykes@go.olemiss.edu*
Nest Microclimate Manipulation Affects Growth, Development, and Heat-shock Protein Production in the Eastern Bluebird (Sialia sialis)
Temperature is important to breeding birds, as the timing and success of reproduction are largely influenced by climatic conditions. Altricial nestlings, which hatch naked and unfeathered, do not begin independently thermoregulating until the later stages of their development. Nest microclimate has been shown to influence avian growth, however, little work has been done to examine whether excessive heat influences the production of protective molecules in birds after hatching. We manipulated the temperature in eastern bluebird nestboxes to examine if nestlings become stressed in response to heat, and how it affects their physiology, as well as whether feather-degrading ectoparasites are influenced by this increase in temperature. We found that nestlings exposed to elevated temperatures gained less mass over time relative to those that received the sham treatment, and were in worsening body condition over the course of their development. We also examined expression of circulating heat-shock protein 70 (HSP70) to determine if there were differential protective responses to heat. Feather-degrading bacterial loads were quantified to determine whether these ectoparasites thrive under a temperature optimum. Overall, this study will provide valuable insights into how within-nest temperature affects the development and physiology of altricial birds.

P2-249 SZUCH, CM*; KEPHART, ML; SEVIGNY, JL; SIMPSON, S; CASSAVAUGH, CM; THOMAS, WK; COOK, GM; New England College, University of New Hampshire; *cszuch1_ug@nec.edu*
Deep-sea Coral Reefs: Genomic Contributions to Bioprospecting in the Marine Environment
The rise of antibiotic-resistant bacteria (ARB) poses a serious threat to the health and safety of humanity on a global scale. The overall objective of this project strives to contribute to mitigating the public health risk presented by ARB through the application of novel genomic and proteomic techniques that aim to discover natural therapeutic agents in the marine environment. Accordingly, we generated a draft genome assembly of the deep-sea coral *Lophelia pertusa* in an attempt to (1) identify the origin of cationic antimicrobial peptides that have been successfully harvested from this stony coral and (2) confirm, complete, and correct their *de novo* sequences. Additionally, this draft genome assembly is--to our knowledge-- the first of its kind, thus providing the scientific community with a new resource for investigating this framework-builder of deep-sea coral ecosystems.

P3-39 TAIT, C*; RAMIREZ, MD; OLSON, M; KATZ, PS; Univ of Massachusetts Amherst; *ctait@umass.edu*
Molecular and behavioral characterization of two reproductive hormones in the nudibranch Berghia stephanieae
Evolutionary pressures impact both gene sequences and behavioral effects of reproductive hormones differentially. We compared the sequences and functions of egg-laying hormone (ELH) and conopressin (CNP) in *Berghia stephanieae*, a nudibranch that is amenable to rearing in the laboratory. ELH and CNP differ strongly in the conservation of their amino acid (aa) sequences. The ELH family shows only moderate aa sequence identity (50% or less) across species, and are most similar at the N-terminus and C-terminus. In contrast, the CNP aa sequence is highly conserved among molluscs, even showing strong similarity to vasopressin and oxytocin in mammals. As hormones, ELH and CNP also differ in their breadth of behavioral effects. Whereas species-specific ELH reliably and solely elicits aspects of egg-laying, CNP is responsible for more varied functions. We identified ELH in transcriptomes of several nudibranchs, including *Berghia*. A gene tree of ELH aa sequences shows that the nudibranch homolog of ELH has undergone changes at the C-terminus compared to other gastropods. We examined the effects of the strongly conserved CNP on mating behavior and the effects of the less well conserved ELH on egg-laying behavior in *Berghia*. CNP aa sequences are highly conserved even as their role in reproductive behaviors differs, and thus the sequence may be evolutionarily constrained. The aa sequences of ELH show more divergence, but a highly conserved behavioral role. This suggests possible co-evolution with receptors to maintain behavioral outcomes.

131-4 TALAL, S*; FARINGTON, R; HARRISON, JF; CEASE, AJ; Arizona State University, Tempe; *stav.talal@gmail.com*

Diet Preference and Requirements Shift Substantially with Age in the South American Locust (Schistocerca cancellata)

Generalist feeders often behaviorally regulate their food choice to achieve their preferred macronutrient ratios to enable maximal growth and survival. However, the vast majority of studies on the topic have examined only a small portion of animal ontogeny, and it is not clear whether preferred ingestion ratios of protein:carbohydrate (P:C) intake targets (IT) vary during development of insects and other animals. Locusts and grasshoppers have been extensively used as models to study P:C IT, and these have generally found that ITs during the final instars showed balanced or carbohydrate-biased ITs. To understand the nutritional requirements during ontogeny, we measured the IT of each instar of the South American Locust, *Schistocerca cancellata*. In addition, we recorded growth performance and survival of locusts reared on single artificial diets varying in P:C for the entire developmental period. Once each week we counted the number of individuals and weighed 20 randomly-selected individuals of each sex and diet treatment. In contrast to studies focused on only the final instar, across the entire development period, performance (assessed as mass gain, survival, and rate of development) was highest on protein-biased artificial diets. Most instars chose protein-biased diets while only the final juvenile instar and adults chose carbohydrate-biased diets. We conclude that both dietary preferences and macronutrient needs of *S. cancellata* change dramatically during ontogeny, and that studies of the final instar are inadequate to predict nutritional needs throughout development. Supported by NSF IOS-1826848 and BARD FI-575-2018.

P2-93 TALAL, S*; YOUNGBLOOD, J; FARINGTON, R; CEASE, AJ; HARRISON, JF; Arizona State University, Tempe; *stav.talal@gmail.com*

Outbreaking Locusts (Schistocerca cancellata) in Paraguay are Carbohydrate Hungry which Increase their Performance

Herbivores are often thought to be protein-limited; however, recent studies with locusts have suggested that outbreaks may be facilitated by high carbohydrate food. In this study, we examined dietary preferences and performance consequences of different dietary protein:carbohydrate (P:C) ratios on South American locusts (*Schistocerca cancellata*) in Paraguay. Marching nymphs (4^{th} and 5^{th} instars) in the field and during lab choice experiments strongly preferred high carbohydrate diets. Single artificial diet experiments showed that survival improved as P:C decreased, despite that mass-specific consumption and growth rates did not vary. Nymphs showed lower survival on local plants compare to artificial diets, suggesting many of the available plants were poor quality food. Locusts given a choice of seven local plants showed a clear preference for one grass species, which had the highest carbohydrate content and carbon to nitrogen ratio. This grass was also the only plant on which the nymphs gained body mass during single-plant feeding trials. Total body lipid content increased as the P:C ratio of the artificial diet decreased. The lipid contents of field marching nymphs were low and similar to those fed 1:1 or higher P:C artificial diets. In summary, foods with high carbohydrate and low protein (low P:C) benefited late instar nymphs by increasing survival and fuels for adult migration. It is plausible that the population growth and ecological success of *S. cancellata* is at least partially constrained by carbohydrate availability in Paraguay. This research was supported by NSF IOS-1826848 and BARD FI-575-2018.

66-3 TALBOT, WA*; WOLF, BO; University of New Mexico; *wtalbot@unm.edu*

Sonoran desert bats show modest capacities for thermoregulation in the heat

In the Sonoran Desert, the radiant heat from highly absorbent surfaces carries the extreme heat of the day well into the night and, with climate change, nocturnal minimal temperatures have increased more than diurnal maxima. As these phenomena are expected to intensify, there is the potential to affect the available foraging time for nocturnal aerial insectivores. We examined the thermoregulatory capacity of six Sonoran Desert bats: pallid bat, *Antrozous pallidus*, big brown bat, *Eptesicus fuscus*, California myotis, *Myotis californicus*, western pipistrelle, *Parastrellus hesperus*, California leaf-nosed bat, *Macrotus californicus*, and Brazilian free-tailed bat, *Tadadarida brasiliensis*. We measured resting metabolic rates, body temperature, rates of evaporative water loss and thermal tolerance using flow-through respirometry. All species had relatively modest thermal tolerance limits (~40 &deg C) compared to nocturnal birds (~48-64 &deg C)and some nocturnal rodents. A limited capacity for evaporative heat loss and lthal body temperatures of ~43 &deg C appear to contribute to these differences in performance in the heat.

101-4 TALBOTT, KM*; SOINI, HA; NOVOTNY, MV; WHITTAKER, D; HIGGINS, B; KETTERSON, ED; Indiana U. Dept. of Biology, Bloomington, IN, Indiana U. Pheromone Institute, Bloomington, IN, BEACON Center for the Study of Evolution in Action, Michigan State U., East Lansing, MI; *kmtalbot@iu.edu*

Does Haemosporidian infection status influence volatile composition of avian preen oil?

The volatile compounds in preen oil, a secretion of the avian uropygial gland, contributes to bird odor. The composition of these compounds has been shown to vary by species, population, individual, sex, and season. But what information does the odor blend contain? Using the dark-eyed junco as a model, we asked whether preen oil composition varies based on the presence and intensity of infection with avian malaria parasites. Haemosporidians are vector-transmitted blood parasites that cause malaria in vertebrate hosts. Mosquitoes that vector these parasites are known to prefer hosts with haemosporidian infections, but the mechanism behind this preference is unclear. If vectors use host odor to find preferred hosts, we predict that preen oil volatile composition of infected birds will vary from those of uninfected birds. In addition, if parasite growth induces a shift in host volatile composition, we predict that one or more volatile compounds should correlate in proportion with parasite load. To test these predictions, we collected preen oil and blood samples from non-migratory juncos in the Appalachian Mountains of Virginia during the early breeding season. We used gas chromatography-mass spectrometry to quantify the relative proportions of 15 volatile compounds in each bird's preen oil composition. Next, we analyzed DNA from blood samples through nested PCR and qPCR to identify haemosporidian infections and assess parasite loads. We will discuss differences in odor blend between infected and uninfected birds of both sexes, and the potential ecological relevance of these differences.

107-5 TANNER, RL*; GLEASON, LU; DOWD, WW; Washington State Univ., Sacramento State Univ.; *richelle.tanner@wsu.edu*

Pathway-Dependent Patterns of Gene and Protein Expression Variation Exposed by Thermal Stress in the Intertidal Mussel

Heterogeneous environments like the intertidal zone vary in environmental conditions over time and space, potentially leading to high inter-individual variation in physiology within a single population. We used gene and protein expression profiling in *Mytilus californianus* mussels exposed to five thermal regimes (4 field and 1 common garden) to better understand how thermal stress may expose or mask inter-individual variation. At a global level, thermal stress in the form of transplanting mussels to a high-intertidal site exposed high variation in global gene expression and tended to canalize global protein expression. We then asked whether thermal stress differentially affects variation in expression of individual genes and proteins within specific biochemical networks. We analyzed both canonical (*a priori*) biochemical pathways and highly interconnected clusters (i.e., empirical or *de novo* "pathways") generated from network co-expression analyses. We found 22 genes in six biochemical pathways that have opposing patterns of variation in gene and protein expression across treatments, and 18 genes that have opposing patterns of variation among treatments (for example, only high variation in ambient conditions). Using a dimension reduction analyses, we found expression was most canalized in common garden conditions across biochemical and empirical pathways. Taken together, these analyses suggest that the complexity of interactions between genes is reduced in protein expression, and the suite of genes with increased variation under thermal stress has limited overlap between transcript and protein expression.

P1-232 TANNER, RL; Washington State Univ.; *richelle.tanner@wsu.edu*

Building a Network of Science Communicators for Change: Strategies from the National Network for Ocean and Climate Change Interpretation

The National Network for Ocean and Climate Change Interpretation has endeavored to build a community of climate science communicators through shared values, standardized training based on social science research, bringing educators and scientists into a shared learning space, and a unique focus on the social and emotional support needed for communicating difficult topics like climate change. At NNOCCI, we use shared societal values and tested metaphors to shift the national conversation on climate change to be positive, civic-minded, and solutions-focused. In the last decade, 184 informal education institutions and 440 individuals have joined the network, all by undergoing a structured training course focused on building trust among our members. Using a dyad structure and a regional model, we achieve high connectivity among members and a lowered barrier to collaboration among members that have not formally met. Our efforts are supported by multiple social medial platforms, including our own www.climateinterpreter.org, and our message has successfully been disseminated to hundreds of thousands of community members through many forms of communication. We look forward to exponentially growing the scientist contingency of our population in the coming years. By building trust and lasting bonds among members nationally, we strengthen a network of climate science communicators that feel emotionally supported in the work they do.

P1-145 TAPSAK, ST*; HRANITZ, JM; PERCIVAL, CR; PULLEY, KL; GONZALEZ, VH; PETANIDOU, T; TSCHEULIN, T; KANTSA, A; BARTHELL, JF; Bloomsburg University of Pennsylvania, Pomona College, Claremont, CA, University of Texas at El Paso, University of Kansas, Lawrence, University of the Aegean, Mytilene, Greece, University of Central Oklahoma, Edmond; *stt52247@huskies.bloomu.edu*

Generalist Pollinators are the Foundation of a Summer Coastal Pollination Network in Dune Habitat.

Climate change and sea level rise exert broad effects on plant-pollinator (p-p) interactions, especially in phenology and frequency of disturbance in coastal pollinator communities. Because coastal habitats face rapid change due to inundation from sea level rise and physical stressors (e.g., salinity or temperature), it becomes important to understand the species that rely on these habitats as support for conservation efforts. The goal of this study is to provide a clearer picture of coastal pollinator networks by describing summer p-p interactions in coastal habitats as a foundation for continuing studies that will compare pollination networks on different islands. For this study, we studied a summer coastal pollination network in the narrow dune habitats (beach berm to marsh) at Kalloni Bay on Lesvos Island. We collected insect-plant visitation pairs from four 100-meter transects of dune habitat in June 2019. Plant-pollinator interactions were analyzed using the Bipartite package in R. Summer pollinators in our samples included Coleoptera, Diptera, Hymenoptera, and Lepidoptera. Most of these were generalist foragers (d'=0.067-0.392) with a low pollination service index (PSI=0.094-0.110). Similarly, most pollinators were peripherals, and few played the role of connectives or module hubs. Coastal habitats on Lesvos Island appear to harbor a large diversity of summer pollinators with low specialization and modularity.

140-1 TARASHANSKY, AJ; LI, P; XUE, Y; QUAKE, SR; WANG, B*; Stanford University; *wangbo@stanford.edu*

Cross-species mapping of cell type atlases identifies conservation and divergence in planarian and parasitic flatworms

Although all animals can heal wounds, only some are capable of regenerating from major tissue losses. Little is known about how and why most animals have lost the ability of whole-body regeneration. To answer these questions, we study two evolutionary cousins: the freshwater planarian, which is an immortal flatworm with unparalleled regenerative ability throughout the animal kingdom, and the parasitic flatworm schistosome, which infects hundreds of millions people and causes one of the most prevalent infectious diseases. Unlike planarians, schistosomes only have limited regenerative ability. Planarian regeneration relies on the pluripotent and tissue-specialized neoblasts to differentiate and produce all missing cell types under the guidance of a set of patterning signals expressed in muscle cells. To test if schistosomes have similar cell types, we have developed a single-cell transcriptomic analysis method (self-assembling manifolds mapping, SAMap) to construct a comprehensive cross-species comparative map of schistosome and planarian cell types, a task that has not been possible previously. This method has allowed us to identify schistosome cell types that are homologous to all planarian pluripotent and tissue-specialized neoblast populations, as well as muscle cells that express the patterning cues. Enabled by this cross-species comparison, We are now systematically examining the functions of these homologous stem cell populations and dissecting the gene circuits that control the fate of these cells.

P1-34 TARDELLI CANEDO, P*; BAKER, CM; MORISAWA, R; PESSEREAU, EJ; BOYER, SL; Macalester College, Harvard University; *ptcanedo@gmail.com*

Phylogeography of Neopurcellia salmoni, a widespread mite harvestman from the South Island of New Zealand, with the first report of male polymorphism in the suborder Cyphophthalmi

Neopurcellia is a monotypic genus of mite harvestmen endemic to the South Island of New Zealand. These dispersal-limited organisms have a paradoxically widespread distribution given their limited dispersal capabilities, suggestive of multiple cryptic species within the lineage. We analyzed the phylogeography of *Neopurcellia salmoni* by reconstructing phylogenetic relationships using DNA sequence data from the fast-evolving mitochondrial locus cytochrome c oxidase I (COI). Tree topologies revealed two distinct and well-supported clades occupying non-overlapping geographical regions of the west coast. The strong correlation between the evolutionary relationships of lineages within *Neopurcellia* and the geographic distribution of its populations indicates that monophyletic groups tend to correspond to similar or adjacent geographic regions, as expected with dispersal-limited organisms. We also used scanning electron microscopy to examine a surprising level of intraspecific variation in the dorsal morphology of these organisms, constituting the first documented case of male polymorphism in the suborder Cyphophthalmi. While the presence of two different morphotypes initially suggested multiple co-distributed *Neopurcellia* species, the seemingly random geographic and phylogenetic distribution of the male morphotypes allows us to reject this hypothesis. The presence of male polymorphism in *Neopurcellia* is hypothesized to be the outcome of strong sexual selection, driving the development of alternative reproductive tactics that may improve mating success by enhancing olfaction or chemoreception between glandular males and their mates.

59-5 TARRANT, AM*; BERGER, C; STEINBERG, DK; Woods Hole Oceanogr. Inst., Virginia Inst. Marine Sci.; *atarrant@whoi.edu*

Feast and Famine: Copepod metabolic condition during summer along the West Antarctic Peninsula

Within the surface waters of the West Antarctic Peninsula (WAP), copepods are the dominant component of the mesozooplankton during summer. Two of the most common species of large copepods exhibit different life history strategies. *Calanoides acutus* is predominantly herbivorous, stores lipids as wax esters, and overwinters in a dormant state. In contrast *Calanus propinquus* is more omnivorous, stores triglycerides, and often remains active during winter. During austral summer 2019, females of both species were sampled along the WAP continental shelf. Chlorophyll profiles and presumed food availability differed dramatically among sampling stations. Physiological condition of the field-sampled copepods is being assessed through transcriptional profiling and enzymatic activity assays. In addition, shipboard experiments were conducted in which copepods were either fed or starved for up to 9 days. Over the experimental period, citrate synthase activity decreased in the starved animals, consistent with metabolic depression and conservation of energetic reserves. Transcriptional profiling of corresponding experimental animals will provide insight into physiological adaptations to patchy food resources and context for interpreting observed patterns in the field.

67-3 TASSIA, MG*; DAVID, KT; HALANYCH, KM; Auburn University, Auburn, AL; *mgt0007@auburn.edu*

Innate immunity evolution in underrepresented metazoans and the implications when opting for similarity-metrics vs. hidden Markov models

In this study, we investigate the evolution of innate immunity signaling components among hemichordates and other underrepresented, and/or non-model, metazoans using a hidden Markov model (HMM)-based approach. Previous studies have shown that although the core innate immunity signaling pathways possess deep roots within Metazoa, the receptors responsible for host-pathogen interfacing exhibit dynamic diversification events within several bilaterian lineages such as annelids, bivalves, and echinoids. Like many signaling pathways, innate immunity-associated proteins fundamentally rely on domains of discrete characteristics – such as hydrophobic ligand binding, transmembrane helices, or catabolic activity. The identification and classification of any given protein's domain architecture is integral for inferring functional conservation/diversification among related proteins, particularly when investigating understudied, non-model taxa. In this study, we investigate three vital innate immunity protein families: Toll-like receptors, NOD-like receptors, and RIG-1-like receptors. The bioinformatic pipeline established here also principally addresses issues raised by database bias towards classic biomedical model systems (e.g., mouse, fly, and human). We show that HMM-based approaches, such as the one used in this study, provide a powerful alternative to similarity-based searches (e.g., BLAST); furthermore, the pipeline developed here can be applied to a large variety of protein families and taxa dependent upon the user's target protein and phylogenetic depth.

65-3 TAYLOR, LD*; WHITE, LD; University of California, Berkeley; *larry.taylor@berkeley.edu*

Building Collaborations with Local Community Colleges to Increase Diverse Students' Access to STEM Fields

The underrepresentation of certain groups in higher academia and STEM fields is directly contrasted by the overrepresentation of these same groups in U.S. community colleges. Relative to their peers at four-year institutions, community college students are much more likely to come from low-income households, are much more likely to identify as members of an underrepresented minority group, and are much more likely to be first-generation college students. Unfortunately, few community colleges offer access to research experiences or specialized biological disciplines, leaving diverse students less prepared to pursue these disciplines or scientific research later in their academic career. This creates an opportunity for museums and four-year institutions to partner with local community colleges to both enrich students' educational experience and increase accessibility to our fields. At the University of California Museum of Paleontology at UC Berkeley, we have developed a program which integrates custom-built, fossil-based laboratory class sessions into the course curricula of local community colleges. By enabling community college students to actively engage with the field of paleobiology and interact with students, researchers, and faculty mentors working in the field, we intend to create an environment where community college students may gain both interest in the field and confidence in their ability to pursue higher academia. We hope that we may help provide a blueprint by which other institutions can build avenues for local community college students to explore their interests and eventually bring their diverse backgrounds and perspectives into our fields.

93-1 TAYLOR, LD*; FINNEGAN, S; O'DEA, A; BRALOWER, TJ; University of California, Berkeley, Smithsonian Tropical Research Institute, Pennsylvania State University; *larry.taylor@berkeley.edu*

Isotopic Analysis of Fossil Coronulid Barnacles as a Means of Understanding Prehistoric Whale Migration

Migration is an integral feature of modern mysticete whale ecology, and the demands of migration may have played a key role in shaping mysticete evolutionary history. Constraining when migration became established and assessing how it has changed through time may yield valuable insight into the evolution of mysticete whales and the oceans in which they lived. However, there are currently few data which directly assess prehistoric mysticete migrations. Here we show that calcite δ18O profiles of modern whale barnacles (coronulids) accurately reflect the known migration routes of their host whales. We then show that δ18O profiles from well-preserved fossil coronulids exhibit trends and ranges similar to those of modern specimens, indicating that multiple Plio-Pleistocene whale populations of both the humpback and gray whale lineage were undertaking migrations of similar extent to those of the present day. We also find that Pleistocene whales congregating on the Pacific coast of Panama included individuals belonging to several different subpopulations, as the recovered δ18O profiles indicate very different migratory paths. Continued work on this project is aimed at integrating fossil coronulid δ18O profiles with paleoceanographic models and emerging proxies that can independently constrain seawater temperature and isotopic composition in order to more tightly constrain the migratory pathways of prehistoric mysticete whales.

122-2 TAYLOR, MS*; O'BRIEN, HD; GIGNAC, PM; Oklahoma State University Center for Health Sciences; *matthew.s.taylor@okstate.edu*

Shrinkage after swimming in iodine? Evaluating the use of hydrogel stabilization for reinforcing nervous tissues before iodine diffusion

As a soft-tissue imaging technique, diceCT (diffusible iodine-based contrast-enhanced computed tomography) offers outstanding opportunities for analyzing small neuroanatomical structures without requiring dissection. Recently, diceCT methods have been refined with respect to preserving, iodine-staining, and scanning neural tissue for visualization. Here, we add to the growing discussion of diceCT "best practices" by testing the efficacy of the STABILITY tissue stabilization protocol, in which samples are reinforced with hydrogel prior to iodine staining. One purported advantage of hydrogel is to limit tissue shrinkage that can occur when a specimen is exposed to high concentrations of iodine. However, infiltrating specimens with hydrogel adds substantial time and additional expenses to an experiment. Although seemingly intuitive, it is unclear if stabilization is a routinely necessary step to obtain satisfactory results. To evaluate the necessity of hydrogel stabilization, we obtained post-mortem brains of 18 juvenile Sprague Dawley rats from an unrelated drug addiction study, wherein some rats were exposed to high levels of morphine and others to a saline control. We applied the STABILITY protocol to half of the brains prior to iodine staining. Using microCT visualizations, we analyzed the two-dimensional shape of the corpus callosum at the mid-sagittal plane and found no significant differences in the structure of this brain region due to either drug treatment ($p = 0.16$) or tissue preservation technique ($p = 0.31$). These results suggest that the costs of hydrogel stabilization may not provide benefits for all neuroanatomical studies.

P1-108 TAYLOR, BK*; KEHL, C; The University of North Carolina at Chapel Hill; *brian.taylor@unc.edu*

Bioinspired trans-equatorial navigation using sequential measurements of magnetic inclination

Diverse taxa use Earth's magnetic field to navigate both locally, and across global scales. Several of these animals have demonstrated the ability to use magnetic inclination (i.e., the angle between the magnetic field vector and the surface of the earth) as a means of poleward or equatorward orientation. However, it is unknown how this sense functionally enables successful navigation or migratory behavior. It is also unclear how animal navigation strategies negotiate the long and short period temporal drift in the magnetic field. Inspired by animal behavior, we task an artificial agent with executing a series of trans-equatorial migrations using sequential measurements of magnetic inclination. The agent is tested both in a static magnetic field, and a temporally dynamic magnetic field that can have long and short period variation, similar in nature to the temporal variation observed in the real geomagnetic field. The findings 1) demonstrate that using sequential inclination measurements is a feasible way to execute a trans-equatorial migration, and 2) examine whether an inclination-based navigation strategy can be tolerant of temporal magnetic field effects. The results can help gain insight into how animals navigate using magnetic inclination to navigate, particularly as the magnetic field changes over time. Additionally, the results may be useful in the development of new autonomous engineered navigation systems that can use the temporally shifting field as a reference, independent of satellite-based navigation technologies.

P1-109 TAYLOR, BK*; KEHL, C; The University of North Carolina at Chapel Hill; *brian.taylor@unc.edu*

A bioinspired navigation strategy that uses magnetic signatures to navigate without GPS in the Northern Atlantic

Diverse taxa use Earth's magnetic field in concert with other sensory modalities to accomplish long-distance migration across continents and ocean basins. However, despite extensive research, how animals use Earth's magnetic field to navigate is an active area of investigation. Earth's magnetic field can also be leveraged for navigation by engineered systems in environments where man-made systems such as GPS are unavailable or unreliable. Some animals use combinations of magnetic inclination and intensity as rare or unique signatures that mark specific locations to enable migration, but the viability of this type of strategy depends on the local magnetic topography. The closer lines of constant magnetic inclination and intensity are to parallel, the more adversity this strategy may face. Inspired by migratory animal behavior, this study implements a magnetic signatures-based multimodal sensing navigation strategy to migrate in an environment that simulates the northern Atlantic Ocean, a seemingly challenging region for a signatures-based algorithm. The strategy uses the magnetic field as a sensory signal to migrate to a prescribed set of points, and must also negotiate a fluid current that simulates the north Atlantic gyre. The strategy contains only a high level representation of the magnetic topography, not an explicit map. The results demonstrate the ability of a signatures based strategy to navigate, and the importance of the interaction between the strategy's implementation, the sensory signal, and external environmental factors that can influence a platform's motion. The findings can be used to better understand animal navigation, and to design new engineered navigation systems that are less dependent on satellite-based navigation.

P3-171 TAYLOR, LA*; PERTUIT, OR; CARSON, IR; TANG, C; DENNIS, AJ; THAWLEY, CJ; JOHNSON, MA; Trinity University, San Antonio, Texas, United International College, Xiangzhou, Zhuhai, China, Davidson College, Davidson, North Carolina; *ltaylor2@trinity.edu*

Artificial Light At Night (ALAN): An Anthropogenic Challenge for Urban Lizard Behavior and Physiology

Artificial light at night (ALAN) is a recent phenomenon that disrupts the behavior and physiology of animals as diverse as humans, birds, rodents, fish, and insects. In this study, we investigated the impacts of ALAN on the behavior and physiology of the green anole lizard (*Anolis carolinensis*). Two groups of 12 male and 12 female wild-caught anoles were exposed to different light-dark cycles in a controlled lab setting for six weeks. One group was exposed to a light-dark cycle that simulated the natural cycle of a summer day in San Antonio, Texas and the other group was exposed to the natural light-dark cycle and a nighttime ALAN regime that simulated the streetlights on an urban university campus. After an acclimation period, we conducted a series of behavioral trials. Three trials were repeated during mid-day and mid-night: open field tests, to examine exploratory behavior; foraging trials, to examine prey consumption; and conspecific trials, to examine same-sex interactions. The fourth trial examined behavioral time allocation over two 24-hour periods. At the conclusion of behavioral trials, we measured body mass and the mass of each lizard's fat pads, livers, and testes or ovaries and eggs. Our data suggest that green anoles exposed to ALAN are more likely to be awake at night. While they are awake, anoles exposed to ALAN appear to use the light to explore, forage, and defend their territory. Additionally, exposure to ALAN does not appear to influence anole reproduction or body composition. In sum, ALAN appears to facilitate an increase in activity level without adversely affecting green anole health over a short-term exposure.

107-7 TEETS, NM*; DALRYMPLE, EG; HILLIS, MH; LEE, RE; DENLINGER, DL; University of Kentucky, Lexington, Miami University, Oxford, OH, Ohio State University, Columbus; *n.teets@uky.edu*

To Freeze or Not to Freeze: Cold Tolerance Strategies in an Antarctic Midge

For freeze-tolerant insects, internal ice formation presents additional challenges beyond cold *per se*, but few studies have directly compared freezing vs. supercooling at the molecular and physiological level. Here, we investigated molecular responses and physiological costs of freezing in the Antarctic midge, *Belgica antarctica*. In previous work, we demonstrated substantial costs to freezing in summer-acclimatized larvae, including mortality and tissue damage, reduced locomotion, and damage to proteins. In this talk, first we directly compare the physiological effects of freezing and supercooling in winter acclimatized larvae. Winter larvae survive freezing and supercooling equally well, and we observed no evidence of sublethal tissue damage in either condition. However, short-term freezing elicited higher expression of certain heat shock protein transcripts, suggesting a higher degree of cellular stress in frozen larvae. Biochemical responses were similar in both cold treatments, although frozen larvae tended to have lower levels of glycogen reserves, suggesting additional energetic costs to being frozen. In an ongoing transcriptomics study, we are directly comparing molecular responses to sublethal freezing and supercooling. Preliminary analyses indicate distinct molecular responses to each treatment, with supercooling eliciting a larger number of gene expression changes overall but freezing resulting in higher expression of stress-related proteins. Together, these studies will contribute towards identifying the precise molecular and physiological processes that are required to survive in the frozen state.

47-2 TEIXEIRA, RV; TITON, SCM; TITON JR, B; GOMES, FR; ASSIS, VR*; University of Sao Paulo; *v.regina.a@gmail.com*

Trace elements and amphibian's immunity - what can we expect?

Amphibians are animals that are closely associated with both aquatic and terrestrial habitats, what makes them vulnerable to different habitats modifications. Among those modifications, those caused by humans as fragmentation, introduction of emergent diseases, invasive species, and pollution can be highlighted as the most worrying. Pollution by trace elements can cause an impact in immune response of amphibians, depending on the amount and duration of exposure. The aim of this study was to evaluate the innate immunity of *Rhinella diptycha* toads at three sites with different contamination levels. Therefore, blood samples were collected to measure corticosterone plasma levels (CORT), neutrophil/lymphocyte ratio (NL) and plasma bacterial killing ability (BKA). Toads were subjected to a challenge with the mitogen phytohemagglutinin (PHA) followed by measurements of swelling response. Animals had organs collected (kidney, liver and spleen) to verify morphometric characteristics and bioaccumulation levels of trace elements specifically in the livers. The sites were divided in three levels of contamination, accordingly to the amount of trace elements found on the sediment, as follow: site 2 > site 1 > site 3. Toads from site 3 (the less contaminated) had higher levels of zinc on their livers, smaller kidneys, and larger spleens when compared to the other two sites. The toads did not presented difference among sites for CORT, NL or BKA, but toads from site 3 showed higher maximum swelling after PHA challenge. Although there is no statistical difference among sites on the main stress markers, CORT presented lower levels in toads living in the less contaminated site. These results indicate that animals living in more contaminated sites might present lower inflammatory response.

P3-16 TELLEZ-GOMEZ, QM*; FLORES-SANTIN, JR; Universidad Autonoma del Estado de Mexico; *quetmaria@hotmail.com*

EMBRYONIC DEVELOPMENTAL EFFECTS OF MATERNAL INGESTION OF CYPERMETHRIN IN JAPANESE QUAIL Coturnix japonica

Pyrethroid pesticides are chemical substances specifically used for the control of insects. Their effectiveness has contributed to its widespread use. However the toxic effects of this pesticides over other animal groups during agricultural practices has been put to question. Such is the case of cypermethrin, a pyrethroid with neurotoxic effects that induces slow growth, fertility issues, morphological and metabolic anomalies in amphibians. In Mexico cypermethrin is an authorized pesticide classified as highly harmful to humans. Birds from the Phasianidae family tend to be terrestrial foragers in crop fields, exposing them directly to the ingestion of the pesticide. The objective of this work is to assess the effects of maternal ingestion of cypermethrin in the development of the embryos. The use of Japanese quail provides a reliable model homologuous to wild populations of birds. A total of 5 females were used for each corresponding experimental group with 3 doses of cypermethrin (0.155g / kg, 0.315 g / kg, 0.6 g / kg) were administered through via feeding tube. A total of 40 eggs per group were collected evaluating mortality rate, weight, egg laying rate, fertility index and quality-length of eggs in females force fed cypermethrin. As well as dissecting at 5, 10, 15 days of embryonic development to obtain data on egg weight, height and diameter, venation, shell weight, yolk, chorioallantoic membrane and embryo, and morphometric data analyzed with Image J. Successful hatching specimens, as well as embryos on the 15th day of development of each experimental group, were sacrificed by inhalation to obtain data on weight, malformations and bone morphology by diaphanization, using the software Image J and statistical test. The data suggests an increased mortality as well delay in growth, and developmental anomalies.

P1-224 TEWKSBURY, C*; WILKINSON, K; MONTUELLE, S; GERSTNER, G; WILLIAMS, SH; University of Michigan School of Dentistry, University of Michigan Department of Statistics, Ohio University Heritage College of Osteopathic Medicine; *clairetewks@gmail.com*

Variability in mammalian chewing using functional data analysis: flexibility in jaw movements in response to food properties in pigs

Chewing is a mammalian motor behavior used to reduce and mix food with saliva before swallowing. During chewing, the jaw moves continuously through opening and closing phases (pitch) while rotating about a vertical axis (yaw) to generate the grinding motion of the teeth in contact with the food. Previously, chewing studies were based upon measurements taken at a finite set of heuristic time points in continuous movements, but functional data analysis allows comparing movements continuously and in their entirety throughout the gape cycle. We hypothesize that variability in jaw movements during chewing will include food-, individual-, and degree-of-freedom (dof)-specific differences. Chewing movements were quantified in 4 pigs feeding on 3 foods (almonds, carrots, and apples) using XROMM. The time series of the three main dofs (pitch, yaw, and condylar translation) were transformed into continuous functional objects and a functional analysis of variance (fANOVA) was used to test differences between individuals, foods, and two-way interactions. Results demonstrate that significant differences exist between individuals, and between food types. However, not all dof were affected similarly. Most of the individual differences occurred in jaw pitch and condylar translation, whereas jaw yaw was consistently inflexible. Pig chewing is therefore characterized by non-negligible individual differences that become richly expressed across foods and that highlight how multiple performances can achieve the same behavior.

58-2 TEWS, VH*; BARNETT, AA; DeSales University, DeSales Univeristy; *vt7905@desales.edu*

Examining the Evolution of Epidermal Growth Factor (EGF) Pathway Ligands in Insects

The EGF pathway is a highly conserved and ubiquitously used cell signaling cascade in the development of many animals. In the highly studied Drosophila melanogaster, four ligands (vein, gurken, spitz and keren) are used to activate the pathway while one ligand (argos) is used to repress activation of the EGF pathway. An arthropod centered phylogenetic analysis showed that the genes which encode 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 which includes flies. In continuation of this research, evidence was provided showing the orthologues of spitz and keren are the result of multiple independent gene duplication events. In an attempt to determine the ancestral role of the spitz/keren gene during insect development, we used RNAi 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.

57-3 THAKER, M*; BATABYAL, A; AMDEKAR, M; Indian Institute of Science, Bangalore, India; *mthaker@iisc.ac.in*

Alternative strategies and the dynamism of color

Alternative social strategies in lizards are often correlated with distinct color forms that are fixed upon development. In the Indian rock agama, *Psammophilus dorsalis*, dynamic physiological color changes allow males to express alternative color patterns for courtship and aggression. These social colours of males (especially the courtship pattern), are conspicuous not only to conspecifics but also to predators, and thus impose a greater risk to males than non-social colors. To balance the predation risk of conspicuous colors with the benefits of social signalling, males switch in and out of color states within minutes. Given population differences in selection pressures, the intensity of color states differs between urban and rural populations, with associated differences in testosterone and corticosterone responses to social challenges. Overall, whole organismal shifts in phenotypic strategies that include hormone responsiveness and health indices, suggest that urban lizards have social coping styles that are reactive and not proactive.

108-3 THANDIACKAL, R*; LAUDER, GV; Harvard University; *rthandiackal@gmail.com*

Turning in Zebrafish: Measuring Body Pressure, Torque, and Work During Spontaneous Turns

Energetic efficiency has long been considered an important feature of routine animal behavior. In fluid environments, fish swim using body undulations to navigate and propel themselves forward, but direct measurement of work done by the body on the fluid has proven challenging. Moreover, fish often rely on unsteady maneuvers during tasks like navigation, feeding or predator evasion. Here we investigate spontaneous turns in zebrafish using a modified Particle Image Velocimetry (PIV) technique. The method is inspired by previous work on micro scale PIV and does not require a laser to record the movements of fluid particles in a specific 2D plane, but makes use of a narrow depth-of-field instead. We combine the obtained flow field measurements with pressure computations to estimate the interaction forces and the mechanical work done between the turning fish body and the fluid. Our results show that the majority of mechanical work is done by the body on the fluid and that energy is transferred to the water in two bursts. Our method allows quantification of the hydrodynamic cost of a turn and additionally provides information about how much each segment along the anterio-posterior body axis contributes to the energy transfer to the fluid. This method provides a rigorous way to quantify hydrodynamic mechanisms of fish swimming, and we expect that it could be valuable for future analysis of hydrodynamics in fish schools.

P1-233 THAWLEY, CJ*; KOSTKA, AL; KOLBE, JJ; Davidson College, University of Rhode Island; *chthawley@davidson.edu*

Ecology by the people: How can citizen science inform our understanding of lizard ecology?

A thorough understanding of many aspects of a species' ecology, including its behavior, habitat use, and seasonality, often requires many observations distributed across large spatial and temporal extents. Logistical and financial considerations, however, can limit the ability of scientists to amass the large datasets needed to address these questions. One potential solution is to use extensive databases of citizen science observations collected by members of the public who are not professional scientists to quantify ecological variation of species. While citizen science data are rapidly increasing in quantity and availability, they may be subject to biases, and their suitability for ecological analyses is not always clear. We leveraged the well-researched ecology of Anolis lizards in Florida to assess whether citizen science observations are appropriate for broad scale analyses of lizard ecology. We created a database of >1500 geolocated, timestamped observations of two species of anoles, the native green anole (*Anolis carolinensis*) and the invasive brown anole (*Anolis sagrei*), from one calendar year (2017) submitted to the citizen scientist platform iNaturalist. We coded each observation for sex, morphology, behavior, and habitat use of the lizard(s) in each photograph. We assessed whether patterns in this citizen science dataset match predictions taken from the peer-reviewed literature and discuss the value of data collected by citizen scientists in complementing those generated by professional scientists.

88-4 THOMAS, KN*; GOWER, DJ; BELL, RC; FUJITA, MK; SCHOTT, RK; STREICHER, JW; Natural History Museum, London, UK, Smithsonian National Museum of Natural History, Washington DC, USA, University of Texas at Arlington, USA, Smithsonian National Museum of Natural History, Washington DC, USA; *kate.thomas@nhm.ac.uk*

Ecological Correlates of Eye Size in Frogs and Toads

A typical frog may elicit the image of a small, leggy vertebrate with bulging eyes. However, relative eye size is highly variable among different species of frogs and toads (Amphibia: Anura). Larger eyes are costlier, but can improve visual performance, so variation in eye size has direct functional implications for vision. Research into major vertebrate groups such as birds, mammals, reptiles, and fishes has shown that ecological traits such as habitat, activity pattern, and behaviours associated with vision are often correlated with the relative sizes of eyes across species. However, anuran eye size has been understudied despite a stunning diversity of anuran ecologies and behaviours, and a single published study found no correlations between eye size and ecology in anurans. We measured anuran eye, cornea, and body sizes in 642 adult specimens representing 211 species and all 55 currently recognized families, and scored five natural history traits for all species from available literature in order to test for ecological correlates of relative eye size. Our data showed that frogs have large relative eye sizes compared to other vertebrates, and their eye diameters scale isometrically with the cube root of mass across species. Relative eye sizes were correlated with adult habitat and breeding ecology. Our study demonstrates the salient role that ecology has played in the evolution of anuran visual systems and highlights the importance of broad taxonomic sampling for detecting macroevolutionary patterns of trait evolution.

7-1 THOMAS, PA*; WHEELER, CR; PEELE, EE; PABST, DA; YOPAK, KE; KINSEY, ST; UNC-Wilmington, University of Massachusetts, Boston; *pat3805@uncw.edu*

Effects of Elevated Temperature on Muscle Development in Juvenile Epaulette Sharks, Hemiscyllium ocellatum

Temperature is known to affect embryogenesis and myogenesis in many fish species. Understanding effects of chronically elevated temperatures on fish muscle development is important for understanding potential effects of warming waters on individual organism health. Epaulette shark (*Hemiscyllium ocellatum*) eggs were reared and hatched˚ for an average of 189 days at their normal mean environmental temperature (27 &degC) and 164 days at an elevated environmental temperature (31 &degC), and markers of muscle development as well as oxidative damage were evaluated. We measured muscle fiber size, nuclear density, and satellite cell density as markers of muscle development, heat shock protein expression (Hsp70), and protein and lipid oxidation (2,4-DNPH and 4-HNE, respectively) as markers of global oxidative damage. We found that elevated temperatures caused individuals to hatch earlier and to have smaller body sizes. Also, skeletal muscle growth was at an earlier stage compared to the normal temperature. Muscle fibers at both temperatures were similar in size and nuclear density, but satellite cell density was higher in the sharks raised at the elevated temperature ($p< 0.0001$). Fibers associated with satellite cells were significantly smaller at the elevated temperature than those at the normal temperature ($p<0.0001$). Generally, at the normal temperature, muscle fiber growth followed a linear trajectory with age post-hatch while muscle fiber growth under the elevated temperature showed greater variability with age. Total oxidative damage was higher at the elevated temperature ($p=0.004$) and increased with time ($p=0.010$), showing that these temperatures may induce oxidative stress which could be detrimental to organismal function and development.

P3-33 THOMAS, P*; PANG, YF; TAN, W; University of Texas at Austin; *peter.thomas@utexas.edu*

Rapid Progestin Induction of Sperm Hypermotility in Marine Fish through Membrane Progestin Receptor Alpha

Knowledge of the mechanisms regulating sperm motility would enable the development of more reliable methods to improve sperm quality and spawning of marine fish in captivity. Acute treatment of southern flounder and Atlantic croaker sperm in vitro with a teleost progestin hormone (20β-S) causes rapid induction of sperm hypermotility and increased fertility through activation of progestin membrane receptor alpha (mPRα,Paqr7) coupled to a stimulatory G protein. The involvement of several intracellular signaling pathways in the sperm hypermotility response to 20β-S was investigated by incubation with inhibitors (I) or activators (A) of Egfr (I:AG1478, A:EGF), Mapk/Erk1/2 (I: U0126), Pi3k/Akt (Pi3k I:Wortmannin, LY294002, Akt I: ML9), Acy/cAMP (I: dd-Ado, A: forskolin), Pde (I: Cilostamide), or calcium (L-type channel I:verapamil) signaling pathways for 30 min. prior to treatment with 20β-S or Org 02-0 (specific mPR agonist) for 1 min. and motility activation with a hyperosmotic medium. The induction of sperm hypermotility by 20β-S and Org 02-0 was blocked by prior treatments with inhibitors of Egfr, Mapk, Pi3k/Akt, Pde, and Acy. On the other hand treatment with activators of Egfr (EGF) and Acy (forskolin) mimicked the effects of the progestins and induced sperm hypermotility. These results indicate that progestins induce sperm hypermotility through Egfr/Mapk/Erk1/2, Pi3k/Akt/Pde, and Acy/cAMP pathways. The progestins caused rapid calcium influx into sperm, an effect blocked by verapamil which also blocked progestin-induced sperm hypermotility. The results suggest progestins activate multiple signaling pathways through mPRα in flounder sperm to induce calcium influx and hypermotility and enhance fertility.

S9-2 THOMPSON, CL*; WILLIAMS, SH; GLANDER, KE; TEAFORD, MF; VINYARD, CJ; Grand Valley State University, Ohio University Heritage College of Osteopathic Medicine, Duke University, Touro University College of Osteopathic Medicine, Northeast Ohio Medical University; *thompscy@gvsu.edu*

Getting Humans Off Monkeys' Backs: Can Ecophysiological Research Inform Primate Conservation and Habitat Management Efforts?

Wild primates face grave conservation challenges, with habitat loss and climate change predicted to cause mass extinctions in the coming decades. We apply knowledge from ecophysiology research to address management efforts in tropical mantled howling monkeys (*Alouatta palliata*). Body mass data spanning ~40 years shows that animals are heavier in riparian compared to drier upland habitats, and exhibit habitat- and sex-specific seasonal shifts in weight. Precipitation increased over these years, with male, but not female, weights also increasing. Collectively, we infer significant, sex-specific impacts of environmental conditions on howler morphology. Jaw-muscle electromyograms from free-ranging animals demonstrate howlers modulate bite size or other behavioral parameters in response to seasonal or longer-term changes in food material properties. Thermoregulation studies indicate that howlers buffer the direct effects of rising temperatures by using cool nighttime refugia and exploit spatial heterogeneity in their habitat to navigate changing thermal pressures. These lines of evidence cumulatively indicate howlers' use of physiological and behavioral mechanisms to adjust to temperature and rainfall changes. While habitat loss in the tropics is unlikely to abate, ensuring that forest fragments are suitably large with dynamic structures, as well as high connectivity between fragments, may aid howlers' survival.

P2-43 THOMPSON, ML*; MCENTIRE, KD; Trinity University, San Antonio TX; *mthomps4@trinity.edu*

Color Morph Distribution of Western Ribbon Snakes (Thamnophis proximus) in Texas

Color is used in a variety of ways by animals, from sexual selection to crypsis and warning coloration. Color variation within a species allows for a species to adapt to the environment and can be a major driver of speciation, as is reported for the western ribbon snake (*Thamnophis proximus*). The four recognized subspecies in Texas are distinguished by their color patterns and geographic distribution: western (*T.p. proximus*), gulf coast (*T.p. orarius*), arid land (*T.p. diabolicus*) and red stripe (*T.p. rubirilineatus*). The color morphs reportedly interbreed which suggests that the subspecies are not reproductively isolated based on color. Many color combinations exist outside of the four variations that are currently defined. To understand which mechanisms might be driving the geographic pattern of color morphs in Texas, we first need to have a solid understanding of the current geographic distribution of the various morphs. Using citizen science data from iNaturalist.com and recorded field observations of the color morphs, we remapped the current range of color morphs and quantified their geographic overlap using ArcGIS software. Analyzing this geographic distribution provides a foundation to explore potential environmental factors as mechanisms driving the persistence of multiple color morphs. Furthermore the current distribution of the defined morphs no longer matches the previous known distributions. Updated maps and color combinations provide a chance to look at changes in the distribution of the various color morphs both spatially and temporally.

24-2 THUBLIN, RN*; MOORE, PA; Bowling Green State University, University of Michigan Biological Station; *rthubli@bgsu.edu*

Crayfish self-medication: crayfish alter their feeding preferences based on parasite loads

Many organisms across the animal kingdom have been shown to utilize plants to self-medicate against parasite infection. Often organisms change their feeding preference based on the degree of parasite infection or impact of parasitism on their physiology. Changes in feeding preference can have large scale ecological impacts if the organism being studied is an ecosystem engineer. Crayfish, an established keystone species and ecosystem engineer, were placed in feeding trials with four different species of macrophytes. After feeding trials, the crayfish were dissected and parasite loads within the hepatopancreas were quantified by image-processing techniques. The percent of the hepatopancreas that was comprised of metacercariae of the parasite *Microphallus sp.* as well as the percentage that was melanized, the crayfish immune response to infection, were correlated to foraging choices and amounts. Crayfish did alter their feeding preferences and amount of consumption as a result of parasite load. In addition, different macrophyte consumption was correlated with the amount of melanization of the parasites. These results indicate that crayfish seem to be able to determine when they are parasitized by *Microphallus sp*. and make feeding decisions based on parasite presence. Establishing a change in feeding preference is the first step to determining if crayfish self-medicate when infected with *Microphallus sp.*

P3-19 THUESON, KA*; RABINOWITZ, SA; HAVIRD, JC; The University of Texas at Austin; *kiley.thueson@utexas.edu*

Nuclear Compensation as the Dominant Form of Mitonuclear Coevolution

Eukaryotes are made up of two different genomes that must interact with one another precisely and mitonuclear coevolution is predicted to maintain these interactions. Nuclear compensation, a form of mitonuclear coevolution, is often assumed, but few have directly tested for it. We tested the hypothesis that positive selection in nuclear-encoded genes is a response to deleterious mutations occurring in mitochondrial (mt) genes. To test predictions stemming from this hypothesis, publicly available sequence and structural data were gathered from across mammals for the oxidative phosphorylation enzyme cytochrome c oxidase (COX). We tested whether nuclear-encoded sites under positive selection were overrepresented at mt contact sites, as predicted by nuclear compensation. While nuclear genes had a greater number of positively selected sites than mt genes, sites of positive selection did not particularly contact mt-encoded sites. We also tested if mt mutations are deleterious when expressed alongside novel nuclear genes. To evaluate this, structural information was used to model mitonuclear hybrids to examine the stability of these hybrids compared with "wildtype" structures where mt genes are expressed against their native nuclear counterparts. Under nuclear compensation, structural stability should decrease without a compensatory nuclear component. Preliminary results suggest stability is similar between native "matched" structures and the "mismatched" structures of hybrids. Despite previous studies showing strong support for mitonuclear coevolution, these preliminary results suggest nuclear compensation may be difficult to detect at the molecular level across taxa. Future work will address whether individual nuclear changes tend to follow mt changes in space and time, as predicted by nuclear compensation.

30-4 TIDSWELL, BK*; TYTELL, ED; Tufts University;
Ben.Tidswell@tufts.edu

Using physical models to examine sensory coordination during fish schooling

Fish and other organisms move together in coordinated groups to defend against predators, give them allies to help gather food, and lessen the metabolic costs of transportation. Whether they are in a herd, flock, or school, animals need to use multiple sensory modalities to form and maintain their groupings. To investigate the role of the different senses involved in schooling behavior, we developed a simple robotic apparatus that could "swim" alongside groups of schooling giant danios Devario aequipinnatus. The system included an elastomer fish model, mounted on a rod, that oscillated its tail back and forth as it moved in a circular track. At certain swimming speeds and tail oscillation frequencies, the danios match speed with the model fish. Because of this, we can test how well the fish can match speed with the robot by perturbing the robot's velocity and quantifying how well the fish track the robot. We can also quantify the importance of different sensory modalities by testing schooling in the dark (so that vision is reduced), or with turbulence in the tank (so that the lateral line sense is reduced). This study will help us to explore how fish use different sensory systems to school in different environmental conditions and how they adapt to changes in the school.

94-1 TILMAN, FE; BAKKEN, GS*; O'KEEFE, JM; Indiana State University; *george.bakken@indstate.edu*

Assessing the Thermal Quality of Artificial Roosts for Conservation of Gregarious Bat Species

Bats (Order Chiroptera) are heavily impacted by habitat loss. Cavity and crevice roosting bats, >50% of bat species worldwide, are losing roost sites to deforestation. Artificial roosts might serve as alternatives, but comparative evaluations of different designs are few. Our comparisons of 3 common designs -- synthetic rubber "bark", a typical flat bat box, and a tall, square "rocket box" -- found Indiana bats (*Myotis sodalis*) strongly preferred the rocket box design. The proximate factors responsible for this preference are not clear, as the 3 designs differed in total volume, roosting surface area, odor, predator protection, and thermal characteristics. Neither do we know if preference translates into reproductive success. To better define causal factors, we exploit parallels with lizard studies to evaluate thermal conditions as related to variations in rocket box construction. Notably, solar radiation and rising warm air creates a vertical thermal gradient in the box. Thus, as do lizards in a gradient experiment, bats may move vertically to select a temperature. Further, many bat species are gregarious, so the amount of space (roosting surface area or volume) available within a temperature range is likely to be important. We compared microclimates in 20 designs differing in height, volume, heat storage, insulation, and air vents; boxes were closed to bats. Regressions to temperatures recorded at 3 heights were used to compute a thermal habitat suitability index established for reptile studies: the integrated product of space × time available at temperatures weighted by a physiological value factor. We found biologically significant differences among designs using ad hoc value factors. However, well-justified physiological and reproductive value factors are also needed.

S8-7 TINGLE, JL; University of California, Riverside;
jessica.tingle@email.ucr.edu

Prevalence of Facultative Sidewinding Locomotion in Non-specialist Snake Species

Terrestrial vertebrates have repeatedly evolved elongate, limbless body plans, which require them to move using different types of locomotion than their limbed relatives do. All limbless terrestrial vertebrates can use lateral undulation, which involves side-to-side waves not unlike those used by swimming eels. After lateral undulation, concertina locomotion has been documented in the widest variety of limbless terrestrial taxa, including caecilians, amphisbaenians, snakes, and at least one lizard. Other types of limbless locomotion are less common and presumably more specialized. For example, we typically think of sidewinding as a gait that only a handful of very specialized species perform, mostly vipers from sandy desert environments. Some of these desert-dwelling vipers are so specialized that they only rarely use other types of locomotion. However, some non-viper species sidewind facultatively in particular circumstances, and a few may regularly sidewind under natural conditions. Numerous accounts report facultative sidewinding in species that more typically perform other types of locomotion. I have compiled these accounts, uncovering evidence that dozens of species perform sidewinding with varying proficiency under a variety of conditions. This compilation indicates that facultative sidewinding may be relatively widespread across several snake families.

104-1 TITON, SCM*; TITON JR, B; TEIXEIRA, RV; LIMA, AS; GARCIA NETO, PG; FERREIRA, LF; ASSIS, VR; GOMES, FR; MARKUS, RP; University of São Paulo, São Paulo, SP, Brazil, University Center Fundação Santo Andre, São Paulo, SP, Brazil;
stefannychristie@gmail.com

Immune and hormonal circadian rhythms in captive bred Bullfrog (Lithobates catesbeianus)

Almost all physiological processes within the organism, including immune parameters and hormones, follow a circadian rhythm. These 24h-day fluctuations are often observed in free-living organisms. However, in anurans, little is known regarding hormonal and immune daily variations, particularly under captive bred conditions. The aim of this study was investigating the immune and hormonal circadian rhythms in captive bred Bullfrogs (*Lithobates catesbeianus*), a species often used as anuran model in laboratory studies. We measured plasma bacterial killing ability (BKA), blood phagocytosis (PP), neutrophil/lymphocyte ratio (NL), plasma corticosterone (CORT), testosterone (T) and melatonin (MEL) levels. Bullfrogs were kept individually in plastic containers in a controlled room (12:12 LD photoperiod [lights on 7am] and 21 ± 2°C) for 7 days. Animals were randomly sampled by cardiac puncture every 3h (5 animals at each time, 40 individuals total). BKA, CORT, T and MEL levels were determined from plasma. Our results show 24h-day rhythms for BKA, CORT, T and MEL, with increased values during the nighttime when compared with daytime for all those variables. Moreover, increased MEL levels were observed only late night (6h after lights turn off; ~ 1am). These results show captive bred Bullfrogs, under artificial conditions, exhibit immune and hormonal circadian rhythms with increased values associated with nighttime. PP and NL were performed from blood leukocytes, and are still being analyzed.

109-7 TITON JR., B*; TITON, SCM; ASSIS, VR; BARSOTTI, AMG; TEIXEIRA, RV; GOMES, FR; University of São Paulo, São Paulo, SP, Brazil; *zuza.bio@gmail.com*

Time-Related Inflammatory Response in Rhinella diptycha Toads

Inflammatory response is a complex process that relies on interactions between multiple endocrine and immune modulators and temporal course of inflammatory responses remains unexplored in amphibians. This study investigated changes in plasma corticosterone (CORT), testosterone (T) and melatonin (MEL) levels, bacterial killing ability (BKA), peritoneal leukocyte phagocytic activity (PP) and neutrophil:lymphocyte ratio (NLR) over time (1, 3, 6 and 18h post injection) following lipopolysaccharide (LPS) immune challenge in toads (*Rhinella diptycha*). Our prediction was that LPS should increase CORT, NLR, BKA and PP, with concomitant decrease in T and MEL. Regarding time related changes, CORT and PP should increase earlier, while BKA and NLR should present a delayed increase, whereas, MEL and T should present more pronounced decrease when those values are maximum in saline-treated toads. LPS induced inflammatory response. Increased CORT were more pronounced 6h and 18h post LPS injection, while MEL decreased independently of time. Although T was not affected by LPS injection, a decreasing trend was observed. Additionally, BKA and NLR also increased following LPS treatment but this effect was related with animal body condition. Individuals with a better body condition also displaying higher BKA and NLR values. Meanwhile, we observed increased PP 1h after LPS injection followed by a decrease thereafter. These results showed that toads respond to an immune challenge by modulating hormonal and immune parameters in a complex way, with effects observed from the first hour and extending for up to 18h following the stimulus.

P1-243 TITON JR., B*; BARSOTTI, AMG; VAZ, RI; TEIXEIRA, RV; NAVAS, CA; GOMES, FR; University of São Paulo, São Paulo, SP, Brazil; *zuza.bio@gmail.com*

Annual Baseline and Post Restraint Hormonal and Immune Variations in Males of Toads (Rhinella icterica)

Theoretical models predict that elevated androgen and glucocorticoid plasma levels in vertebrate males during reproductive season should promote immunosuppression. Additionally, some studies also report decreased stress response during this season. Therefore, this study investigated annual variation in plasma corticosterone (CORT) and testosterone (T) levels, as well as plasma bacterial killing ability (BKA), in males of toads (*Rhinella icterica*) from a natural population, including response to a movement restraint stress on these variables. The predictions were that all traits should vary over the year showing higher hormonal levels during reproductive season and lower BKA, whereas, intensity of response to a stressor should be lower at this season. As predicted, baseline CORT, TESTO and BKA showed higher values during reproductive season. Moreover, baseline CORT was positively correlated with both TESTO and BKA. Therefore, higher androgen and glucocorticoid levels during reproductive season are associated with enhanced immune properties. Despite fluctuation of CORT baseline, post-stress levels remained uniform over the year, indicating that toads reached similar maximum values despite annual scope variations. Otherwise, T decreased in response to restraint before reproductive season but increased in response to this stimulus during and after reproductive season. Meanwhile, BKA decreased due to stressor after reproductive period, which might indicate a relation with large energy investment during reproductive season.

P1-268 TITUS, BM; LAROCHE, RAS*; RODRíGUEZ, E; WIRSHING, H; MEYER, CP; American Museum of Natural History, New York City, Rice University, Houston, Smithsonian Institution, Washington, DC; *rasl850148@gmail.com*

Host Identity and Symbiotic Association Affects the Genetic and Functional Diversity of the Clownfish-Hosting Sea Anemone Microbiome

All eukaryotic life engages in symbioses with a diverse community of bacteria that are essential for performing basic life functions. In many cases, eukaryotic organisms form additional symbioses with other macroscopic eukaryotes. The tightly-linked physical interactions that characterize many macroscopic symbioses creates opportunities for microbial transfer, which likely affects the diversity and function of individual microbiomes, and may ultimately lead to microbiome convergence between distantly related taxa. Here, we sequence the microbiomes of five species of clownfish-hosting sea anemones that co-occur on coral reefs in the Maldives. We test the importance of evolutionary history, clownfish symbiont association, and habitat on the genetic and predicted functional diversity of the microbiome, and explore signals of microbiome convergence in anemone taxa that have evolved symbioses with clownfishes independently. Our data indicate that host identity shapes the majority of the genetic diversity of the clownfish-hosting sea anemone microbiome, but predicted functional microbial diversity analyses demonstrate a convergence among host anemone microbiomes, which reflect increased functional diversity over individuals that do not host clownfishes. Further, we identify up-regulated microbial functions in host anemones that are likely affected by clownfish presence. Taken together our study reveals an even deeper metabolic coupling between clownfishes and their host anemones, and what could be a previously unknown mutualistic benefit to anemones that are symbiotic with clownfishes.

P2-173 TITUSKIN, JR*; BRADY, SP; SEETHARAMAN, K; MCKEON, AM; RAFFEL, TR; Oakland University, Rochester, MI, Oakland University; *tituskinjuliar@gmail.com*

Metabolic effects of temperature and food provisioning support a MTE/DEB model of thermal acclimation in axolotls

Thermal acclimation responses, i.e., effects of past temperatures on an organism's thermal performance curve, have important implications for species responses to increased temperature variability. Adaptive changes in thermal limits (i.e., CTmax) are thought to reflect altered heat-shock protein expression, but we know less about physiological mechanisms driving changes to other parts of the thermal performance curve. Our prior study found higher metabolic performance of the Mexican axolotl (*Ambystoma mexicanum*) following cold-temperature acclimation (i.e., "cooler is better"). Based on principles from Metabolic Theory of Ecology (MTE) and Dynamic Energy Budget theory (DEB), we postulated that this effect was driven by a mismatch between respiratory and digestive thermal performance curves, resulting in a negative energy budget at warmer temperatures. In the current study, we sought to test further predictions of our MTE/DEB hypothesis and to reconcile past conflicting results by subjecting juvenile axolotls to a combination of thermal-acclimation and food-provisioning treatments. We then measured respiration rates, activity levels, and plasma lipid concentrations at new "performance" temperatures. Our respirometry data confirmed the previously observed "colder is better" pattern and generally indicated higher respiration rates with greater food provisioning, consistent with our hypothesis. However, individuals that were warm acclimated, fasted, and tested at a cold temperature had higher than expected respiration rates and activity levels, possibly reflecting increased foraging activity. Evidence of positive effects of food provisioning and cold-acclimation on triglyceride levels was also consistent with our hypothesis.

S1-11 TODGHAM, AE; University of California Davis; *todgham@ucdavis.edu*

Two Plus Two Doesn't Equal Four: The Importance of Incorporating Realistic Environmental Variability in Understanding the Resilience of Antarctic Fishes to Climate Change

Although the Southern Ocean is experiencing some of the fastest rates of ocean change, few studies have explored how Antarctic fishes may be affected by co-occurring warming (OW) and acidification (OA). Organisms within these oceans may be some of the most vulnerable to environmental change, having evolved under stable conditions for millions of years. Early life stages are of particular concern as they are thought to be more sensitive to changes in climate-related variables than adults. Our research investigated the combined impacts of OA and OW on emerald rockcod (*Trematomus bernacchii*) juveniles and naked dragonfish (*Gymnodraco acuticeps*) embryos. Taking an integrative, multi-stressor approach combining metabolism, growth and development, cardiac performance, and behaviour, this research provides insight into the physiological plasticity of early life history stages of polar fishes to changing ocean conditions and how co-occurring stressors can interact synergistically to impact performance during early development. Our results provide evidence of stressor-induced energetic trade-offs in physiology and behaviour that may be an important mechanism leading to vulnerability of Antarctic fishes to future ocean change. Mechanisms and implications of non-linear interactions between multiple stressors will be discussed, with a focus on energy metabolism.

59-2 TOH, MWA*; LOBERT, GT; MORAN, AL; University of Hawai'i at Mānoa; *tohmw@hawaii.edu*

Thermal Sensitivity of Early Life History Stages of Antarctic Invertebrates

A paradigm of Antarctic biology is that Southern Ocean ectotherms are highly stenothermal, owing to millions of years of evolution under cold and thermally stable conditions. Given the predicted rapidity of climate change, it has become important to understand the response of polar ectotherms to rising temperatures. However, compared to adult stages, relatively little is known about the ecology of Antarctic invertebrate embryos and larvae or their sensitivity to temperature. For some Southern Ocean invertebrates, small increases in temperature have been shown to dramatically increase metabolic and developmental rates. Our study investigates the effect of rising temperatures on the development and metabolic performance of larvae from a range of Antarctic invertebrate taxa, including nudibranchs, echinoderms, and pycnogonids. Animals will be collected by SCUBA divers, and embryos and larvae will be assessed for thermal sensitivity using several indices of physiological performance. We will expose embryos and larvae to temperatures ranging from ambient to their experimentally determined critical temperatures and measure the effects of temperature on (1) heart rate, (2) oxygen consumption (as a proxy for metabolic rate), and (3) lethal temperature (as LT50). This will provide insight into the upper thermal limits of early stages of a diversity of Antarctic taxa, and potentially shed light on the mechanisms underlying failure at high temperatures. This research will be conducted starting in September 2019, at McMurdo Station, Antarctica. The goal of this study is to provide insight into the vulnerability – or resilience - of Antarctic ectotherms to rising ocean temperatures. Funded by NSF-OPP-1745130 to ALM.

S2-11 TOLLA, E; University of Glasgow; *2038705T@student.gla.ac.uk*

Rhythmic Neuroendocrine Expression of DNA Methyltransferase Enzymes in Seasonal Models

Seasonal reproduction is a strategy used by temperate zone animals to maximise the propagation of the species. The hypothalamus in birds and mammals is responsible for timing seasonal breeding. Seasonal epigenetic modifications in the hypothalamus have been demonstrated to regulate long-term timing of reproduction and energy balance in several photoperiodic species. Enzymes involved in *de novo* DNA methylation (Dnmt3a/b) are expressed within the hypothalamic-gonadal axis and exhibit seasonal variation. The objectives of my research were to investigate the effect of thyrotrophin-stimulating hormone (TSH) and triiodothyronine (T3) on the photoperiodic regulation of DNA methyltransferase enzyme expression. I tested the hypothesis that TSH or T3 in short day hamsters would stimulate hypothalamic expression in Siberian hamsters. Short winter-like day lengths induced a significant reduction in *Dnmt3a/b* in the hypothalamus. Male hamster hypothalamic *dnmt3a* nor *dnmt3b* expression did not vary in response to TSH. Then, I examined the impact of photoperiod and daily T3 injections or saline on hypothalamic *dnmt3a/b* expression and female reproductive physiology. SD photoperiods were observed to reduce body weight and uterine weight. Unlike previous reports in male hamsters, daily T3 injections in SD females were ineffective to stimulate gonadal recrudescence. Hypothalamic *Dnmt3a* and *dnmt3b* expression was reduced in SD, independent of T3. These data suggest that an alternative hormonal signal regulates *dnmt3a* and *dnmt3b* expression or that cyclical *dnmt3a/b* expression reflect an endogenous circannual timing system. Ongoing work seeks to identify whether long days reduce hypothalamic *dnmt3a/b* expression during the Japanese quail photoperiodic response. These data indicate that reduced neuroendocrine DNA methylation permits seasonal gonadal recrudescence.

107-6 TOMANEK, L.*; MAY, M.; VASQUEZ, C. ; TODGHAM, A.; California Polytechnic State University, San Luis Obispo, Univ. California, Davis; *ltomanek@calpoly.edu*

From Cellular Omics to Phenomics: The Role of Sirtuins in the Cellular Stress Response

The cause-and-effect chain of events across biological levels of organization is still an elusive target, challenging the integration of organismal systems. Several thioesters along metabolic pathways, e.g., acetyl-CoA, can interact with proteins to form post-translational modifications (PTMs), i.e., acyl-lysines. These PTMs affect protein function. NAD-dependent deacylases, i.e., sirtuins (SIRTs), can remove these PTMs, shift metabolism and activate an oxidative stress response (OSR), supporting cellular homeostasis during stress. We used a high temporal resolution time course to assess the effects of transcriptomic and proteomic changes on gill tissue and organismal phenotypes in response to heat stress and sirtuin inhibition in the intertidal mussel *Mytilus californianus*. Using proteomics, inhibitor studies showed that SIRTs affect molecular chaperones, oxidative stress proteins, metabolic enzymes and signaling proteins during heat stress. Additional inhibitor studies showed that food availability and heat stress during acclimation change how SIRTs affect multiple levels of organization: cells (ciliary activity), tissues (particle velocity and respiration rate of gill, siphon opening of mantle) and organismal performance (clearance rate) in *M. californianus*. Finally, these results are dependent on the circadian rhythm of mussels, in part because SIRT5 levels undergo circadian changes in abundance. The studies were funded by the NSF-grant IOS-1557500 to L. T. and A. T.

P2-8 TOPPING, NE*; JOST, JA; Bradley University Peoria Il; *ntopping@mail.bradley.edu*

Investigating the seasonal patterns of zebra mussel (Dreissena polymorpha) growth and physiology using field enclosures in central Illinois

Since its introduction, the zebra mussel has caused widespread destruction by reproducing often, attaining high densities, and negatively impacting the ecosystem. While zebra mussel physiology has been examined for a range of abiotic factors, less is known about the impacts of biologically relevant habitat fluctuations, especially on a cellular level. In addition, there are discrepancies in the reported optimal conditions, which is likely the result of a large geographic range and localized adaptation. Therefore, this study aimed to investigate links between ambient conditions (water temperature, water quality, and food availability) and mussel performance (survival, growth, reproduction, and the levels of several cellular markers) by tracking mussels using field enclosures from September 2018 through July 2019. Survival was high, even when temperatures regularly exceeded 31°C, suggesting lethal limits are quite high for this population. Shell growth was highest when temperatures were moderately warm (June) and lowest when temperatures were both cold (November) and extremely hot (July). Tissue growth was highest in October, suggesting mussels gain mass in the cool autumn temperatures after spawning is complete. Significant tissue loss was detected in July, which likely reflects mass lost due to spawning as well as the negative impacts of thermal stress. These data indicate a temporal separation in soft tissue and shell growth. Despite high variation in habitat conditions over time, there were no significant differences in several stress markers examining oxidative stress and energy metabolism. Interestingly, there were significant differences in heat shock protein levels, with levels being highest in September and October when temperatures were moderate.

P2-58 TORRES, B*; JELKEN, M; OMANE, H; BELLESIA, G; HAYSSEN, V; Smith College, Northampton, MA; *vhayssen@smith.edu*

Linguistic Bias in Reproduction

The English language is not gender neutral. For instance, the word *virile* characterizes sexual strength and energy, positive traits in females and males, but its synonyms are manly, masculine, or male. English has no equivalent word for female sexual strength and energy. Since English is currently the established language of science, then, logically, science is also not gender neutral. For example, the word *egg* conflates the female gamete (an ovum) with the product of conception (a zygote), thus obscuring the independent contribution of females to conception. In addition, value judgements infuse the language of reproductive medicine. That bias alters how patients and doctors view the process. For example, the term '*miscarriage*' suggests the mother is at fault for miscarrying the fetus, when, more likely, the fetus itself was defective. 'Gestational-loss' or 'pregnancy loss' are more value-neutral terms for the same process. This poster will review a variety gender-biased or value-laden terms and suggest some gender- or value-neutral substitutes.

P1-263 TORRES, T*; WATSON, CM; SHIPLEY, MM; Midwestern State University; *tdtorres95@yahoo.com*

Fatty acid composition of native milkweed species (Asclepias) of North Texas made available to insect predators

Milkweed are latex producing plants that are familiar perennials in the grasslands of North America, and serve as an excellent model for the study of host/herbivore interactions. Leaves of *Asclepias curassavica, viridis, asperula, stenophylla, tuberosa,* and *viridiflora*, each being a native milkweed species in Texas, were used to construct a lipid profile that will allow an analysis of the assimilation of fatty acids to milkweed bugs and monarch butterfly larvae, two predators of *Asclepias*. Lipids were extracted from leaf samples using a mixture of chloroform/methanol/water in a 4:2:1 ratio. The fatty acids were then converted to fatty acid methyl esters (FAMEs) to be further analyzed by gas chromatography-mass spectrometry (GC-MS). The fatty acid within milkweed that was found in highest abundance was linolenic acid (18:3) followed by palmitic acid (16:0) and stearic acid (18:0). Interestingly, linolenic acid was seen in very high abundance in some leaves from the same plant but completely absent in others. Further testing will be conducted to analyze if linolenic acid production is a response to insect predation. This information will be utilized to provide a more thorough understanding of the transition of fatty acids from the milkweed plant to specialist predators.

P1-66 TOSTO, NM*; ROSE, E; MASONJONES, HD; University of Tampa, FL; *nicole.tosto@spartans.ut.edu*

Quantifying Sexually Selected Traits in the Female Gulf Pipefish (Syngnathus scovelli)

Reliably quantifying the strength of visual sexual signals, such as iridescence, has been challenging across the field of evolutionary biology. The Iridescence Detection and Isolation Algorithm (IDIA) was designed to isolate the iridescent signal from photographs for quantification of ornamentation. The Gulf pipefish, *S. scovelli*, served as a model system due to their sex-role-reversed polyandrous mating system and sexual dimorphism, with females possessing sexually selected iridescent bands on their abdomens. Using the IDIA, female iridescence was reported in two ways, including a manual measurement of each individual band and an automated measurement taken by drawing a polygon around all bands on the torso, to remove user bias. Our results indicated that the iridescence calculated from the two approaches were strongly correlated. We were also able to detect geographical variation in female ornamentation and stronger iridescent bands in lab-reared females compared to their parental population. Females from the Florida coast had greater iridescence compared to females collected from the Texas coast. However, lab-reared fish from a Texas parental population showed the greatest iridescence overall, indicating environmental conditions, such as turbidity, could affect the strength of female visual signals. Lastly, we utilized the IDIA for an environmental application by detecting the development of iridescence in male pipefish exposed to synthetic estrogen. Exposed males began expressing banding patterns with iridescence levels within the range of females. The results from this study confirm the feasibility of using the IDIA for measuring sexually selected traits and investigating estrogen exposure in natural populations by detecting morphological changes in exposed males.

1-4 TOVAR, RU*; GIGNAC, PM; The University of Texas at Austin, Oklahoma State University Center for Health Sciences ; *rubenut@utexas.edu*

The Comparative Anatomy ¸of Degenerate Neural Structures Using Diffusible Iodine-based Contrast-enhanced Computed Tomography (diceCT)

The paedomorphic *Eurycea* salamander clade of Central Texas exemplifies a continuum of morphological characteristics associated with aquatic-subterranean living: the surface-dwelling Texas salamander (*E. neotenes*) exhibits typical optic anatomy and acuity; the intermediate Comal blind salamander (*E. tridentifera*) maintains reduced but non-functional eyes; and the obligate subterranean Texas blind salamander (*E. rathbuni*) has an incompletely developed optic system. Together this genus represents a transformation series of karst phenotypes and a potentially exemplar system for using comparative approaches to understanding vertebrate ocular evolution in the face of relaxed selective pressures. More than a century ago Eigenman described ocular histology in *E. rathbuni* adults as a focal troglodyte; yet, neither the extent of optic-nerve persistence in this taxon nor among its congeners has since been documented. In this study we employed gross and micro-scale imaging techniques to elucidate features of *Eurycea* optic anatomy with a particular interest in the central nervous system. Specimens from aforementioned taxa were fixed with 100% EtOH, contrast-enhanced with alcoholic iodine (I2E), micro-CT scanned, and digital reconstructed using 3D rendering software for comparison to histological sections. Here we report on the 3D, internal soft-tissue systems of the eye in each taxon, documenting habitat-specific configurations of optic musculature and neuroanatomy for the first time—including for *E. rathbuni*, which surprisingly appears to retain complete bilateral optic nerves even though it lacks the mid-line decussations associated with an optic chiasm.

132-1 TOWNSEND, JP*; GEMMEL, BJ; SUTHERLAND, KR; COLIN, SP; COSTELLO, JH; Providence College; Marine Biological Laboratory, University of South Florida, University of Oregon, Roger Williams University; Marine Biological Laboratory; *jptownsendii@gmail.com*

Ink release and swimming behavior in an oceanic ctenophore, Eurhamphaea vexilligera Gegenbaur, 1856

Of the upwards of 150 ctenophore species, the oceanic ctenophore Eurhamphaea vexilligera is peculiar in its release of a pigmented and bioluminescent ink, secreted from numerous small vesicles that line its comb rows. To date, in situ observations by SCUBA divers have proved the most fruitful method of observing these animals' natural behavior. We present the results of one such contemporary SCUBA-based observation of E. vexilligera, conducted in the Gulf Stream waters off the coast of Florida using high resolution photography and video. Utilizing underwater camera systems purpose-built for filming gelatinous zooplankton, we observed E. vexilligera ink release and swimming behavior in situ. From these data, we describe the timeline and mechanics E. vexilligera ink release in detail, as well as the animal's different swimming behaviors and resulting ink dispersal patterns. Our footage also revealed a previously-undescribed rolling swimming behavior, accompanied and possibly facilitated by a characteristic change in overall body shape. These observations provide further insight into the behavioral ecology of this unique ctenophore and may serve as the foundation for future kinematic studies.

44-2 TOXOPEUS, J*; DOWLE, EJ; RAGLAND, GJ; University of Colorado, Denver, CO, University of Otago, New Zealand; *jantina.toxopeus@ucdenver.edu*

Tracking Physiological Time: Timing and Duration of Cold Exposure Impacts Seasonal Life History Timing in a Temperate Insect

Many organisms time their development to ensure that a specific life stage coincides with a specific resource. Development rate of ectotherms varies with temperature, and therefore environmental temperature can affect life history timing. Many temperate insects overwinter in diapause, a dormant state of developmental arrest that can promote appropriate life history timing, mitigating the effects of temperature on development. However, this may not be the case for all insects, especially for non-photoperiodic insects, whose diapause is not regulated by daylength. The apple maggot fly *Rhagoletis pomonella* spends most of the year as a pupa in diapause, eclosing as an adult in late summer to lay its eggs in the fruits of its host plants. However, *R. pomonella* has a surprisingly flexible and dynamic diapause program, and can terminate diapause without any chilling or photoperiodic cues. *R. pomonella* is therefore an interesting model to study how non-photoperiodic insects regulate the timing of diapause termination, and the role of temperature in this regulation. To test the thermal sensitivity of the diapause program, we collected diapause *R. pomonella* pupae from hawthorn fruits in Denver, CO, and exposed them to differing lengths of winter conditions (4 °C) at different times during their pupal development. We then measured time to eclosion after transfer to summer conditions (21 °C). The impact of low temperatures on eclosion varied with both the timing and length of winter, suggesting that the thermal sensitivity of diapause development changes with age. This study challenges our understanding of how insects "keep track of" physiological time in diapause.

49-3 TRACY, CR*; MCWHORTER, TJ; University of California Riverside Boyd Deep Canyon Reserve, University of Adelaide Roseworthy; *christopher.tracy@ucr.edu*

Paracellular absorption in the slow(er) lane: a brief review of reptilian paracellular nutrient absorption

Some mammals and birds rely on passive, paracellular absorption of small, water-soluble nutrients (e.g. small carbohydrates) as a significant component of overall absorption of those nutrients. This is particularly important in small, flying mammals and birds, possibly as a means to fuel high metabolic demands despite small guts and fast digesta passage. But how important is paracellular absorption of those same nutrients for low metabolic rate taxa like reptiles? Our studies on herbivorous lizards and crocodilians suggest that paracellular nutrient absorption in these low metabolic demand vertebrates represents a relatively small, but significant proportion of total absorption, particularly in younger animals whose rapid growth may increase metabolic demands. This appears to support the hypothesis that paracellular absorption provides a low-cost source of additional energy for some species or life stages. At this time, paracellular absorption has been measured only in a few ectothermic species, and there have been few studies of ontogeny of paracellular absorption, so many questions about patterns in reptilian paracellular absorption remain unanswered

65-5 TRAN, MV*; MILLER, A; ODAKA, Y; OWEN, P; WILSON, K; University of Cincinnati Blue Ash College; *tranmk@uc.edu*
Designing Multifaceted Research Experiences for Undergraduates in Integrative Biology
Undergraduate research is a way for students to build important skillsets and develop interpersonal connections with fellow students and faculty. Practically speaking, undergraduates often seek research experiences as a way to explore various topics and identify the topics that they find most interesting. Thus, the firsthand experience gained by participating in undergraduate research can be used to help students make more informed decisions regarding the their educational and career paths. The biological sciences are comprised of numerous subfields in which students can specialize and therefore a major goal of undergraduate research experiences in biology should be to maximize the number of subfields to which students are exposed. However, finding projects and study systems that accomplish this goal within a single research experience is often difficult. This presentation will focus on the development of an annual summer research experience for freshman and sophomore undergraduates that provides student with experiences integrating various biological subdisciplines into a single project. Using a single study species, we designed student research projects that allowed students to test hypotheses related to ecology, behavior, microbiology, and molecular biology so students could better understand how each of these subfields contributes to our understanding of biology as a whole. Students learned both field and laboratory techniques through interaction with faculty with different areas of expertise in biology. This presentation will describe the process of creating these research experiences and outline both the successes and challenges of the project over the initial two years of implementation.

P1-51 TRAN, HN*; LOWER, SE; Bucknell University, Lewisburg, PA; *hnt001@bucknell.edu*
Using computational approach to identify candidate odorant receptor genes in the most common firefly species in North America, Photinus pyralis
The insect odorant receptor (*Or*) gene family has been studied and hypothesized to play a critical role in reproduction. Odorant receptor proteins, located on the olfactory sensory neuronal dendrites, detect odorant chemicals such as pheromones and then mediate key behaviors such as mate choice. Although olfaction is known to play a predominant role in sexual communication, there is still a large amount of olfactory genes absent from most insect species. In this study, we investigate the sequencing data of one of the most common fireflies in North America, *Photinus pyralis* (Coleoptera: Lampyridae). This firefly species is well known for their use of light signals to attract mates, but our knowledge of their odorant receptors still remains elusive. Recent advances in genome sequencing have provided tools to identify the *Or* gene repertoires in *P. pyralis* sequence data. The aim of this study was to develop an overview of *P. pyralis*' ability to detect chemical signals at the molecular level. Using bioinformatics analysis, we identified a set of 27 putative *Or* genes in the *P. pyralis* transcriptome. A phylogenetic tree was constructed from *Or* sequences of *P. pyralis* and other beetles species. It showed that all the candidate *Or* sequences of *P. pyralis* were clustered with at least one Coleoptera ortholog. Results of this study provide a foundation for future studies on the expression and function of the *P. pyralis Or* candidates. The study also provides a better understanding of the molecular basis and evolutionary history of mating signals in the Lampyridae family.

40-4 TRAVIS, KG*; KAWANO, SM; California State Uni., Long Beach, George Washington Uni.; *kevin.travis@student.csulb.edu*
Comparative biomechanics of submerged and emerged walking in the epaulette shark (Hemiscyllium ocellatum)
Epaulette sharks (*Hemiscyllium ocellatum*) are benthic fishes that commonly use a tetrapod-like "walking-trot" gait to move along the substrate and will occasionally emerge out of water to navigate reef flats. Given these characteristics, epaulette sharks have been considered a functional analog for tetrapodomorph fishes and may exhibit similar locomotor biomechanics as living salamanders (a common modern analog for early tetrapods). This study aims to broaden analyses of the locomotor biomechanics of epaulette sharks while fully submerged vs. partially emerged to allow for more direct comparisons to published work on salamander locomotion. We collected 3D kinematics of the paired fins between both environmental conditions while simultaneously obtaining 3D ground reaction forces (GRFs) from the fins. Subadult sharks were recorded under submerged (n=3) and partially emerged (n=2) conditions with two high-speed video cameras (200 fps) while individuals moved along a waterproof 3D force plate. Preliminary results from a single individual suggest that the average maximum protraction angle of the pectoral fins was higher when partially emerged compared to fully submerged while the maximum protraction of the pelvic fins remained relatively consistent. Additional analyses to compare the GRFs between paired fins and environmental conditions are ongoing and would yield a more comprehensive evaluation of the functional role of paired fins during aquatic and terrestrial locomotion. Comparisons of these results to salamander locomotor biomechanics would then enable quantitative analyses on the functional consequences of using fins versus limbs for a walking-trot gait, potentially providing insights on the biomechanical limitations of moving onto land.

P3-136 TREERS, LK*; STUART, H; University of California, Berkeley; *ltreers@berkeley.edu*
The Effect of Shell Shape on Burrowing Dynamics in Granular Media
The dynamics of burrowing and locomotion within granular media by legged invertebrates is extremely complex. The forces experienced by organisms are governed by substrate properties, the path taken through the substrate, and geometrical properties of the organism's body. We focus on developing a numerical method for analyzing such forces in three-dimensional space, expanding upon granular resistive force theory (RFT) (previously developed by Chen Li et. al, *Science*, 2013) to be more easily applied to irregular shapes useful for analyzing biological organisms. This method allows for element-wise integration of forces over a surface, as a function of object insertion angle and direction of insertion. While RFT was developed for dry sand settings, we assume that its key principles apply in some saturated media, and test the limits of this assumption. We explore the effect of "terradynamic streamlining" of shell shape on insertion forces, both through a numerical model and experimental trials. As a biological model, we choose to study the pacific mole crab *Emerita analoga*, a marine arthropod capable of rapid self-burying in saturated granular media. We compare the resistive forces of the crab carapace shape with more canonical geometric shapes, to analyze the potential streamlining advantage of the crab body profile. Other crustacean shell shapes are also considered via the developed 3D numerical method created for this work. We then consider the effect of body trajectory on total energy consumption to burrow. The energy cost of burrowing is compared for various burrowing paths and oscillations, as predicted by RFT. The burrowing strategy of *Emerita analoga* (which features oscillation in body pitch throughout a burrowing event) is compared with theoretical results, in order to analyze its effectiveness.

2-5 TREIDEL, LA*; CLARK, RM; WILLIAMS, CM; UC Berkeley, Sienna College; *lisa.treidel@berkeley.edu*

Females pay the price: high costs of reproduction dictate sensitivity to diet quality in adult crickets

Primary productivity and thus food quality are predicted to fluctuate along with changing global climates. Organismal performance and life history investments are limited by suboptimal diets, unless feeding behavior is altered to compensate. Further, nutritional demands of life history traits differ. We hypothesized that optimal diets should shift through ontogeny along with investment in life history and predicted that behavioral responses and performance consequences of imbalanced diets will change concordant with life history demands. Within populations of the wing polymorphic cricket *Gryllus lineaticeps*, alternative development trajectories produce adult morphs that specialize in either dispersal or reproduction. We characterized dietary preferences and compensatory feeding strategies on imbalanced diets, by feeding last instar and adult crickets one of three isocaloric diet treatments: 1) protein-biased diet (2P:1C), 2) carb-biased diet (1P:4C), or 3) both diets (choice). As last instars, dispersal morphs needed to consume more food to support muscle development, and met this higher caloric requirement irrespective of diet macronutrient content. Males did not alter their feeding behavior across life stages. In contrast, females selected a more protein-biased diet and shifted their regulatory strategy to avoid overconsuming excess macronutrients on imbalanced diets as adults. Consequently, adult females incurred large caloric and protein deficits on the carb-biased diet, which in turn constrained reproductive investment and resulted in a reduction of ovary size and energy provisioning. These findings suggest that when physiological demands are high, behavioral adjustments do not fully offset costs of imbalanced diets, leaving specific individuals more sensitive to fluctuations in food quality.

49-1 TREVELLINE, BK; MARTíNEZ-MOTA, R; DERTING, T; DARRACQ, A; PASCH, B; DEARING, MD; KOHL, KD*; Univ. of Pittsburgh, Univ. of Utah, Murray State Univ. , Murray State Univ. , Northern Arizona Univ.; *kevin.d.kohl@gmail.com*

Nutrient manipulation differentially affects microbiome structure and host physiology in rodents with distinct dietary niches

Mammals must extract sufficient energy and nutrients from their diets for survival and reproduction. The digestive system and its resident gut microbiota are highly dynamic and responsive to diet, likely aiding in the maintenance of optimal digestion. However, studies investigating microbial and physiological responses to diet are typically conducted on a single species. Therefore, we have poor understanding of how the flexibility of the digestive system and gut microbiome structure varies across species. We conducted feeding trials with three species of rodents with distinct dietary niches: montane voles (*Microtus montanus*, herbivorous), white-footed mice (*Peromyscus leucopus*, omnivorous), and southern grasshopper mice (*Onychomys torridus*, insectivorous). Rodents were fed four different diets varying in their concentrations of fiber and protein for a period of five weeks. Rodents were dissected for measurements of gut morphology, and gut content samples were collected to inventory microbial communities via 16S rRNA sequencing. We found that several aspects of gut anatomy exhibited species-specific responses to diet. For example, small intestinal length showed no changes in voles, while in white-footed mice it increased in length in response to high fiber diets, and in grasshopper mice it increased in length in response to low protein diets. Similarly, the gut microbiota exhibited species-specific responses to diet. These data suggest that the flexibility of the digestive system and gut microbiota may be adapted to species-specific dietary niches.

102-3 TREVELLINE, BK*; MAIER, M; MARTINEZ-MOTA, R; DERTING, T; PASCH, B; DEARING, MD; KOHL, KD; Univ. of Pittsburgh, Univ. of Utah, Murray State Univ., Northern Arizona Univ., Univ. of Utah; *brian.trevelline@gmail.com*

Investigating the mechanisms of diet-induced metabolic depression in wild rodents

Many animals can lower their metabolic rate to conserve energy during changes in diet. This phenomenon is widespread across vertebrates, but the responsible mechanisms are not well understood. It is thought that animals achieve a hypometabolic state by reducing the mass of energetically-costly organs, but reduced mitochondrial activity could also play a role. We assessed the impact of diet on digestive physiology and metabolism in three species of rodents with different natural diets: grasshopper mice (*Onychomys torridus*; insectivore), white-footed mice (*Peromyscus leucopus*; omnivore), and montane voles (*Microtus montanus*; herbivore). Rodents were placed on either a high-fiber (37%) or low-fiber (12%) diet for 5 weeks, after which we measured resting metabolic rates via open-flow respirometry and weighed energetically-costly tissues, such as heart, gut, liver, and kidney. *O. torridus* fed high-fiber diets had significantly reduced metabolic rate, but *P. leucopus* and *M. montanus* did not. Interestingly, *O. torridus* on high-fiber diets exhibited greater gut masses and, opposite of our expected result, larger kidney masses. *P. leucopus* and *M. montanus* had significantly larger kidneys on high-fiber diets. Further, *O. torridus* on high-fiber diets exhibited higher mass-specific mitochondrial activity (measured by citrate synthase activity) in liver tissue, despite no significant differences in liver masses. These results suggest that rodents with different natural diets employ divergent mechanisms to compensate for sub-optimal diets, and that metabolic depression involves more than a reduction in organ size.

P1-55 TSAI, HP*; GRIFFIN, C; Missouri State University, Virginia Tech; *HTsai@MissouriState.edu*

The cartilaginous hips of Diplodocoidea: functional implications for highly specialized locomotor behaviors among sauropods

Sauropods are characterized by exceptionally massive body size and highly derived appendicular morphologies. However, the rarity of cartilage preservation in the fossil record has hampered inferences on their locomotor biology, such as loading, range of motion, and muscular attachments. This study investigated the evolutionary and functional significance of pelvic and femoral cartilages in Diplodocoidea, a diverse and well-represented clade of sauropods. We digitized femora, pelves, and caudal vertebrae of 35 sauropod and outgroup taxa before estimating key transitions in cartilage morphology using ancestral state reconstruction of osteological correlates. Like other sauropods, the rugose femoral head growth plate indicates thickening of hyaline cartilage in the capital region. However, diplodocoids uniquely possess terminally flattened capital growth plates, which indicates a greater contribution of hyaline cartilage in forming the convex, functional femoral head. Moreover, the expanded metaphyseal shelves of diplodocoid femora suggests extensive contribution of fibrocartilage in constructing the ventral femoral head. Finally, rugosities on the postacetabular ilial rim, as well as dorsoventrally expanded transverse processes on the anterior caudal vertebrae, suggest that diplodocoids possessed massive postacetabular cartilages that expanded the ilial blade caudally, buttressed by the anterior caudal transverse processes. This novel interpretation of the pelvic skeleton challenges traditional anatomical reconstruction of the diplodocoid hindlimb, and suggest that the hips and tail are functionally integrated to allow diplodocoids to adopt a greater range of locomotor postures, potentially even tail-assisted bipedalism.

P1-110 TSAI, E*; NAISBETT-JONES, L; LOHMANN, C; LOHMANN, K; Department of Biology, University of North Carolina at Chapel Hill ; *emtsai@live.unc.edu*

Magnetic Map Sense of Gulf Flounder (Paralichthys albigutta)

Gulf Flounder, a species of migratory flatfish commonly found in coastal waters spanning from North Carolina to the Gulf of Mexico, travel significant distances (10s-100skm) from shallow coastal nursery areas to reach deepwater spawning sites. However, the sensory basis guiding this movement remains a mystery. Previous research suggests that some aquatic animals can sense the earth's magnetic and use that ability both to determine direction (a magnetic compass sense) and as a "magnetic map" for determining position on the earth's surface, similar to a GPS used by humans. We aimed to determine if Gulf Flounder possess a "magnetic map sense," which would allow them to use the Earth's magnetic field to guide their migration from spawning grounds to feeding areas and back. To search for the presence of a magnetic map sense, we exposed flounder to one of two artificially-generated magnetic fields that replicate magnetic fields located north (near New Jersey) and south (near Jamaica) of the experimental site of Morehead City, NC. Juvenile flounder were placed in a small orientation arena and allowed to swim freely in either the New Jersey or the Jamaica field for 1.5 hrs. Video analysis indicated that flounder tested in the northern magnetic field of New Jersey significantly oriented towards magnetic SE, and flounder tested in the southern magnetic field of Jamaica showed weak orientation towards magnetic NE. Results from these two treatments were significantly different. These results provide evidence for a magnetic map sense in Gulf Flounder, adding flounder to the growing list of marine migrants that utilize this cue.

P1-193 TSE, A*; CALEDE, J; The Ohio State University; *tse.64@osu.edu*

Quantifying the link between cranial morphology and diet in Soricidae using geometric morphometrics

The family Soricidae is one of the most species-rich mammalian families and is present in all major temperate landmasses except Australasia. Although much attention has been given to studying taxonomic diversity, little work has been undertaken on the ecological disparity within the family. Here, we seek to determine if the disparity of cranial morphology among skulls of different shrew species reflects adaptations to their diverse diets. Indeed, although shrews are sometimes considered uniformly invertivorous, there are in fact variations in the size and hardness of the food consumed across species. As such, we expect variations in the biomechanical demands for different diets and consequently in skull morphology.
We used geometric morphometrics to capture variations in cranial morphology in a sample of 132 shrew specimens representing 41 species spanning all three sub-families of Soricidae. Each species was assigned to a diet category based on published literature. We placed landmarks and semi-landmarks on the lateral and ventral side of the skull and dentary to capture the size and shape of muscle attachments, teeth, and in-levers/out-levers. The results of our principal component analysis reveal that morphology is indeed linked to dietary ecology. Thus, for example, shorter snout width and dome-shaped skull are associated with processing larger and/or harder food. Our canonical variate analysis confirms that the diet of a shrew can be inferred from its morphology. An additional analysis including centroid size enables even better discrimination between diets and hints at the role of body size in determining the feeding range of shrews.

S3-7 TUCKER, A. S.; King's College London; *abigail.tucker@kcl.ac.uk*

Developmental basis of tooth regeneration

During evolution of mammals there has been a move towards a reduction in the number of times teeth are replaced over an animal's life-time. Most mammals have two sets of teeth (diphyodont), while most reptiles have continuous replacement (polyphyodont). This shift to reduced numbers of replacements is thought to have been driven by an increase in tooth shape complexity together with the advent of tooth occlusion. Therefore there appears to be an evolutionary trade off between tooth number and tooth complexity. Although two sets of teeth is the norm for mammals (deciduous teeth followed by permanent teeth), a number of mammals have reduced the number even further and have only one set of teeth (monophyodont), or a mixed dentition where some teeth in the jaw replace while others do not. This condition allows for investigation into the mechanisms that determine whether to replace or not within a single animal. This talk aims to understand how the number of replacement teeth is controlled using a comparative evodevo approach. What signals stop further tooth development in mammals? How do teeth influence the development of their replacements? Can extra generations be generated? The research takes advantage of a number of model and non-model species, encompassing a variety of replacement patterns (monophyodont, diphyodont, polyphyodont). The findings shed light on the potential to generate additional teeth, both from a zoological and biomedical perspective.

3-7 TUCKER, E L*; HSIEH, S T; Temple University, Philadelphia, PA; *liz.tucker@temple.edu*

Leg Length, Not Stiffness, Allows Bipedal Lizards To Navigate Drops

Natural terrain varies enormously in surface properties and contour; yet animals are able to move rapidly over these surfaces with apparent ease. Much is known about compensatory strategies of bipedal parasagittal and crouched runners over perturbations. For example, guinea fowl have been shown to lengthen their legs over sudden drops in terrain, whereas humans tend to change the stiffness of their limbs to compensate for drops, obstacles and changes in surface compliance. In contrast, dogs and cockroaches do not change their limb stiffness. Little is known, however, about how bipedal sprawled runners contend with perturbations and why such a diversity of strategies might exist. We ran 4 basilisk lizards (*Basiliscus vittatus*) over flat terrain (control) as well as drops of 40% their leg length. Basilisks were able to accomplish this task without any detriment to their running speed ($p = 0.962$). In general, they shortened their stride ($p = 0.0025$), while keeping stride frequency and duty factor constant. Lizards landed in the drop with a more upright body angle, touchdown angle and tail pitch while using a wider step than when unperturbed ($p < 0.05$). They also straightened their leg ($p = 0.0227$) but did not stiffen it. Lizards reached intermediate or control level values of tail pitch, body angle and touchdown angle by the next step. This response is very similar to the that used by guineafowl, for which their stability has been associated with the crouched limb posture. We propose that the sprawled, crouched posture found among many vertebrates and invertebrates can potentially convey greater locomotor stability for a similar reason—the ability to lengthen the limb can compensate for unexpected changes in surface contour.

133-2 TUNE, TC*; MA, W; IRVING, T; SPONBERG, S; Georgia Tech, Illinois Institute of Technology; *ttune3@gatech.edu*

X-Ray Diffraction of Synchronous Flight Muscle Reveals Thick Filament Force-Length Hysteresis Varies With Muscle Function

The energetic and functional versatility of muscle at the macroscopic level depends on the collective action of myosin motors in the contractile lattice. For example, myosin heads on thick filaments are out of register with actin binding sites, which limits crossbridge binding. However, due to compliance in myofilaments, filament strain change alters actin-myosin kinetics facilitating crossbridge cooperativity. Recent work in isometric active and passive muscle shows that thick filament strain at the sarcomere level has a nonlinear relationship with whole muscle force. However we do not know if this relationship holds under dynamic conditions. If not, then the dynamics of strain in the filaments could help shape work production in an intact muscle. To see how force and thick filament strain are related dynamically, we performed work loops at different phases of activation on isolated *Manduca sexta* flight (DLM) muscle with simultaneous time-resolved x-ray diffraction. Consistent with earlier results, we found that the thick filament underwent strain changes of .2+/-.1% and the overall elastic response was similar to that of vertebrate muscle. However the relationship between thick filament strain and force during the course of the work loop was hysteretic, with the difference in thick filament strain at the same force at different points in the work loop cycle being between 30 to 60% of the total amplitude. Taking into account potential contributions of non-filament based passive forces (e.g. extracellular matrix) could not account for the hysteresis. Changing the phase of activation modulates the hysteresis with *in vivo* conditions produce only half that of peak negative power conditions. Taken together these results mean that there is not a one-to-one relationship between myofilament strain and muscle force.

P2-27 TUNNELL WILSON, W/T*; JACKSON, K; JACOBS, J/L; SEKITS, N; SMITH, E/N; Whitman College, University of Texas at Arlington, University of Texas at Arlington; *tunnelwt@whitman.edu*

Insights into the Evolutionary History of Lamprophiid Snakes from Vertebral Morphology Using Computed Tomography

Understanding snake vertebrae is essential to understanding snake evolution. Molecular techniques can provide divergence times and relationships between lineages, but further understanding of the extinct ancestors of living snakes comes from the fossil record. The fossil record of snakes consists primarily of vertebrae. Examining the vertebral morphology of living snakes in an evolutionary context has the potential to illuminate how similar transformations occurred in the fossil history of snakes. Africa has been less studied than other continents, both in terms of snake paleontology and the study of extant snakes. The Lamprophiidae is a large and diverse family of primarily African snakes whose phylogenetic relationships have only relatively recently started to be resolved through molecular phylogenetics. We examined vertebrae from 24 species representing ten main lineages within Lamprophiidae along with four elapid species for comparison. We used micro-computed tomography (micro-CT) scanning to non-destructively extract vertebrae for morphological study. We then described all vertebrae using a synthesis of characters used by snake paleontologists to provide insight into these previously undescribed or under described taxa. We present our findings in the context of recent molecular insights into the phylogenetic relationships among lamprophiid snakes.

76-4 TURNER, ML*; GATESY, SM; Brown University; *morgan_turner@brown.edu*

Looking inside the sole: intermetatarsal mobility in the American alligator

Feet mediate animal-substrate interactions across an animal's entire range of limb poses used in life. Despite its importance, the foot is typically either ignored or treated as a "black box"—an anatomically complex set of visually obscured components that are difficult to simulate. The most dominant skeletal elements are the metatarsals, the ‘bones of the sole.' In plantigrade animals, intermetatarsal mobility offers the potential for active reconfiguration within the foot itself. Using marker-based XROMM, we measured metatarsal kinematics in three juvenile American alligators (*Alligator mississippiensis*) across their locomotor and maneuvering repertoire on flat surfaces. Alligators are capable of postural extremes—from a belly sprawl to a high walk—and the foot is flexible enough to accommodate these diverse poses. Initial results reveal: 1) Regardless of limb placement, the metatarsals conform to the ground to maintain fully plantigrade contact throughout most of stance. Coordinated intermetatarsal motion adapts foot shape based on phase, spreading in stance up to 200% of the most compressed configuration during swing. 2) Intermetatarsal mobility contributes significantly to everted and inverted foot poses. Alligators predominantly inverted the pes; up to 40 degrees of inversion-eversion was measured, whereas only 10 degrees of ab-adduction was found. Continuing work will put intermetatarsal mobility in context of crural, pelvic, and digital kinematics, with the aim to understand the inner workings of the pedal "black box” and how it contributes to animal locomotion.

P3-248 TURNER, M*; CLARDY, T; DONATELLI, CM; University of Washington, King Fahd University of Petroleum, University of Ottawa; *msturn@uw.edu*

Bits and Pieces: Using Fractals to Understand Complex Morphology

Fractal analysis is a mathematical principle used to measure the complexity of a system or phenomenon. Generally speaking, it tells us how a system takes up space from a macro to a micro level. For example, imaging a coastline from space vs from an airplane vs from standing on the beach. To quantify complexity, we calculate the fractal dimension of the system. The fractal dimension has been used extensively for image and signal processing, and in some fields of biology such as neuroscience. More recently, the use of fractal analysis has been adopted by the morphology community to measure complexity in physical systems such as the lateral line in fishes and the ossicles in sea stars. In this study, we show the results of our modification the fractal dimension framework from 2D to 3D to be used with CT scans. With the recent surge in open access, high resolution, CT scans there is a need for new methods of comparison. In this work, we compare the fractal dimension measured in 2D and 3D of four biological systems: fish lateral lines, seastar ossicles, mollusc shells, and vertebrae. We also discuss best practices for using this method in 2D vs 3D depending on the system.

P2-168 TURRELL, M*; LEAL, M; University of Missouri; *mstx5p@mail.missouri.edu*

Microclimate Influences Variation in the Upper Thermal Tolerance of a Complex Lifecycle Amphibian

Microclimatic conditions experienced by individuals within a population can vary dramatically, particularly in the thermal regime. Notably, the temperature experienced by developing embryos can result in individual differences in physiological traits due to acclimation. Complex lifecycle amphibians, such as pond-breeding Spotted Salamanders (*Ambystoma maculatum*), provide an opportunity to evaluate whether the temperature experienced by developing embryos affects the upper thermal limit of those individuals in later life stages. We investigated the effect of aquatic microclimate on critical thermal maxima (CT_{max}) during multiple stages in the lifecycle of *A. maculatum*. Utilizing a replicated split-clutch experimental design, we raised *A. maculatum* in partially-shaded and sunny treatments, which were located ~100 m apart. We measured the water temperature of each treatment and found that salamanders in the sun developed at a mean temperature of 13.9°C, while those in the partial-shade developed at a mean temperature of 12.5°C. We also measured CT_{max} of larval and metamorphic salamanders from both treatments and found that individuals from the sun treatment had a significantly higher CTmax (larval $\bar{x}$ = 37.4°C and metamorphic $\bar{x}$ = 37.8°C) than individuals from the partial-shade treatment (larval $\bar{x}$ = 36.2°C and metamorphic $\bar{x}$ = 36.9°C). Our results suggest *A. maculatum* may display intrapopulation variation in thermal tolerance due to acclimation to distinct microclimatic conditions. However, our results are insufficient to determine if the variation between treatments is due to seasonal or developmental acclimation. More generally, our findings strongly suggest that the natural microclimate variation commonly encounter by pond breeding salamanders can impact the physiological traits of individuals, potentially contributing to differences in fitness.

P3-65 TWEETEN, KA*; SCOLLICK, JA; St. Catherine University; *katweeten@stkate.edu*

Tracking of Labeled Sperm Suggests that Diploid Populations of Sexually Reproducing Lumbriculus Cross Fertilize

Diploid populations of *Lumbriculus* we have collected from the littoral regions of lakes and sloughs in the upper Midwest states of Minnesota, Iowa, Wisconsin, and Montana demonstrate a sexual mode of reproduction during the summer months. From mid-April through mid-August, collected worms have reproductive structures including atria, testes, ovaries, sperm sacs, male and female funnels, and spermatheca and produce cocoons containing viable embryos. Histological sections of the worms stained with hematoxylin/eosin show the presence of sperm in spermatheca, suggesting that cross-fertilization is occurring in these hermaphrodites. To obtain more direct evidence of outcrossing, worms showing reproductive structures were incubated with Hoechst 33342. This DNA stain penetrated into the worms, labeling a variety of cells including sperm. Uptake of the stain by sperm heads was verified using tissue sections of worms embedded in gelatin/albumin. Fluorescently labeled sperm were observed in sperm sacs, testes, and atria. Labeled worms were then incubated with unlabeled worms for 2-5 days. Some pairings resulted in formation of cocoons containing viable embryos, indicating that the labeling with Hoechst stain did not disrupt the ability of the sperm to fertilize eggs. Detection of labeled sperm in homogenates from unlabeled worms following their incubation with labeled worms suggested that outcrossing had occurred. To substantiate these results, tissue sections are being examined to determine if the transferred, labeled sperm are localized within the spermatheca of recipient worms.

41-2 TYLAN, C*; LANGKILDE, T; The Pennsylvania State University; *clh319@psu.edu*

Immune Function Changes in Response to Consumption of and Stings from Fire Ants, an Invasive Predator and Prey of Native Lizards

Native ecosystems have been exposed to alterations from invasive species for decades, and the spread of non-native species is likely to continue in the future. Therefore it is important to understand the effects invasive species have on the animals in ecosystems into which they have been introduced. An excellent model system for addressing these questions is that of the eastern fence lizard (*Sceloporus undulatus*), which has been dealing with invasive stinging fire ants (*Solenopsis invicta*) for over 70 years. The presence of these invasive, predatory fire ants at a site has resulted in a number of morphological, behavioral, and physiological changes in the native fence lizards. This includes changes to their immune functions, decreasing some, while increasing or having no effect on others, as compared to lizards from ecologically similar sites which are not yet invaded by fire ants. We seek to discover if any of these immune changes are stimulated in lizards naïve to fire ants by direct exposure to fire ants, either through consumption of the ants, or by the ants stinging the lizards. These are both common routes of fire ant exposure in fence lizards, as the ants are both predator and prey, envenomating lizards via stings, but are also a frequent lizard food source. Understanding what changes in immunity are caused directly by exposure to fire ants, as opposed to evolved over time, will contribute to our understanding of how native species adapt to the presence of invasive species, and how quickly this can occur.

115-1 UEHLING, JJ*; INJAIAN, AS; TAFF, CC; WINKLER, DW; VITOUSEK, MN; Cornell Univ., Cellular Tracking Technologies; *jju8@cornell.edu*

The relationship between glucocorticoids and movement behavior during breeding in a free-living passerine

Movement patterns have wide-ranging effects on survival and population trends, and can greatly differ between individuals of the same species. However, we still do not understand the full suite of factors and mechanisms that generate differences in movement behavior. Hormones likely influence movement behavior, but their complete role is unclear. Glucocorticoid hormones (GCs) may contribute to vertebrate movement decisions; previous studies have demonstrated connections between GCs and movement during vertebrates' breeding seasons. Here, we examine the relationship between GC expression, movement behavior (geographic space use, distance travelled) and parental provisioning of offspring in breeding tree swallows (*Tachycineta bicolor*). We ask whether baseline corticosterone (CORT, the avian GC) predicts female swallows' fine-scale movement patterns and nestling provisioning rates, and if variation in these behaviors affects fitness (i.e. fledging success). To monitor movement behavior, we used two methods: solar-powered radio tags ("life tags”), which transmit unique identifying codes to an array of receivers across the breeding site; and a network of RFID boards, which record nest box visitation patterns. Because higher CORT tends to be associated with greater activity, we predicted that birds with higher baseline CORT would use larger geographic spaces for foraging, would travel farther, and would provision their nestlings more frequently. If our results show that CORT levels relate to movement and provisioning patterns, our findings would shed light on the role of GCs in coordinating movement, and how these movements relate to fitness outcomes.

88-1 UHRHAN, MJ*; FABIAN, JM; SIWANOWICZ, I; LIN, HT; Imperial College London, UK, HHMI Janelia Research Campus, Ashburn, VA USA; *myriam.uhrhan18@imperial.ac.uk*

Mechanosensors on Dragonfly Wings for sensing Aeroelasticity

Unlike wings of vertebrates, insect wings can only be actuated and controlled at the wing base. All wing deformations are results of passive interactions between aerodynamic loading and wing structural mechanics. This property of the wing is called aeroelasticity. To control and monitor such a complex system, insects have evolved an assortment of mechanosensors on the wing veins. It is not known, however, what and how each wing sensor captures information to support flight control. Dragonflies were the first insects to take flight over 300 million years ago, and remain the top flier in the insect world. Not surprisingly, their wings have significantly more mechanosensors than other insects' wings. Identifying the positioning and function of each type of sensor in the dragonfly wings is likely to reveal the key to aeroelastic sensing. We combined different imaging techniques to quantify the distribution of wing sensors and identified a novel sensor type. Punctuating the major wing veins, this mechanosensory consists of one bristle and one curious bump structure. To gain insight into how this sensor might function to detect flight-relevant forces, we modelled the interactions between sensors and surrounding airflow. Our simulations show that the bump filters out airflow in spanwise direction and that the aerodynamic forces acting on the sensor in chordwise direction differ with varying flight velocity. Thus, we speculate that the sensor location on the ridges of the wing veins enables the sensor to detect changes in the surrounding chordwise airflow.

P3-1 UJHEGYI, N*; BÓKONY, V; Plant Protection Institute, Centre for Agricultural Research, Budapest, Hungary; *ujhegyi.nikolett@gmail.com*

Skin Coloration as a Possible Non-Invasive Marker for Skewed Sex Ratios and Gonadal Abnormalities in Immature Common Toads

Environmental pollution and climate change can bias the sex ratios of animal populations in which sexual development in sensitive to environmental contaminants and temperature. Investigating these effects in field studies and ecotoxicological experiments is important but difficult when males and females cannot be distinguished without sacrificing them. We examined the utility of skin coloration as a non-invasive sex marker in juvenile common toads (*Bufo bufo*) that appear sexually monomorphic. We raised toadlets in the lab, and exposed the tadpoles to one of six treatments: two concentrations of two feminizing pollutants each and two controls. Before the first hibernation, we measured the hue, saturation and brightness of the toadlets' dorsal skin from photographs, and sexed them by inspecting their gonads. We found significant sexual dichromatism with males being yellower-greener and brighter than females. Although only 34% of males and 85% of females could be categorized correctly from photographs, the ratio of greenish and reddish individuals as categorized subjectively by human vision correlated strongly with the sex ratio of treatment groups. Treatment with 1 μg/L 17α-ethinylestradiol resulted in 100% females, with similar coloration as normal females. Intersex individuals occurred in treatment groups with 3 μg/L glyphosate and 1 ng/L 17α-ethinylestradiol; these animals were less saturated and darker reddish-brown compared to normal individuals. These results suggest that skin coloration may help in assessing phenotypic sex and gonadal abnormalities in common toads.

P2-163 UNFRIED, LN*; TEETS, NM; University of Kentucky, Lexington, KY; *laura.unfried@uky.edu*

Benefits of Rapid Cold Hardening at Sublethal Temperatures in Drosophila melanogaster

Rapid cold hardening (RCH) is a type of phenotypic plasticity in which a short period of chilling increases tolerance to otherwise lethal temperatures. While RCH has a well-established role in protecting ectotherms against physiological damage at lethal temperatures, these temperatures are infrequently experienced in the field. However, less is known about the effect of RCH on organisms at ecologically relevant, nonlethal temperatures. To better understand the role of RCH at temperatures more commonly experienced in the field, we tested the hypothesis that RCH protects against sublethal cold injury in *Drosophila melanogaster*. In a preliminary experiment we measured flies' ability to survive a 2 h cold shock between 0 and -6°C, and we found that all flies died following a 2 h cold shock at -4.5°C, while nearly 100% survive at -3°C. Thus, we are using 2 h at -3°C as our discriminating temperature to test the extent to which RCH protects against sublethal cold injury. For these experiments, adult D. melanogaster are exposed to one of three treatments: control (25° for 2 h), direct chilling (-3° for 2 h), or RCH (4° for 2 h followed by -3° for 2 h). Following these treatments, we are testing the ability of RCH to protect tissues from sublethal damage, reduce the time taken to recuperate from torpor at low temperatures, and recover locomotor activity following cold stress. Beyond the work presented here, we will test the extent to which RCH protects against suborganismal cold damage, preserves energy balance, and improves fecundity following cold stress. Together, these experiments will provide a thorough assessment of the ability of RCH to protect against sublethal cold injury.

P2-214 UNSWORTH, CK*; ASTLEY, HC; University of Akron; *cku3@zips.uakron.edu*

Quantifying the compliance of the millipede body while traversing irregular terrain

Navigating obstacles in terrestrial environments poses demands upon and animal's stability, traction, and propulsion. Legged animals often clear relatively small obstacles by stepping over them. Alternatively, myriapods have low clearance and high surface contact via with dozens to hundreds of limb contacts points at once. A key to a millipede's success at navigating uneven surfaces is its body and leg compliance. This study investigates the relative contributions of body and leg compliance of millipedes as they traverse steps and ramps. Preliminary analyses show that mean maximum body curvatures under the same conditions tend to remain consistent between multiple trials (dorsal 0.99 +/- 0.18 $^{1}/_{cm}$; ventral 1.45 +/- 0.30 $^{1}/_{cm}$) and that ventral pitch was higher than dorsal in 81% of trials. The coefficient of variation in dorsal and ventral curvature also tended to increase with increasing ramp angles and, on average, decrease with increasing step heights. This suggests that millipedes modulate their curvature under different conditions and may have optimal body postures when traversing obstacles. Future work will explore the passive and active mechanisms millipedes use to optimize this posture during locomotion using elastic beam theory, which could lend insight into optimal stiffness and compliance properties to create more stable and efficient terrestrial robots.

P3-245 UPADHYAY, A*; STAYTON, TC; HAGEY, TJ; Mississippi University for Women, Bucknell University; *aupadhyay@myapps.muw.edu*

Convergent Evolution in Toe Pad Shape Across Pad Bearing Lizards

Adaption is a process by which an organism becomes fit for the environment around it. Whenever a species colonizes a new environment, they go through adaptations that lead to changes in their morphology. We focus on lizards, specifically geckoes, anoles and skinks and how their toe pads may have changed as they colonized different parts of the world. The purpose of our study was to study the similarities and differences between lizard toe pad shape and how they may have changed through convergent and divergent evolution. We suspect convergence between distantly related species but it has never been quantified before. Photographs of the underside of gecko, anole, and skink hind feet were taken from live and preserved specimens. These toe pads were then digitized using a process called geometric morphometrics. Digital landmarks were placed on these images to outline the shape of the toes using tpsDig software (Rohlf 2010). We used the R package geomorph to align our data and convevol to test for significant levels of morphological convergence.

P2-15 URBAN-GEDAMKE, E*; CONKLING, M; MUNROE, S; MCCARTHY, PJ; WILLS, PS; POMPONI, SA; Florida Atlantic University; Fort Pierce, FL, Wageningen University, Netherlands; *urbane@fau.edu*

Evaluation of 3-D Cell Culture Methods for Marine Sponges

For decades, scientists have attempted *in vitro* culture of marine sponge cells and met with little success. Recently, the use of an optimized nutrient medium in two-dimensional cell culture has produced rapid cell division in three species of sponges in the genus *Geodia*. Continued division after the cells have formed a confluent monolayer has not yet been achieved. In addition, evidence shows that cells that are cultured in a two-dimensional environment exhibit changes in morphology and functionality. The use of three-dimensional cell culture techniques may increase the number of cells cultured *in vitro* by providing more surface area for the cells to adhere to. It may also promote normal functioning of the cells through increased cell-to-cell and cell-to-extracellular matrix communication, which are believed to perform a key role in cell functionality and morphology. This research combines the use of optimized medium with three-dimensional cell culture methods to culture cells of the marine sponge *Geodia neptuni*. Optimization of the culture methods demonstrated here may lead to the ability to scale up *in vitro* culture of biomedically important marine sponge species for the production of marine natural products.

25-2 URCA, T*; RIBAK, G; Tel-Aviv University, Tel-Aviv, Israel; *TomerUrca@gmail.com*

The Effect of Body Mass on Long-Distance Flight Efficiency in a Wood Boring Beetle, the 'Mango Stem Borer', Batocera Rufomaculata.

The Mango stem-borer, Batocera Rufomaculata, is an invasive species accidently introduced into Israel in the early 1950's and is one of its largest beetle species. Females lay eggs in the stems of Ficus trees and the boring larvae tunnel through the stem causing substantial damage to the host tree before emerging as flying adult. Adult beetles may differ in body mass 7-folds (1 - 7 gr) as a direct result of food availability and quality during larval growth. Research conducted at our lab has shown that smaller beetles, that developed on a poor diet, have higher long-distance flight endurance compared to large beetles, that developed on a richer diet, thus suggesting that smaller beetles are more efficient flyers. The physiological and biomechanical mechanisms increasing the flight efficiency of smaller beetles are currently unknown. Here, we examined the wingbeat kinematics of small and large beetles flying tethered in a wind-tunnel under increasing wind speed conditions. Flapping kinematics were extracted using two high-speed cameras and a set of two force transducers connected to the tether arm measured the forces exerted by the beetle during flight. Smaller beetles showed a preference for flight at lower wind speed. Nevertheless, the smaller beetles generated more lift per body mass than larger beetles at the preferred speed of larger beetles. Furthermore, the aerodynamic power per lift was lower in the smaller beetles indicating their higher flight efficiency. Measurements on revolving beetle wings have shown that larger ones require a higher power input/lift than smaller ones. This data suggests that smaller beetles possess elevated flight capabilities facilitating their dispersal from the less favorable environments in which they developed.

5-6 USHERWOOD, JR; The Royal Veterinary College, University of London; *jusherwood@rvc.ac.uk*

The possibility of zero-work gaits in sprawled and parasagittal quadrupeds: insights from linkages of the industrial revolution

Animal legs are diverse, complex and perform many roles. One defining requirement of legs is to facilitate terrestrial travel with some degree of economy. This could, theoretically, be achieved without loss of mechanical energy if the body could take a continuous horizontal path supported by vertical forces only – effectively a wheel-like translation, and a condition closely approximated by walking tortoises. If this is a potential strategy for zero mechanical work cost among quadrupeds, how might the structure, posture and diversity of both sprawled and parasagittal legs be interpreted? In order to approach this question, various linkages described during the industrial revolution are considered. Watt's linkage provides an analogue for sprawled vertebrates that use diagonal limb support, and shows how vertical-axis joints could enable approximately straight-line horizontal translation while demanding minimal power. An additional vertical-axis joint per leg results in the pull-out screen support as an analogue for tortoise limbs. This allows walking without any tipping or toppling, and has the potential to translate the body with zero work. The Peaucellier linkage demonstrates that parasagittal limbs with lateral-axis joints could also achieve the zero-work strategy. Suitably tuned four-bar linkages indicate this is feasibly approximated for flexed, biologically realistic limbs.

P1-85 UTT, DJ*; FOLTZ, SL; Radford University, Radford, VA; *dutt1@radford.edu*
The Effects of Light Pollution on Nesting Behavior in Eastern Bluebirds and Tree Swallows
Artificial light pollution (ALP) has the potential to have far-reaching effects on the behavior and success of many species of wildlife. Increased levels of ALP at night can impact nighttime behaviors, including sleep cycles, roosting sites choices, and predator-prey interactions. ALP could enable hunting or foraging at night but may also expose some species to potential predators. Two species that could be impacted by ALP are the eastern bluebird (*Sialia sialis*) and the tree swallow (*Tachycineta bicolor*), native insectivorous songbirds that readily breed in human-developed areas. Here we studied how ALP could potentially affect the parental behavior of these species in both an urban park and a rural farm environment, as well as the potential effect had by ALP on nestling health and the overall success of these birds' nests. We measured late evening and early morning ALP at nest boxes during the breeding season and monitored the nests progress via regular checks. We also recorded parents' responses to our nest checks, focusing on defensive behaviors such as alarm calls and dives. Analyses of behavioral data are ongoing but ALP readings at both sites were in most cases lower than expected. Therefore, we predict that effects of ALP on the birds at these sites may be less than expected.

6-5 UYANIK, I; SEFATI, S; CHO, K; ANKARALI, M M; FORTUNE, E S; COWAN , N J*; Hacettepe University, Ankara, Turkey, Johns Hopkins University, Baltimore, MD, Middle East Technical University, Ankara, Turkey, New Jersey Institute of Technology, Newark, New Jersey, Johns Hopkins University,Baltimore, MD; *ncowan@jhu.edu*
Variability in Locomotor Dynamics Reveals the Critical Role of Feedback in Task Control
Animals vary considerably in size, shape, and physiological features across individuals, but yet achieve behavioral performances that are virtually indistinguishable between conspecifics. We examined how animals compensate for morphophysiological variation by measuring the system dynamics of individual knifefish (*Eigenmannia virescens*) in a refuge tracking task. Kinematic measurements of *Eigenmannia*were used to generate individualized estimates of each fish's locomotor plant and controller revealing substantial variability between fish. To test the impact of this variability on behavioral performance, these models were used to perform simulated `brain transplants'---computationally swapping controllers and plants between individuals. We found that simulated closed-loop performance was robust to mismatch between plant and controller. This suggests that animals rely on feedback rather than precisely tuned neural controllers to compensate for morphophysiological variability.

P2-135 VALADEZ, J*; WILLIAMS, C; BEAUDOIN, G; Trinity University; *jullianvaladez@gmail.com*
Red-light activated neuronal control with an optimized mammalian expression vector
Optogenetics is the process by which a light-operated ion channel is expressed in neurons to enable photon-activation of action potential firing in neurons. This project identified mechanisms of innovation in the usage of optogenetics in selective activation of neural networks. Building on the work done previously with ChrimsonR, a red-shifted variant of channelrhodopsin-2 identified by the Boyden lab from a novel microbe, we identified and optimized expression of the protein. Using epifluorescent and confocal microscopy, we compared GFP expression between original and optimized constructs of the plasmid by transiently transfecting the plasmid into HT22 cells, a murine neuronal cancer cell line. Unlike several other promoters we concurrently tested, we find that the CaMKII-alpha promoter does not express efficiently in the undifferentiated HT22 cells. We have analyzed the effect of additives required for differentiation to enhance expression from the CaMKII-alpha promoter. Optogenetic stimulation during electrophysiology confirmed expression of ChrimsonR, and evaluated the efficacy of the new plasmid. Adeno-associated virus produced with the new ChrimsonR plasmid was purified using an iodixanol density gradient centrifugation, dialysis, and anion-exchange chromatography. The purified adeno-associated virus will be surgically injected into mice to test the plasmids efficacy in vivo. Thus, we have created an optimized optogenetics vector that will enable optical control of two different inputs.

P2-204 VALENCIA, M/M*; ASHZAND, B/A; BOWENS, J/L; MONROY, J/A; HORNER, J/M; California State University San Bernardino, Claremont Colleges; *007074841@coyote.csusb.edu*
The effects of different exercise regimes on tendon remodeling in mice (Mus musculus)
Tendons are series elastic structures that connect and transmit energy between bone and muscle. The elasticity of tendon aids the musculoskeletal system in absorbing, transferring, and dissipating energy, but the stiffness of a tendon may change over an individual's lifetime due to remodeling of tendon due to overuse, disuse, or aging. The molecular mechanisms and degree of remodeling possible in tendons are not well understood. In this study, we first investigate the remodeling efficacy of different types of exercise on tendon gross morphology and mechanics in mice (*Mus musculus*) by implementing exercise regimens with varying mechanical loading: voluntary wheel running, treadmill running, and repeated jumping. After 4 weeks of training, tendons were harvested for mechanical testing. Preliminary results show that treadmill mice have the lowest stiffness but the largest cross-sectional area of the exercise regimens. Jumping mice tendons demonstrated the highest failure stress but were not the stiffest. These data will be utilized to inform future studies on best practices for loading tendons in a laboratory setting.

P3-82 VALLE, PF*; ROCERETO, SK; RANK, NE; DAHLHOFF, EP; Santa Clara Univ, Sonoma State Univ; *edahlhoff@scu.edu*

Star-crossed lovers: Mitonuclear interactions may affect reproductive activity and offspring performance in a montane leaf beetle

Mismatch between nuclear and mitochondrial genomes is a potentially strong driver of physiological adaptation, yet challenging to investigate due to reduced reproductive success of parents and performance of offspring. In montane populations of the leaf beetle *Chrysomela aeneicollis*, variation at the glycolytic enzyme locus *phosphoglucose isomerase (Pgi)* and the mitochondrion is concordant along a north to south thermal gradient. Recent studies of naturally-introgressing populations show that performance and reproductive success of mitonuclear mismatched individuals is lower than individuals with matched genomes, especially after exposure to physiological stress. To directly investigate how the mitochondrion is interacting with nuclear gene products to cause these patterns, a large number of matched and mismatched offspring of known mitochondrial type is required. To test feasibility of generating such individuals, adult beetles were collected from populations at the northern (N) and southern (S) edges of *C. aeneicollis'* latitudinal range in the Sierra Nevada, sorted by sex and allowed to mate with a partner of the same (NfNm, SfSm) or opposite (NfSm, SfNm) origin. Male mating frequency was lowest for NfNm pairs and highest for SfSm pairs. In contrast, fecundity was 50% lower for NfSm females than SfNm ones, a directional mismatch that may be due to mitonuclear incompatibility. Fecundity was intermediate for same-site crosses. For larvae, running speed after heat stress was significantly lower for NfSm and SfNm offspring than those from same-site crosses. Studies of mitochondrial physiology and genetics are underway. Results to date demonstrate feasibility of laboratory crosses to alter adult reproductive success and generate offspring that differ in physiological performance characters among mitonuclear types.

P1-76 VAN BREUKELEN, NA; SANTANGELO, N*; Salem Community College, Carneys Point, New Jersey, Hofstra University, Hempstead, New York; *nicholas.santangelo@hofstra.edu*

Aggression by convict cichlid pairs as a means to deter brood mixing in a natural setting

Parental aggression can be a costly behavior and flexible in its expression based upon context. While defense of offspring from potential predators has been well studied in the convict cichlid, it is unclear why parents are aggressive towards other parental pairs who are not likely offspring predators. In this experiment we explore the aggressive behavior of pairs towards parental pairs and unpaired individuals using bottle presentations in the field. We found that parental pairs displayed more towards other parental pairs compared to unpaired individuals. We attributed this difference as a means to prevent brood mixing. Bites did not differ between treatments, however there was a sex difference in bites, with males preferring to bite males and females showing no preference. As the higher level of display was observed both in the presence and absence of fry, we also examined the pair response to fry alone. Focal pairs were more aggressive to stimulus fry which were larger than their own, indicating these fry represent a risk to the focal pair, as predicted by previous findings on brood mixing. We conclude that pair aggression towards parental pairs as a means of preventing brood mixing is greater than pair aggression towards unpaired fish which are offspring predators.

S2-10 VAN OERS, K*; SEPERS, B; SIES, W; GAWEHNS-BRUNING, F; LAINE, VN; VERHOEVEN, KJF; Netherlands Institute of Ecology (NIOO-KNAW); *k.vanoers@nioo.knaw.nl*

Epigenetic insights into the Heritability of Exploratory Behaviour in a Songbird

The search for the hereditary mechanisms underlying quantitative traits traditionally focussed on the identification of underlying genomic polymorphisms such as SNPs. It has now become clear that epigenetic mechanisms, such as DNA methylation, can consistently alter gene expression over multiple generations. In this talk, I will use exploratory behaviour in a Eurasian songbird, the great tit *Parus major*, as an example to highlight the challenges of genomic approaches. Furthermore, I will present preliminary results on how genetic variation in DNA methylation affects variation in exploratory behaviour using WGBS and RRBS approaches in a 4-generation artificial selection experiment and their F2 inter-cross. I will briefly elaborate on the challenges when studying epi-genomics in an ecological model species. The explanation of variation in DNA methylation offers a great opportunity to combine genetic and non-genetic approaches to explain the inheritance of complex traits.

P2-166 VAN SANT, MJ*; OUFIERO, CE; Cameron University, Towson University; *mvansant@cameron.edu*

Effects of Dehydration on Cutaneous Water Loss and Preferred Body Temperature in Sceloporus consobrinus

We have previously found that the lizard *Sceloporus consobrinus* could reduce rates of cutaneous evaporative water loss (CEWL) when exposed to desiccating conditions (e.g. warmer temperatures), suggesting plasticity in CEWL. As lizards were exposed to temperature differences without the ability to behaviorally thermoregulate, we wanted to further explore plasticity in CEWL by examining the relationship between preferred body temperature, CEWL and hydration status from the same lizard population in southwestern Oklahoma during 2018 and 2019. We expected that when lizards were dehydrated they would choose lower body temperatures and reduce rates of water loss by increasing resistance of the skin. We measured CEWL of 21 males using a Vapometer in the field as well as in the lab and used CEWL along with ambient environmental variables to calculate skin resistance to water loss. Lizards were housed individually in cages with a basking lamp and were free to choose a range of body temperatures through behavioral thermoregulation. Lizards were then dehydrated by withholding food and water for seven days in the lab. Measurements of CEWL, body temperature, and body mass were measured before and after fasting on all lizards. Dehydrated lizards lost an average of 24% body mass and chose lower body temperatures. Dehydration was not significantly correlated with resistance, but body temperature was. Lizards choosing higher body temperatures had lower rates of cutaneous water loss. These results and their implications will be discussed in more detail.

111-6 VAN WASSENBERGH, S.*; BöHMER, C.; ABOURACHID, A.; Universiteit Antwerpen, Belgium, Muséum National D'Histoire Naturelle, France; *sam.vanwassenbergh@uantwerpen.be*
Analysis of the Shock Absorption Paradox in Woodpeckers
The beak and beak-braincase interface of woodpeckers are hypothesised to serve as a shock absorber to minimise the harmful deceleration of the woodpecker's brain upon impact when pecking trees. This idea has become the common believe of how these birds protect their brain against injury, and seems supported by the presence of a relatively large zone of spongy bone at the frontal region of the braincase. However, since any absorption or dissipation of the head's kinetic energy upon impact implies lower peak forces exerted by the tip of the beak on the tree, evolving any type of shock absorber will probably impair the bird's hammering performance. To study this 'woodpecker shock absorption paradox', we first analysed the kinematics of the upper beak and braincase (eye centre position) based on high-speed videos (up to 4000 frames per second) of two black woodpecker individuals (*Dryocopus martius*) during pecking, and found that decelerations virtually did not differ between the beak and the braincase during impact, indicating a very stiff beak-braincase interface. Secondly, forward dynamic modelling of wood penetration events by a head with variable degrees of shock attenuation confirms the adaptive advantage of such stiff cranial systems without shock absorption. Finally, numerical modelling predicted that intra-cranial pressure in *D. martius* safely remained below half of those corresponding to the approximate threshold of concussions in primates. Together, these results show that the multi-component cranial skeleton of the black woodpecker is used as a stiff hammer during pecking to optimise pecking performance, and not as a shock absorbing system to protect the brain.

52-2 VANDENBROOKS, JM*; VIMMERSTEDT, J; HUFFAKER, M; ANGILLETTA, JR., M; Midwestern University, Arizona State University; *jvandenbrooks@midwestern.edu*
Oxygen limits the thermal tolerance in embryos of terrestrial endothermic and ectothermic animals
Oxygen availability and temperature are two of the most important environmental factors affecting all of animal life. However, the two are not independent of each other and may exert similar selective pressures on animals. Life stages that have poorly developed circulatory systems or are incapable of oxygen regulation may be more susceptible to high temperatures at lower oxygen levels. Through a series of experiments on lizards, birds, and insects, we have begun to examine the interactive effect of oxygen and temperature on terrestrial animals exposed to hypoxia, high temperatures, and a combination of both during various life stages and levels of activity. While the results of these experiments have been mixed in their support for the concept of an effect of oxygen during periods of thermal stress, one pattern has emerged – the thermal tolerance of embryonic stages are particularly susceptible to oxygen variation. This pattern holds true for both ectotherms and endotherms. In embryonic lizards, hypoxia strongly reduced thermal tolerance, while hyperoxia mildly increased thermal tolerance. By contrast, quail embryos showed a marked decrease in thermal tolerance in hypoxia and a marked increase in thermal tolerance under hyperoxia indicating they are oxygen limited even under normal environmental conditions. However, while the embryos were significantly impacted by oxygen, the thermal tolerance of adult lizards and insects were unaffected by oxygen variation. Based on these experiments, the effect of oxygen on thermal tolerance varies depending on the life stage. More experiments under ecologically relevant conditions and behaviorally relevant activities need to be carried out to further test these hypotheses.

109-8 VANDEPAS, LE*; STEFANI, C; TRAYLOR-KNOWLES, N; BROWNE, WE; GOETZ, FW; LACY-HULBERT, A; National Oceanographic and Atmospheric Administration, Seattle, WA, Benaroya Research Institute, Seattle, Wa, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, FL, Dept. of Biology, University of Miami, Coral Gables, FL, University of Washington, Dept. of Immunology and Benaroya Research Institute, Seattle, Wa; *vandepaslauren@gmail.com*
Tick, Tick, Boom: Exploring diverse immune cell behaviors in ctenophores and oysters
Innate immunity is an ancient defense mechanism that operates in multicellular organisms to detect and eliminate pathogens and distinguish self from non-self. Animal immune cells deploy diverse behaviors during pathogen detection and elimination, including phagocytosis, secretion of inflammatory cytokines, and expulsion of nuclear material - the casting of extracellular DNA "traps" (e.g. ETosis). While cells capable of mammalian neutrophil-like ETosis behavior were recently described in several bilaterian invertebrate taxa, the cellular immune system of the non-bilaterian clade Ctenophora remains almost completely undescribed. We have developed and deployed microscopy and biochemical approaches to explore and compare immune cell behaviors in model ctenophore (*Mnemiopsis leidyi*) stellate cells and oyster (*Crassostrea gigas*) hemocytes. Our findings suggest a variety of cell types may be competent for a range of anti-microbial responses, including ETosis. We also find that some immune cell type behaviors may be activated by non-canonical signaling pathways. This data provides an opportunity to explore both conserved and novel aspects of pathogen defense mechanisms associated with the evolution of the animal innate immunity.

1-6 VARGAS, M*; MARTINEZ ACOSTA, VG; Univ. of the Incarnate Word; Marine Biological Laboratory; *mavarga9@student.uiwtx.edu*
Regeneration of Negative Phototactic Response in Lumbriculus variegatus
Lumbriculus variegatus, an aquatic annelid, is capable of regeneration from a few body segments (Martinez and Zoran, 2009). In this study, we investigate photoreception during regeneration. Photoreceptors are found within the posterior-most segments of an adult worm, as suggested by Drewes and Fourtner (1989). A simple phototactic assay demonstrates a suite of behavioral responses when regenerating worm fragments are exposed to white light. Anterior (Ant) and posterior (Post) worm fragments demonstrate significant differences in the amount of time to negatively phototact [Control (C) vs Ant $p= 0.42$, $df=5$: C vs Post $p=0.047$, $df=5$]. Worms were also tested using an environmental chamber that provides a native habitat filled with sediment layers. To better describe location of photosensitive cells in posterior segments, Anti-Futsch (22c10; Developmental Hybridoma Bank) and Anti-G-α Subunit q/11/14 (Santa Cruz Biotechnology) antibodies, previously described as markers for photoreceptors in other worm species, were used. 22c10 immunoreactivity was localized to the cytoplasm within cells found along the ventral epithelial surface of the worm. These 22c10 positive cells are found adjacent to serotonergic axonal connections that extend toward the ventral nerve cord. G-alpha protein was more broadly expressed within small epithelial cells extending into the cuticle as well as within neuronal cell bodies extending from the ventral nerve cord. Taken together these data represent one of the most extensive studies of photoreception in *Lumbriculus*.

P3-190 VARGAS, C*; GRAHAM, Z/A; PALAORO, A/V; ANGILLETTA, M/J; Arizona State University , Universidade Federal de São Paulo; *cvarga16@asu.edu*

Sex Differences in Offensive and Defensive Investment in Crayfish Claws

Many animals possess weapons that have evolved to inflict damage to opponents during territorial encounters. Although the offensive capacity of these weapons are important determinants of contest success, the defensive capabilities of the weapons are also important. However, current theory only accounts for investment into offensive performance, and not defensive endurance. To help better understand these dynamics, we investigated claw strength, cuticle thickness, and injury rates in male and female virile crayfish (Faxonius virilis). Both male and female virile crayfish engage in aggression over access to both food and shelters. Thus, we expected each sex to invest similarly into the offensive and defensive abilities of their weapons. Interestingly, we found that despite males having proportionally larger claws, the average strength for a given size was similar between the sexes. Furthermore, we did not detect any sex differences in defensive ability (cuticle thickness) or injury rates. Overall, we demonstrated that both male and female virile crayfish invest similarly into the offensive and defensive ability of their claws.

53-1 VARGAS, R*; VALENTINI, A; GARCIA, M; STEFFENSON, M; St. Edward's University; *rvargas6@stedwards.edu*

The Immunological Response of Leg Autotomy in Tigrosa helluo Involving Hemocyte Protein Analysis

Autotomy is a survival mechanism utilized by various organism, in which an individual voluntarily loses a body part in response to an external stressor, often in the form of a predator attack. While this capability is a benefit towards immediate survival, there are notable impediments towards the overall survival of an autotomized individual. Behavioral and physiological alterations are commonly present following the autotomy event. The molecular components aiding in the recuperation of an organism after the loss of a leg have been of particular interest as they are indicative of the organism's overall immunological activity. In invertebrates, the hemocytes incorporated within hemolymph are important factors in cellular immunity. Within responses to leg autotomy, hemocyte interactions with foreign matter entering through an open wound can be assessed through the various proteins involved with the hemocyte activity. By analyzing the proteins present in the hemolymph of the wolf spider *Tigrosa helluo* after autotomy, we were able to identify the overall presence and function of the proteins associated with this stress response. Protein concentration and prophenoloxidase activity, a precursor for the organisms encapsulation response, was measured in both the controlled and autotomized female *Tigrosa helluo* and the control sample of the males. While there was no significant differences between either of the parameters across any of the sample groups, the observed patterns of this preliminary data suggests a possible difference between protein activity in females and males, and a difference in the prophenoloxidase activity in autotomized individuals compared to non-autotomized individuals.

48-8 VARNEY, RM*; SPEISER, DI; KOCOT, KM; Univ. of Alabama, Univ. of South Carolina; *rvarney@crimson.ua.edu*

The genome of the chiton Acanthopleura granulata: perspectives on biomineralization from polyplacophorans

The wide diversity of structures produced through biomineralization by molluscs has long been of interest to materials science. Despite technological advances, materials produced by molluscs at ambient temperature and pressure are often superior to manufactured materials in their combinations of desirable features (e.g. strength and flexibility). Chitons (Mollusca; Polyplacophora) are a promising system in which to study biomineralization because they produce a wide range of calcified structures including shell plates and sclerites. They also coat the teeth of their tongue-like radula with a range of iron oxides including magnetite. Comparative genomics permits comparisons of genetic toolkits across molluscs. Here we present the first genome of a chiton, the first from any aculiferan mollusc. We employed a hybrid assembly strategy combining Illumina and Oxford Nanopore followed by optical mapping. We produced a 605.9 Mbp assembly in 87 scaffolds with an N50 of 23.9 Mbp and a BUSCO score of 96.2%. We identified many genes hypothesized to be part of the biomineralization toolkit of conchiferan molluscs. To better understand how chitons produce iron structures, we analyzed known iron-associated proteins and located chiton-specific iron-binding regulatory sites in the untranslated regions of certain genes. We will combine further screening for iron-regulatory domains with sequencing of transcriptomes to determine gene expression patterns underlying the biomineralization of iron oxides such as magnetite. By comparing the genetic toolkits of conchiferans and aculiferans, we will be able to reconstruct the ancestral suite of biomineralization genes in molluscs. Further, by sequencing the first genome of a chiton, we are now better-positioned to study both the evolution and mechanisms of the natural production of iron structures in chitons.

P2-14 VARNEY, RM*; KINGSTON, ACN; KOCOT, KM; SPEISER, DI; Univ. of Alabama, Univ. of S. Carolina; *rvarney@crimson.ua.edu*

Localized physiological changes regulate the biomineralization of magnetite in the radula of the chiton Acanthopleura granulata

Iron presents a conundrum to animals: it is necessary for many physiological processes but free molecules of iron catalyze production of reactive oxygen species (ROS). As a consequence, animals tightly regulate the uptake and transport of iron. In most cases, animals use iron in its molecular form, but some animals create iron-mineralized structures. Chitons (Mollusca; Polyplacophora) feed by scraping algae from rocks with rows of teeth carried on a tongue-like radula. Chitons coat their teeth with iron oxides, most notably magnetite, and they constantly produce new rows of teeth. Crystalline structures such as magnetite require specific physiological conditions to grow. To characterize how local physiological conditions vary across the chiton radula, we measured pH, reactive oxygen species, and iron distribution across the tooth rows in the radula of *A. granulata*. Using a pH-sensitive dye, we discovered a dramatic change in pH across the radula: in contrast to a typical physiological pH ~7 across other tissues, a narrow band of 6 tooth rows was pH 4. To better understand how chitons regulate pH across the radula, we measured the activity of carbonic anhydrase and found that the region of highest activity matched the region of lowest pH. Using a ROS-sensitive fluorescent dye, we found higher amounts of ROS in the low-pH band of the radula, likely due to the presence of higher amounts of free iron. The localized patterns we observed indicate that tightly regulated physiological conditions contribute to the mineralization of iron in the chiton radula. This work increases our understanding of how chitons mineralize teeth with magnetite in spite of the toxicity of free iron and contributes to an understanding of how animals balance iron's utility with its potential toxicity.

136-2 VAZ, D/F*; HILTON, E/J; Virginia Institute of Marine Science, College of William & Mary; *dbistonvaz@vims.edu*

When Five Means Four (and Something Else): Ontogeny of the Pectoral Fin of the Plainfin Midshipmen, Porichthys notatus (Batrachoididae: Batrachoidiformes), with implications to evolution of Batrachoidiformes

Batrachoidiformes is a monophyletic group of mostly benthic, ambush-predatory fishes, and characteristic for having large pectoral fins. This order is unique for having the skeleton of the pectoral fin with five radial basals, in contrast to four found in other fishes. The homology of each radial basal, however, is uncertain. A hypothesis for the higher number of radial basals would be an additional segmentation of the embryonic pectoral radial plate during early life development. To investigate such question, a series of the early life stages of Plainfin Midshipmen, Porichthys notatus (5 to 28 mm TL), was collected during the summers of 2017 and 2018, and skeletal ontogeny was investigated by clearing-and-staining. Results obtained from early stages of P. notatus were used as a proxy to explain the variation in the order. The early stages of development (6-7 mm TL) of the petoral fin of P. notatus have two cartilaginous structures: a pectoral radial plate and the propterygium. Later development shows that the segmentation of the pectoral radial plate forms the four ventral radial basals. At 7-8 mm TL, the propterygium grows in its longitudinal axis and fuses with a group of cells that migrate from the pectoral radial plate, forming the dorsalmost "radial basal”. These findings have implications to the systematics of Batrachoidiformes. In genera Triathalassothia, Batrichthys, Riekertia, Halobatrachus, and Perulibatrachus, the dorsalmost basal radial (i.e., compound propterygium) remains cartilaginous, similar to found in other fishes (i.e., plesiomorphic state). All other species of Batrachoidiformes have an ossified compound propterygium and this shared feature might be an evidence of shared ancestry.

87-1 VAZQUEZ, S; PHAN, A; JOSEPH, M; PACE, CM*; Le Moyne College; *pacecm@lemoyne.edu*

The aerial righting ability of the brown marmorated stink bug, Halyomorpha halys.

How an animal recovers from perturbations in stability, such as falling, can have consequences for how it survives and thrives. Falling winged insects right themselves mid-air via asymmetric flapping and flightless insects have been shown to use leg positioning to achieve aerial righting success. However, how different morphologies impact insect aerial righting ability is unknown. Unlike previously studied insects, *Halyomorpha halys* is characterized by a broad flat shield-like body. In addition, *H. halys*'s locomotor abilities become seasonally impaired in the winter during diapause, potentially affecting flight. To assess the contribution of different morphological structures on *H. halys*'s aerial righting ability, landing success and timing of locomotor events were recorded from the following morphological categories: alive; alive with the wings glued shut; dead; and dead with the legs removed. *H. halys* was filmed at 1000Hz falling after being dropped from a ventral side-up starting position. Landing success of dead *H. halys* (both intact and with legs removed) was low (~30%). While living *H. halys* (both intact and with wings glued shut) had a higher landing success (~75%). This suggests that morphology alone isn't sufficient for successful landing. Living *H. halys* spread their legs wide upon initiation of falling and intact *H. halys* opened their wings shortly after while still upside down in the air. It is unclear how (or if) leg positioning changes when wings are unable to open and it is possible that *H. halys* switches between different aerial righting strategies depending on the circumstances.

119-1 VAZQUEZ-MEDINA, JP*; ALLEN, KN; TORRES-VELARDE, JM; LAM, EK; University of California, Berkeley; *jpv-m@berkeley.edu*

Primary tissue culture provides a system for functional genome-to-phenome investigations in marine mammals

Marine mammals exhibit dramatic physiological adaptations and offer unparalleled insights into mechanisms that drive convergent evolution on a short time-scale. Some of those adaptations (i.e. extreme tolerance to hypoxia, prolonged food deprivation) challenge established principles of matching metabolic supply and demand. Non-targeted omics studies have begun to uncover the genetic basis of such adaptations, but tools for testing their functional significance are currently lacking. A powerful approach for understanding the molecular etiology of physiological adaptation is cellular modeling, which is essential for accelerating genome-to-phenome research in organisms in which transgenesis is impossible. Gene perturbation in primary cells can directly evaluate whether positive selection or gene loss confers functional advantages such as hypoxia or stress tolerance. Hence, we have established ex vivo systems (skeletal muscle myotubes, flow-adapted endothelial cells) to conduct functional studies that can provide the missing link between genome- and organism-level understanding of physiological adaptation in marine mammals. Using these systems, we are starting to uncover the adaptive responses that drive stress tolerance in elephant seal muscles, which can switch metabolic pathways to support ATP production during chronic exposure to glucocorticoids. We are also dissecting the molecular drivers of hypoxia and oxidative stress tolerance in seal endothelial cells, which face constant fluctuations in oxygen tension derived from the diving response. Finally, we are developing adipocyte cultures from mesenchymal stem cells and muscle cells from reprogrammed skin cells to study the molecular drivers of metabolic adaptation in less accessible species.

76-3 VEGA, CM*; ASHLEY-ROSS, MA; Wake Forest University; *vegacm11@wfu.edu*

Turtling the salamader: the role of lateral undulation in sprawling limb kinematics

Lateral undulation and trunk flexibility which offer performance benefits to maneuverability and stability are important characteristics of sprawling postured tetrapod locomotion except for turtles. Despite their bony carapace preventing lateral undulations, turtles have been able to improve their locomotor performance by increasing stride length via greater limb protraction. Would a generalized sprawling tetrapod respond with the same kinematic changes if lateral undulations were limited? The goal of this study was to determine the role of the lateral movement of the vertebrae in tiger salamanders (*Ambystoma tigrinum*) by reducing the role of vertebral flexibility. 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 on the fore and hindlimbs were digitized using DLTdataviewer5. Protraction and retraction angle calculations and statistical analyses were performed in R. We thus predict that increased range of limb movement may be a compensatory mechanism available to a wide range of tetrapods challenged with reduced lateral undulation.

43-6 VELOTTA, JP*; ROBERTSON, CE; SCHWEIZER, RM; MCCLELLAND, GB; CHEVIRON, ZA; University of Montana, McMaster University; *jonathan.velotta@gmail.com*

A developmental delay in thermogenesis is associated with adaptive shifts in gene expression in high-altitude deer mice

Aerobic performance is strongly tied to fitness as it often determines an animal's ability to find food, escape predators, or survive extreme conditions. At high-altitude, where severe reductions in O_2 availability and cold temperatures prevail, maximum metabolic heat production (thermogenesis) is a performance trait that has evolved under natural selection. Understanding how thermogenesis evolves to permit survival at high-altitude will yield insight into the links between integrated physiology, whole-organism performance, and fitness. Previous work in deer mice (*Peromyscus maniculatus*) suggests that low O_2 availability at high-altitude forces a trade-off, whereby developing deer mouse pups delay the onset of thermogenesis in order to preserve limited energetic resources. In order to determine the mechanistic causes of this delay, we analyzed the transcriptomes of thermogenic organs, brown adipose tissue (BAT) and skeletal muscle, across the first 27 days of post-natal development in deer mice native to low- and high-altitude. We show that developmental delays in thermogenesis are correlated with shifts in the expression of gene regulatory networks that function in nervous system control, fuel supply, and vascularization of BAT, and aerobic metabolism and mitochondrial function in skeletal muscle. These results suggest that the delay in thermogenesis is attributable to a delay in the activation and aerobic capacity of thermo-effector organs. We provide evidence that many of the regulatory changes are adaptive. Our results suggest that a delay in the development of thermo-generation is adaptive at high-altitude, and may represent an alternative resource allocation strategy to balance competing energetic trade-offs.

P1-91 VENUTO, A*; CROWE, S; NICOLSON, T; ERICKSON, T; East Carolina University, Greenville, NC, Stanford School of Medicine, Stanford, CA; *venutoa18@students.ecu.edu*

Life without a lateral line: A new genetic model to study lateral line-mediated behaviors in zebrafish.

The lateral line (LL) is a hair cell-based sensory system that is important for swimming coordination, schooling, rheotaxis, and predator/prey detection in aquatic vertebrates. Previous behavioral studies have often relied on acute disruption of LL function by ototoxic compounds, but a genetic model is preferable to better understand the long-term contribution of the LL to fish behavior and learning. However, since inner ear and LL hair cells share many core functional components, it has been challenging to find a genetic mutant which specifically disrupts LL function. This work describes the first genetic model for the congenital loss of LL function in adult fish. We have found zebrafish ohnologs of a gene required for hair cell function whose mRNA expression patterns are cleanly partitioned between inner ear and LL hair cell populations. Genetic disruption of each ohnolog results in specific loss of either auditory/vestibular function or LL function. Since the LL mutants are adult-viable and exhibit normal auditory and vestibular behaviors, we can investigate LL-mediated behaviors and learning in adult fish. We have begun our analysis of these "lateral line-less" fish by evaluating their growth, survivability, and rheotactic behavior. We also characterize a novel swim bladder over-inflation phenotype associated with the LL mutants. In summary, this novel genetic mutant provides a unique opportunity to study lateral line function and to examine the long-term contributions of the lateral line input to fish development and behavior.

P1-172 VERNASCO, BJ*; EMMERSON, MG; GILBERT, ER; SEWALL, KB; WATTS, HE; Washington State University, Virginia Tech; *ben.vernasco@wsu.edu*

Migratory state and patterns of steroid hormone receptor expression in the pectoralis muscle of a nomadic migrant, the pine siskin (Spinus pinus)

The flight muscles of birds undergo multiple physiological changes during the transition from a nonmigratory to a migratory state. Both the hypothalamic-pituitary-adrenal and -gonadal (HPA/HPG) axes have been proposed to coordinate the physiological changes associated with this transition. For example, the HPA axis is thought to be associated with processes related to fueling migration, while the HPG axis is proposed to mediate flight muscle hypertrophy. However, the specific components of these endocrine signaling pathways that coordinate the physiological changes associated with the migratory transition are not well understood. We hypothesize that variation in the sensitivity of the flight muscles to steroid hormones produced by the HPG and HPA axes is important for coordinating the physiological changes that occur during the migratory transition. To assess this hypothesis, we used qPCR to quantify mRNA expression levels of genes for steroid hormone receptors associated with the HPA axis (mineralocorticoid and glucocorticoid receptors) and HPG axis (estrogen receptor alpha and androgen receptor) in the pectoralis muscle of captive, adult pine siskins (*Spinus pinus*). Samples were collected from captive subjects either prior to (i.e., during the winter) or after they entered the spring nomadic migratory state. By examining expression patterns of steriod hormone receptors across this migratory transition, this study adds to the growing body of literature aimed at understanding the endocrine mechanisms involved in coordinating the physiological changes associated with migration.

79-4 VERNASCO, BJ*; DAKIN, R; SISSON, Z; HAUSSMANN, MF; RYDER, TB; MOORE, IT; Washington State University, Carleton University, Bucknell University, Bucknell University, Smithsonian Migratory Bird Center, Virginia Tech; *ben.vernasco@wsu.edu*

Using Telomeres to Assess Patterns of Biological Aging in a Cooperative Lek-breeding Passerine, the Wire-Tailed Manakin (Pipra filicauda)

Telomere lengths are reflective of an individual's biological age as telomeres shorten in response to both environmental and physiological perturbations and shorter telomeres are associated with higher mortality risks. Therefore, telomere length measurements can be used to understand what factors influence aging rates as well as how reproductive behaviors vary as an individual's mortality risk increases and future reproductive potential declines. Here, we measured the telomere lengths and reproductive behaviors of known-age, male wire-tailed manakins (*Pipra filicauda*) to understand how telomeres relate to a male's chronological age, social status, and reproductive investment. Wire-tailed manakins are a lekking passerine and males form cooperative display coalitions wherein multiple males perform coordinated courtship displays for females, but only one male within the coalition reproduces. Male wire-tailed manakins must ascend a social hierarchy as floater males and only gain reproductive opportunities upon becoming a territory-holder. More cooperative floater males are quicker to become a territory-holder and more cooperative territory-holder sire more offspring. Our results show that only among territory-holding males do telomere length decline with age. Additionally, independent of a male's age and social status, those with shorter telomeres interacted with coalition partners more frequently, maintained more exclusive positions within their social network, and tended to have more coalition partners. Overall, we identify status-specific patterns of aging and our results suggest males increase their reproductive investment as their future reproductive potential declines.

117-7 VETTER, BJ*; SISNEROS, JA; University of Washington; *bjvetter@uw.edu*

The swim bladder enhances sound pressure sensitivity and bandwidth of the lagena in female plainfin midshipman (Porichthys notatus)

The plainfin midshipman fish (Porichthys notatus) is an established neuroethological model for investigating mechanisms of acoustic communication because the reproductive success of this species is dependent on the production and reception of social acoustic signals. Midshipman possess three otolithic end organs capable of sound detection. The largest of these is the saccule and the sensitivity of this hearing end organ is well established, but the sensitivity and function of the putative auditory lagena is less understood. Previously, we showed that the midshipman lagena had a similar low-frequency sensitivity to that of the saccule but the lagenar thresholds were much higher. Furthermore, work from our lab demonstrated that midshipman possess sexually dimorphic swim bladders that effectively enhance sound pressure detection. The swim bladders of females have rostral horn-like extensions that project close to the inner ear end organs, especially the lagena, while nesting males lack such extensions. The aim of this study was to determine whether these swim bladder extensions enhance auditory lagenar sensitivity to sound pressure and higher frequencies. We characterized the lagenar sensitivity of reproductive females with intact (control) and removed swim bladders. Our results show that control females with intact swim bladders displayed auditory evoked lagenar potentials up to 1005 Hz while females with removed swim bladders displayed evoked potentials only up to 505 Hz. Furthermore, the control females had the lowest thresholds (highest sound pressure sensitivity), with average thresholds at the characteristic frequency (85 Hz) that were 6 dB lower than those without swim bladders. These findings suggest that the midshipman lagena is sensitive to sound pressure indirectly and maybe important for the detection of social acoustic signals.

P2-224 VICK, CP*; GIFFORD, ME; University of Central Arkansas, Conway, AR; *cvick2@cub.uca.edu*

Climbing Performance as a Physical Cost of Reproduction in Prairie Lizards (Sceloporus consobrinus)

Bearing offspring can put females at disadvantages, in predator escape, foraging, and the overall energetic cost. We investigated the effects bearing offspring has on vertical locomotion in the Prairie Lizard (*Sceloporus consobrinus*). We used field-collected gravid lizards from the Ozark Mountains of Missouri. Female lizards were encouraged to run up a vertical racetrack made of tree bark to simulate natural perches. Each trial was video recorded and analyzed to measure the amount of time it takes a lizard to cross 10 cm of the racetrack. We compared maximal speeds for females while gravid and within one week after laying eggs. Therefore each female served as its own control. Due to the extra weight gravid females carry, we expect to see a significant reduction in climbing speed and interpret this difference in climbing speed as a cost of reproduction. Reduced speed can put gravid females at a higher risk of predation. As such, we predict that gravid females will choose perches in the field that reduce the need to rely on climbing behavior.

P1-84 VIERNES, RC*; FARRAR , VS; AUSTIN , S; FEUSTEL, T; FLORES, L; ASMAI, R; ARIAS, JG; CALISI, RM; University of California, Davis; *rcviernes@ucdavis.edu*

Ex-spleen-ing Trade-offs Between Immunity and Reproduction during Parental Care in the Rock Dove, Columba livia

Caring for offspring often requires various behavioral and biological tradeoffs, such as decreased immune function, as parents prioritize reproductive efforts over personal survival and growth. Using the model of the rock dove, we investigated the relationship of prolactin, a hormone essential for facilitating parental care behaviors, with gene activity of its receptor in the spleen, an organ whose function is critical to the maintenance of the vertebrate lymphatic system. We found that prolactin receptor expression in the spleen of both sexes is dynamic, mirroring circulating hormone patterns and significantly increasing when chicks first hatch and during nestling care. Now we are testing whether elevated levels of circulating prolactin characteristic of these time points are the cause of increased prolactin receptor expression in the spleen, and how this affects spleen function.

P1-20 VILLAFRANCA, N.*; WEGLARZ, M.; HAMLYN, S.; VAUGHAN, D.; STENESEN, D.S; SOPER, D.M; University of Dallas, Mote Marine Laboratory, Plant A Million Corals; *nvillafranca@udallas.edu*

Investigation of Coral Growth and The Genetic Expression of The Hippo Growth Signaling Pathway in Orbicella faveolata

Coral growth is a critical aspect to reef health, resilience under rapidly changing environmental conditions, and restoration efforts. Although fragmenting has been occurring for many years in an effort to restore reefs, recently it was discovered that microfragmenting, the process of cutting one piece of coral into many small pieces (~3-5 polyps), induces exponential growth. Our study investigates the process by which microfragments of 10 different genotypes from the stony coral species *Orbicella faveolata* grow. Using a dissecting microscope fixed with a camera, we recorded new polyp formation on the microfragment edges. We then extracted tissue from both the edge and center of five genotypes for analysis of the Hippo Growth Pathway (HGP)expression, which is a conserved signaling pathway that is known to exist in Drosophila, mammals, and cnidaria. Two primers for the Cyclin-E transcriptional factor were utilized to determine if the Hippo Growth Pathway is present and to examine the level of expression for center and edge tissue. We found that the HGP is present in *O. faveolata* and that there is higher expression of the Cyclin-E transcriptional factor in edge vs. center tissue in each of five genotypes. Despite consistently higher levels of expression on the edge tissue of Cyclin-E, genotypes varied significantly in the degree to which expression differed ($p = 0.001$). Future work will focus on developing primers for other transcriptional factors involved with the HGP.

P2-86 VINSON, A*; LATTIN, C; Louisiana State University; *abbyvinson29@gmail.com*

House Sparrows Show Wide and Repeatable Individual Variation in Behavioral Responses to Novel Objects and Foods

Individuals that hesitate to approach or interact with novel objects in their environment can be described as neophobic. Urbanization, pollution, and the introduction of non-native species impact an animal's natural habitat, and populations of wild animals frequently come into contact with novel objects and novel foods. Therefore, an individual's willingness or hesitation to approach a new object or food can determine the individual's – and even the population's – survival. Within populations of wild House Sparrows (*Passer domesticus*), it has been observed that individuals vary widely in their responses to novel objects and foods. We set out to characterize the neophobia responses of wild-caught sparrows (n=24) using a panel of behavioral tests in a laboratory environment. In all tests, we removed food dishes overnight. In the novel object test, we either replaced food dishes (control) or replaced food dishes with one of the five different novel objects placed in, on, or near the food dish (novel object treatment). In in the second test, we gave sparrows either their normal mixture of seeds and food pellets (control) of one of four different novel foods (novel food treatment). The third test exposed sparrows to the same novel object for four consecutive days (novel object habituation). We found that in the novel object and food treatments responses were highly variable, although most individuals displayed repeatable behavioral phenotypes throughout all treatments.

P1-227 VIOLOET, E*; DEVINE, K; KENALEY, CP; Boston College; *violet@bc.edu*

A Matter of Scales: Evaluating the Function of Fangs in Deep-sea Fishes

Due to the difficulties of observing in-situ behaviors at extreme depths, the feeding behavior of deep-sea fishes is rarely observed. However, gut-content studies reveal many species are capable of consuming prey that exceed 50% of the body length. Large needle-like fangs are a hallmark of predatory deep-sea fishes and thus are often implicated in the impaling of large prey. A recent modeling study of the viperfish (*Chauliodus sloani*) suggest that its enormous fangs are powered by weak adductor muscles. This raises a fundamental question: Are enormous teeth used for impaling or some other function such as caging? To answer this, we performed puncture-resistance test on typical prey items of *C. sloani*, species of the mesopelagic family Myctophidae. We found that myctophid scales are extremely puncture resistant, requiring 20-80 N for failure over a range of specimens 30-70 mm. Given the extremely low bite force of a viperfish, their fangs are incapable of piercing these prey. The bite force of *C. sloani* would have to be amplified 3,000-4,000 times to puncture the largest prey items it consumes. We therefore conclude that the fangs of a viperfish are not impaling devices, but rather likely used in caging.

P3-50 VIRGIN, EE*; KEPAS, ME; HUDSON, SB; FRENCH, SS; Utah State University; *emilyevirgin@gmail.com*

Comparisons of egg yolk physiology and hatchling quality between urban and rural Side-blotched lizards (Uta stansburiana)

Physiological maternal effects are adaptive if differential allocation increases offspring fitness, and therefore, maternal fitness. Oviparous animals can alter offspring phenotypes in response to changes in the environment by varying the allocation of physiological factors (e.g., hormones, nutrients, immune factors) to the yolk. Although the relationship between egg yolk physiology and offspring phenotype is well-documented, it is unclear how anthropogenic change (i.e., urbanization) influences maternal allocation of physiological factors and offspring quality. In this study, we compared the egg yolk physiology and offspring quality of Side-blotched lizards (*Uta stansburiana*) occupying urban and rural environments using a split clutch design. We extracted yolk samples from half of the eggs within a clutch and measured bactericidal capacity, energy metabolites, and oxidative physiology. The other half of the clutch was incubated until hatching. Following hatching, we collected hatchling morphometric data and assayed hatchling wound healing ability. Studying the transgenerational impacts of urbanization will help us better understand how organisms are responding to changing landscapes.

35-3 VITEK, NS*; MCDANIEL, SF; BLOCH, JI; Stony Brook University, NY, University of Florida, Gainesville, FL , Florida Museum of Natural History, Gainesville FL; *natasha.vitek@stonybrook.edu*

Is variation in molar tooth crown morphology of the Grasshopper Mouse (Onychomys leucogaster) a reflection of selection or drift?

A longstanding question in evolutionary biology is to understand the role of local adaptation, as opposed to neutral processes, in shaping morphological variation among populations. Differentiating between these alternatives for fossil bones and teeth is critical for interpreting the drivers of historical change. However, this work is particularly challenging because molecular indicators of selection and drift are lacking in fossils. Here we used the molars of the extant, insectivorous rodent *Onychomys leucogaster* as a test case to develop expectations for the fossil record. The similarity across environments of the insects comprising the diet of *O. leucogaster*, at least with respect to their mechanical properties, suggest that selection on molars, primarily through diet, may be homogeneous across the distribution of the species. We used geometric morphometrics to measure morphology, ddRAD sequencing to estimate population structure, and measures of climate, primary productivity, and phenology to measure environment. We evaluated support for the two hypotheses by comparing morphology, population structure, and environment while accounting for geographic distance via P_{ST}-F_{ST}-comparisons using multiple matrix regression with randomization. Depending on whether we quantified morphology in terms of size, shape, or size and shape together, we found variably significant relationships between morphology and population structure, but never with environment or geographic distance. In sum, these results indicate that we cannot eliminate drift as the mechanism driving morphological divergence in tooth shape and size.

P3-167 VON HAGEL, AA*; MALINGEN, SA; DANIEL, TL; University of Washington, Seattle, WA; *danielt@uw.edu*

Predicting muscle length changes from EMG activation in Manduca sexta

Dynamic coordination of animal motion depends on the interaction between the neuromuscular system and body mechanics. An open challenge is whether one can predict muscle length changes from the electrical activation patterns (electromyogram: EMG) in fully intact animals. This challenge arises from the myriad forces acting on any contracting muscle. We asked if we can predict the magnitude and time course of muscle length changes induced from measured EMGs in *Manduca sexta* where there is a one-to-one relationship between the timing of muscle electrical activation and length-wise contraction. During flight, the dorsal longitudinal muscles (DLMs) the antagonist dorsal ventral muscles (DVMs) deform the thorax, indirectly powering wing flapping. We recorded DLM and DVM EMG activity during *in vivo* tethered flight. Simultaneously, we used 3D high-speed video of thorax deformation to measure the change in length of the DLM muscles. Using Fourier transform methods, we confirmed that the primary frequency of our two signals matched, consistent with previous work demonstrating the synchronous activation of this muscle group. The average percent length change on the dorsal aspect of the thorax was 0.76 % (SD 0.72%) suggesting large variability in muscle shortening across trials and individuals. We also found large variation in the phase between length change and electrical activation. Preliminary results show a frequency dependent increase in the phase of muscle length change relative to activation. The one-for-one correspondence between muscle activation and shortening in *M. sexta* allows us to decipher the relationship between activation and functional outcome.

P2-67 WADE, K*; MONCEAUX, C; CLOSE, M; GRUBB, O; STRICKLAND, T; O'BRIEN, S; Radford University ; *Kwade15@radford.edu*

Trenbolone Half-life and Metabolism in Gambusia

Endocrine-disrupting chemicals (EDCs) can be widespread contaminants in the environment, found in clothing, plastics, pesticides and more (Zoeller 2012). These EDCs can interfere hormone receptors or hormone processing (Zoeller 2012) which is causing a rise in concern regarding this category of chemical pollutants (Sifakis et al., n.d.). Here we examine the impact of Trenbolone (tren) an anabolic steroid that is used in cattle farming to promote rapid weight gain. Tren is synthetic testosterone mimic that is not fully metabolized and thus found in cattle excrement (Ankley 2003). As such, tren has been known to wash into agricultural runoff and is found within the aquatic environment (Cole 2015). In this study, we utilize mosquitofish (*Gambusia holbrooki*) as a model to explore the impacts of tren on aquatic wildlife. *Gambusia* are often used as a mosquito control method in agricultural areas. Here we exposed *Gambusia* to 5 ppt and 10 ppt of tren for a month-long trial. Fish tissues were then analyzed to explore the impact of ecologically-relevant levels of tren exposure on fish metabolism and morphology.

9-7 WAGNER, JM*; PARKER, J; California Institute of Technology, Pasadena; *jwagner2@caltech.edu*

Chemical Cues Underly an Interspecies Symbiosis by Triggering a Modular Social-Behavioral Program

Interspecies social behaviors have traditionally been challenging to study because they are difficult to reconstitute in lab. Here, we demonstrate a stereotyped, robust interspecies grooming program for study of social behavior. *Sceptobius lativentris* is a host specific guest rove beetle which infiltrates colonies of the velvety tree ant (*Liometopum occidentale*). The beetle is the quintessential social parasite: it dies rapidly when isolated from ants, has lost its wings and disperses on ant trails, and grooms host ants to steal their nestmate recognition pheromones (CHCs), which it uses to disguise inside colonies. Using infrared illuminated behavioral arenas, we have reconstituted the beetles' stereotyped grooming program in lab which we have annotated with deep learning tools. Though *S. lativentris* exhibits strict host specificity in nature, it promiscuously grooms divergent species of ants. It does not, however, groom a hemipteran which peripherally associates with *L. occidentale*. We hypothesize that a core set of cuticular pheromones conserved in ants provide the odor cue triggering *S. lativentris* social behavior. To test this, we employed a robotized ant-beetle interaction arena which allows application of ant chemicals to a moving dummy object. This arena gives a controlled set up to demonstrate the necessary and sufficient cues for *S. lativentris* grooming. In addition to establishing the behavioral tractability of *S. lativentris* as a model system of social symbiosis, we have also worked to establish molecular tools for the beetle. We performed RNA sequencing of the beetle and olfactory structures (legs, antennae), assembled its transcriptome, and annotated odorant and gustatory receptors. Together, these behavioral and molecular tools establish an exciting new system to investigate social symbiosis.

73-7 WAINWRIGHT, DK*; SUMMERS, DA; Yale University, New Haven CT, Harvard University, Cambridge MA; *dylan.wainwright@gmail.com*

Crushing prey in the open ocean: the pharyngeal jaws of lanternfishes

Lanternfishes are a diverse family of fishes with 246 described species that live in open ocean waters worldwide. These fishes are estimated to account for over 60% of deep-sea fish biomass and are crucial food sources for many larger fishes, cetaceans, and squids. Many lanternfishes live deeper in the water column during the day, but migrate closer to the surface at night to consume zooplankton. Despite the clear ecological and evolutionary importance of lanternfishes for open ocean environments, we generally know little about this group due to the difficulties of observing them alive. In order to develop our ecomorphological knowledge of lanternfishes, we have used µCT to study their cranial morphology, with a special focus on pharyngeal jaws. Pharyngeal jaws are common to all teleosts and are a second set of jaws formed by modifying the posterior-most set of gill arches into tooth-bearing bones that can help process and transport food. We demonstrate that one clade of lanternfishes (Gonichthys spp. and Centrobranchus spp.) have highly modified pharyngeal jaws, where the upper tooth plates have enlarged molariform teeth and appear to occlude in a lateral-medial fashion, as opposed to the normal arrangement where upper and lower tooth plates occlude in a dorso-ventral fashion. The modified upper pharyngeals are hypertrophied and crush prey between the left and right upper tooth plates using enlarged musculature and a novel muscle attachment. Unlike other lanternfishes, the clade of species with modified jaws specializes in consuming planktonic shelled gastropods. This discovery represents a unique and novel instance of durophagy by a small-bodied, open-ocean, and zooplanktivorous group of fishes.

P3-93 WAITS, DS*; RIBEIRO, R; KOCOT, KM; BULLARD, SA; HALANYCH, KM; Auburn University, Auburn, AL, University of Alabama, Tuscaloosa, AL; *dsw0002@auburn.edu*

You Aren't What You Eat: The Impact of Sequence Contamination on Phylogenomics of Blood Flukes (Platyhelminthes; Schistosomatoidea)

Sequence contamination occurs regularly in high-throughput sequencing. Whether due to mistakes at the bench or intrinsic to the samples, contamination has the potential to not only waste sequencing effort but also lead investigators to erroneous conclusions. Given that most organisms have high amounts of foreign DNA and the prevalence of high-throughput sequence data, contamination-screening approaches are a necessary part of any bioinformatics pipeline. In pipelines used for phylogenomics, contamination has the potential to introduce confounding signal ("noise"), especially when determining orthologous groups of genes. Blood flukes are ideal candidates to elucidate the impact of contamination since they mature in the blood of vertebrates and probably ingest erythrocytes and plasma components. Here we investigated how post assembly contamination screening approaches affected the final topology of a phylogenomic analysis. We employed a standard phylogenomic pipeline on 34 blood fluke transcriptomes, which resulted in 761 orthology groups (OGs). We used two contamination-screening methods that were based on BLAST sequence comparisons (with varying levels of stringency), resulting in ten datasets that differed in OG content. These ten datasets were additionally pruned of paralogs, yeilding 17-308 final OGs. Six tree topologies were inferred from these datasets, but differences were minor. Interestingly, the two least stringent and the second-most stringent datasets resulted in identical topologies. Our results suggested that standard paralog detection is sufficient for contamination screening in phylogenomic pipelines.

S10-10 WALDROP, LD*; MOHAMMADI, S; RADER, JA; HE, Y; Chapman University, UNC Chapel Hill, University of North Texas; *waldrop@chapman.edu*

Using uncertainty quantification to infer physical constraints on the evolution of fluid-structure functional systems

Understanding evolution, in part, requires understanding how variation will change the functional performance of biological structures. Variation provides the raw material on which natural selection acts to shape these structures, but the performance consequences of variation are difficult to predict in complex, non-linear functional systems. Computational models have long been used to better understand the biomechanics of biological structures, but their usefulness has been historically limited in informing studies of evolution. This work strives to integrate the detailed, computational models with studies of evolution and morphological diversity through unique quantitative analysis tools. We apply uncertainty quantification to simple computational models of three functional systems involving fluid-structure interactions: odor-capture by crustacean antennules, blood-pumping by the tubular hearts of tunicates, and gliding performance in birds. We use generalized polynomial chaos expansions in conjunction with Sobol indices to assess and describe the role of variation in the performance of each system across a wide morphological and kinematic space. From these techniques, we infer the strength of physical constraints on the evolution of biological structures in each system.

S10-0 WALDROP, LD*; RADER, JA; Chapman University, UNC Chapel Hill; *waldrop@chapman.edu*

Introduction to Melding Modeling and Morphology

Biomechanics seeks to understand the form and function of organisms. Researchers have largely taken two tacks toward this goal: 1) observing and modeling representative organisms to infer form based on function, or 2) quantifying trait diversification and evolutionary constraint to infer function based on form. This has led to the development of sophisticated tools including, but not limited to mathematical and computational modeling on first tack, and geometric morphometrics, classic biomechanics manipulation experiments, and phylogenetics on the other. These are powerful approaches, and they have much to offer each other toward understanding the evolution and biodiversity of form and function, yet there has been little work to date on combining computational modeling and morphometrics. A few works have started to bridge this divide, but these methods are under-developed and not widely used. Recent advancements in computational power that previously limited attempts to both model function and to handle and analyze large data sets make this an ideal moment to spur development of collaborative efforts, and as such, the purpose of this symposium is to examine the idea of studying the evolution of functional structures using mixed methods of classic biomechanics, together with computational and mathematical modeling, all in a phylogenetic framework. The symposium brings together speakers with backgrounds in both approaches with the hope of promoting ideas by speakers who have worked to develop methods to bring both sides together.

64-2 WALKER, S M*; CHRISTEN, P; TAYLOR, G K; University of Leeds, University of Applied Sciences and Arts Northwestern Switzerland , University of Oxford; *s.m.walker@leeds.ac.uk*

Haltere kinematic and dynamics measured using time-resolved microtomography

Halteres are the dumbbell-shaped, reduced hindwings found in Diptera (true flies) and are a defining feature of the order. During flight, the halteres beat in antiphase with the wings and function as gyroscopic sensors of Coriolis force produced during whole body manoeuvres. This rapid sensory mechanism is one of the reasons why flies are amongst the most agile and manoeuvrable of all flying insects. However, in order to detect the tiny Coriolis forces, halteres must be exquisitely tuned so that the signal is not masked by the much larger inertial forces due their own acceleration. This is believed to be achieved by beating in a perfect plane, which allows the orthogonal component of the Coriolis forces to be detected in isolation from the primary forces. However, this has not been confirmed experimentally. Here, we use time-resolved microtomography to visualise the halteres in tethered blowflies, *Calliphora vicina*, during induced roll manoeuvres. We used the measured 3D haltere kinematics to calculate the corresponding dynamics. Surprisingly, we found large primary forces acting in the same plane as the Coriolis forces. These were caused by significant out-of-plane motions at the haltere base, and may be an artefact of tethering. Furthermore, this base motion produces a force that matches the Coriolis forces that would be produced by a constant pitching motion. Flies will therefore be sensing a fictitious force during tethered flight that could result in changes to their behaviour and requires careful consideration when designing such experiments.

P1-259 WALKER, NJ*; MORALES, OJ; BOYLES, JG; WARNE, RW; Southern Illinois University, Carbondale; *nikki.walker@siu.edu*
Glucocorticoid and Behavioral Responses to Environmental Perturbations
Changing environmental states can impose homeostatic costs on animals that trigger shifts in physiology and behavior. We tracked fecal corticosterone fluctuations and movement behavior of banner-tailed kangaroo rats (*Dipodomys spectabilis*) over time and in response to changes such as habitat disturbance, season, lunar phase, and experimental manipulations. Corticosterone (CORT), a glucocorticoid, is a homeostatic hormone that is thought to mediate both physiological and behavioral responses to environmental perturbations. We predict that fecal CORT profiles, movements, and habitat use will shift in response to these perturbations. For granivorous rodents, we expect these shifts could influence trophic interactions and the plant community through changes in seed consumption, dispersal distances, or preferential consumption of particular plant species. Banner-tailed kangaroo rats are one of the most abundant rodents in this part of the Chihuahuan desert and their burrows provide refuge for many other species. Shifts in stress hormone levels and behavior could impact the entire small mammal community. There is no doubt we live in a rapidly changing world; experimental tests such as these can provide insight into how animal physiological and behavioral responses to changing environments can influence ecological community dynamics.

P1-103 WALKOWSKI, W G*; SANTANA, A; LESLIE, C E; GORDON, W C; BAZAN, N G; FARRIS, H F; Department of Cell Biology and Anatomy LSUHSC, New Orleans and Neuroscience Center of Excellence LSUHSC, New Orleans, Neuroscience Center of Excellence LSUHSC, New Orleans, Department of Integrative Biology UT Austin, Austin, Neuroscience Center of Excellence LSUHSC, New Orleans , Department of Cell Biology and Anatomy LSUHSC, New Orleans, Neuroscience Center of Excellence LSUHSC, New Orleans; *wwalko@lsuhsc.edu*
Endocrine Control of Retinal Sensitivity in Hyla cinerea
Many behavior patterns that are strongly modulated by hormones, such as mate choice are mediated by visual processing. Yet, little is known about the effect of reproductive hormones on the retina, in particular, which is critical to understanding how visual signals are processed during these behaviors. This project focuses on the retina itself by examining the effects of sex steroids on spectral sensitivity, or the ability to detect differences in color signals. Our hypothesis is that hormones modulate stimulus sensitivity in the retina during reproductively receptive phases and influence mate choice behavior through modulation of color vision. We tested the effect hormones on color vision using the green treefrog (Hyla cinerea), which detect and respond to wavelengths spanning (and beyond) the human visible light spectrum. Experiments used electroretinograms (ERGs) to compare stimulus threshold and response amplitude in the retina of reproductive and non-reproductive female frogs. Additionally, we compared retinal activation before and after injections of human chorionic gonadotropin (hCG), which causes secretion of estrogen and progesterone in females and testosterone in males. Our findings indicate that reproductive state and hormone injections cause an increase in sensitivity to particular wavelengths of light in female frogs. Future experiments will determine the functional consequences of this endocrine modulation of vision using behavioral assays under different wavelengths of light.

68-3 WALL, CB*; RITSON-WILLIAMS, R; POPP, BN; GATES, RD; University of Hawai'i at Mānoa, California Academy of Sciences, Hawai'i Institute of Marine Biology; *cbwall@hawaii.edu*
Spatial variation in biochemical and isotopic composition of corals during bleaching and recovery
Ocean warming and the increased prevalence of coral bleaching events threaten coral reefs. However, the biology of corals during and following bleaching events under field conditions is poorly understood. We examined bleaching and post-bleaching recovery in *Montipora capitata* and *Porites compressa* corals that either bleached or did not bleach during a 2014 bleaching event at three reef locations in Kāneʻohe Bay, Oʻahu, Hawaiʻi. We measured changes in chlorophylls, tissue biomass, and nutritional plasticity using stable isotopes ($\delta^{13}C$, $\delta^{15}N$). Coral traits showed significant variation among periods, sites, bleaching conditions and their interactions. Bleached colonies of both species had lower chlorophyll and total biomass, and while *M. capitata* chlorophyll and biomass recovered three months later, *P. compressa* chlorophyll recovery was location-dependent and total biomass of previously bleached colonies remained low. Biomass energy reserves were not affected by bleaching, instead *M. capitata* proteins and *P. compressa* biomass energy and lipids declined over time and *P. compressa* lipids were site-specific during bleaching recovery. Stable isotope analyses did not indicate increased heterotrophic nutrition in bleached colonies of either species, during or after thermal stress. Instead, mass balance calculations revealed variations in $\delta^{13}C$ values reflect biomass compositional change (i.e., protein:lipid:carbohydrate ratios). These results highlight the dynamic responses of corals to natural bleaching and recovery and identify the need to consider the influence of biomass composition in the interpretation of isotopic values in corals.

P3-180 WALLACE, KJ*; HOFMANN, HA; University of Texas at Austin; *kwallace@utexas.edu*
Neuroendocrine basis of cognition and behavior in a highly social cichlid fish
How do an individual's decision-making and behavioral tendencies change when their social environment is altered? Individual variation in cognitive performance can be predicted by more general consistent behaviors such as aggression, neophobia, and sociability. Yet we know little about how the social environment influences the neuromolecular processes underlying this relationship between behavior and cognition. Here we manipulate naturalistic communities of the cichlid fish *Astatotilapia burtoni*, a model system in social neuroscience, to quantify behavioral tendencies and cognition across socially dominant males, subordinate males, and females. We assess individuals' cognitive performance and cognitive style (how they approach a cognitive task) in a spatial maze followed by a reversal, a novel object recognition task, and a social competence task. This test suite is repeated after an experimental perturbation that allows some subordinate males to ascend in social status. Throughout, we assay circulating glucocorticoid and androgen levels. We then use quantitative real-time PCR of the immediate-early genes *egr-1* and *c-fos* to determine to which extent the neural activity patterns in core nodes of the vertebrate social decision-making network (SDMN) correlate with behavior, cognitive style and performance, and social competence. Finally, in the same SDMN nodes, we measure the activity of genes associated with stress reactivity, decision-making, and social behavior. Our results provide uniquely comprehensive insights into the cognitive, behavioral, and mechanistic underpinnings of decision-making in a complex and dynamic social community.

P1-143 WALTERS, LJ*; PHLIPS, EJ; BADYLAK, S; MCCLENAHAN, G; SACKS, PE; DONNELLY, MJ; University of Central Florida, Orlando, University of Florida, Gainesville; *linda.walters@ucf.edu*

Recruitment and Survival of the Eastern Oyster Crassostrea virginica when Challenged by the Brown Tide Aureoumbra lagunensis: Field Results

Within the Indian River Lagoon (IRL) estuarine system along Florida's east coast, blooms of the marine microalga *Aureoumbra lagunensis* in excess of 1×10^{6} cells mL^{-1} have occurred on three occasions since 2012. All blooms coincided with times of peak reproduction and growth of the eastern oyster *Crassostrea virginica*. Over five years of field data on monthly recruitment and four years of data on natural densities of *C. virginica* were compared to bi-monthly cell counts of *A. lagunensis*. In addition to expected temperature and salinity-driven variations in recruitment, *A. lagunensis* cell density negatively impacted oyster recruitment to the system. Cell counts in excess of 200,000 per ml had the greatest impact on recruitment, although significant negative effects began with cell counts greater than 9658 per ml. Our highest mean shell length (47 mm) and mean oyster densities (1060-1176 per m^2) were, however, recorded in June 2015 and 2016 during a 15-month bloom event. Therefore, adult oysters did not die in large numbers either rapidly or slowly during this prolonged bloom of *A. lagunensis*. Reduced recruitment during blooms did lead to decreased adult oyster populations in subsequent years. While many biotic and abiotic variables simultaneously influence *C. virginica*, these field results demonstrate significant negative impacts of *A. lagunensis* on oyster recruitment but not on adult survival of *C. virginica*.

96-7 WAN, KY; University of Exeter, UK; *k.y.wan2@exeter.ac.uk*

Gait Rhythmogenesis and Spatiotemporal Ordering in Self-propelling Unicellular Microorganisms

Interlimb coordination is a highly dynamic phenomenon which enabled the first vertebrates to negotiate terrestrial habitats during the evolutionary transition from sea to land. Surprisingly, attainment of complex limb coordination is by no means exclusive to organisms that possess a nervous system. Instead, single-celled microeukaryotes, which may be mere microns in size, can also enact complex movement gaits for swimming using multiple, fast-moving locomotor appendages called cilia and flagella. These appendages are structurally and functionally similar to epithelial cilia, which in mammalian systems are responsible for directional flow generation and transport. Here, I demonstrate novel features of spatiotemporal flagellar coordination in unicellular algae. I show that the algal flagellar apparatus - comprising basal bodies and interflagellar fibres - actively couples groups of flagella to achieve dynamic locomotor patterning. Resolving gait dynamics at the single-flagellum level in both free-swimming and micropipette-fixed individuals, I will demonstrate spontaneous transitions in behaviour including gait-intermittency, reversible rhythmogenesis, and gait-mechanosensitivity. In particular, during forward propulsion quadriflagellate algae can actuate four flagella to assume trotting or gallop gaits, but oscillations can be activated/inactivated selectively in subsets of the flagella. These findings suggest that a network of intracellularly-coupled algal flagella can function as a central pattern generator, which allows for distinguishable control and ordering of individual oscillators in the network and thus complex symmetry-breaking dynamics. Such symmetry-breaking processes provide a means for cell reorientation (such as towards light for photosynthesis) and responsive navigation in complex environments.

P2-94 WANG, SY*; ZAVALAGA, CB; POLITO, MJ; Louisiana State University, Universidad Científica del Sur; *swang67@lsu.edu*

Consistent Foraging Niche Partitioning Between Two Peruvian Seabirds Under Varying El Niño-La Niña Conditions

The ecology and productivity of the Northern Humboldt Current System is affected by interannual temperature fluctuations caused by the El Niño-Southern Oscillation (ENSO). The availability of Peruvian anchoveta (*Engraulis ringens*) is closely related to ENSO conditions, oscillating between warm, less productive El Niño and cool, more productive La Niña years. These conditions have the potential to induce a bottom-up effect on predators such as the Guanay cormorant (*Phalacrocorax bougainvillii*) and Peruvian booby (*Sula variegata*), whose diets consist of >80% anchoveta. We used carbon ($\delta^{v}C$) and nitrogen ($\delta^{v}N$) stable isotope analysis of whole blood to investigate the isotopic foraging niches of boobies and cormorants across ENSO fluctuations. We found significant differences in $\delta^{13}C$ and $\delta^{15}N$ values between species independent of ENSO conditions, indicating consistent foraging niche partitioning. The stable isotope values of both seabirds exhibited a parallel response to ENSO, with higher $\delta^{13}C$ and $\delta^{15}N$ values in both species in La Niña conditions relative to El Niño conditions. Several non-exclusive mechanisms could have led to higher blood isotope values during La Niña conditions. Upwelling and increased primary production can result in higher stable isotope values of primary producers at the base of the food web, which influences $\delta^{13}C$ and $\delta^{15}N$ values at higher trophic levels. Alternatively, both birds may be shifting their diet to higher trophic level prey, and/or that food chains may be elongated, during productive La Niña years. Planned analysis of stable isotope values as well as stable isotope values and stress hormones in *P. bougainvillii* and *S. variegata* feathers will help to resolve these mechanisms as well as help to assess the physiological implications of foraging under varying ENSO conditions.

P3-179 WANG, JY*; PAGGEOT, LX; FRIESEN, CN; SOLOMON-LANE, TK; HOFMANN, HA; YOUNG, RL; The University of Texas at Austin; *joyce.wang@utexas.edu*

Neural Transcriptomic Responses to Social Opportunity

Individuals respond to social challenges and opportunities at the levels of behavior, hormone profiles, neural activity, and gene expression. How these processes are integrated into context-appropriate behavior is not well understood. Behavioral responses to social stimuli are highly plastic and depend on many factors such as social status, past experience, motivation, stress and hormone levels. In vertebrates, this complex process depends on distributed processing of sensory signals across a highly interconnected set of limbic and hypothalamic brain areas known as the social decision making network (SDMN). Here, we characterize the neural transcriptomic response to a social opportunity using the highly social African cichlid fish *Astatotilapia burtoni*. We provided a subordinate male an opportunity to ascend in social status and quantified behavior and physiology at 1 hour, 1 day, and 1 week after the onset of social ascension, followed by microdissection of three critical SDMN nodes (homologs of the preoptic area, hippocampus, and lateral septum), which were subjected to Tag-Seq to obtain high-quality transcriptomes. Our results show that the three brain areas have distinct transcriptomic profiles and that gene expression profiles change in characteristic ways as animals ascend in social status in a complex manner. We identified 18 distinct gene expression trajectories, which are common to all three brain areas. Our results provide insight into the neuromolecular changes occurring throughout the process of social ascent.

76-1 WANG, Y*; OTHAYOTH, R; LI, C; Johns Hopkins University; *ywang460@jhu.edu*

Cockroaches bend head and use legs differentially to traverse grass-like beam obstacles

Cockroaches are excellent at traversing dense obstacles in complex terrain. For example, to traverse grass-like beam obstacles, the discoid cockroach often transitions from a pitch mode, in which its body pitches up against the beams, to a roll mode, in which its body rolls to align with the gaps between beams. A recent study in our group found that passive body vibration from oscillatory leg propulsion helped discoid cockroaches and robots traverse grass-like beam obstacles, because the kinetic energy fluctuation helps the body overcome a potential energy barrier to transition from the pitch to the roll mode. Here, we further study the neuromechanics of traversal by measuring active adjustments of head and legs (N = 8 individuals, n = 64 trials). We attached BEEtags to the animal body and head and small markers to the abdomen and legs and used automatic marker and DeepLabCut tracking to obtain ~200,000 digitized points to reconstruct detailed 3-D kinematics. When the animal pitched up against the beams (body pitch angle = 33° ± 15°), its head flexed repeatedly (standard deviation of bending angle = 8.8°). Then, the animal used its two hind legs differentially, extending one while flexing the other (difference in toe distance from body coronal plane between left and right legs = 10 ± 3 mm). These adjustments helped the animal transition to the roll mode into the gap, after which the hind legs pushed to propel forward while the abdomen flexed (standard deviation of flexion angle = 8.5°) to reduce terrain resistance (P < 0.05, ANOVA). A potential energy landscape model with a bendable head suggested that head bending lowered the potential energy barrier to transition from the pitch to the roll mode. Our study showed that active adjustments complement passive mechanics to help animals traverse complex terrain.

120-4 WANG, J; QI, Z; HAN, P; DONG, H; WAINWRIGHT, DK; LAUDER, GV; ZHU, J*; BART-SMITH, H; University of Virginia, Harvard University; *justinwang2011@gmail.com*

Tuna robotics: Computational FSI optimization of a tuna tail-informed propulsor with high efficiency

In this work, a combined experimental and computational approach is used to find the optimal structural design for a tuna-based robotic model (tunabot) that can achieve high tail beat frequency (up to 15Hz). The numerical modeling approach employs a flow-structure-interaction (FSI) immersed boundary solver for low-Reynolds number viscous flows. The experimental approach uses a stereo-videographic technique to obtain the three-dimensional, time-dependent caudal fin deformation and kinematics of a yellowfin tuna in steady swimming. Informed by the biological data, an inverse structure design method together with a gradient-based optimization method are then used to find the optimal structure design of the propulsor for the tunabot to achieve efficient swimming. The primary objectives of the computational effort are to quantify the swimming performance of the tunabot with different bending stiffness in tail design as well as to investigate the role of chord-wise flexibility and spanwise-wise flexibility in high-performance robot model design. The results of this work will also help us to examine the key hydrodynamic features shared by the robot swimming and fish swimming and lay the foundation to explore a fish-like performance space for bio-inspired autonomous underwater vehicles.

S8-5 WARD, AB*; REDMANN, E; ALQAHTANI, A; SHEIKH, A; MEHTA, RS; Adelphi Univ, UC Santa Cruz; *award@adelphi.edu*

East Coast Travel Is An Uphill Battle: Terrestrial locomotion in American Eels

Extreme body elongation is often linked with the ability to move between aquatic and terrestrial habitats. Fish are known to move onto land to escape poor water conditions, for better breeding sites, or other high quality resources. One highly elongate species known to traverse terrestrial environments is the American eel (*Anguilla rostrata*). American eels have a unique life cycle during which eggs are laid in the Sargasso Sea and leptocephalus larvae are transported along the coast. Glass eels then move into freshwater systems and mature into yellow eels which may spend decades in freshwater prior to becoming sexually mature (silver eels) and returning to the Sargasso Sea to reproduce. Along the east coast of the United States, many of the rivers from where American eels may migrate are blocked by dams. Despite this anthropogenic barrier, eels are found upstream of dams. Previous work has shown that glass eels can climb the vertical sides of a dam, but this behavior has not been described in older eels. In this study, we expand our understanding of eel terrestrial locomotion by examining eels moving along sand, loose pebbles, and fixed pebble substrate) and 4 inclines ranging from 0 to 15 degrees. Eels were resistant to climbing the higher inclines and often moved into a concertina-like locomotion in comparison to the undulatory locomotion they often used at lower angles. Distance ratio, a measure of the effectiveness of movement, was lower at higher inclines indicating more lateral movement of the body. These experiments reveal that steep inclines 15+ degrees impose additional effort on locomotion for this commercially important fish. By understanding these constraints, we can help develop management strategies to mitigate the increased energetics imposed by dams.

70-1 WARDILL, TJ*; FEORD, RC; SUMNER, ME; PUSDEKAR, S; KALRA, L; GONZALEZ-BELLIDO, PT; University of Minnesota, University of Cambridge; *twardill@umn.edu*

Binocular stereopsis in cuttlefish improves prey targeting.

To assess depth information, some animals utilize the disparity between left and right visual fields, in a process called stereopsis. This strategy is commonplace in vertebrates, having evolved multiple times independently. However, only one invertebrate species, the praying mantis, has been demonstrated to possess stereoscopic vision. Here, we set out to test for stereopsis in cuttlefish, a cephalopod mollusk. In addition to their notorious cognitive and camouflage abilities, cephalopods are visually driven hunters. The camera type eyes of cephalopods exhibit remarkable convergence to those of vertebrates, both in their anatomical features and vergence movements. However, neither squid or octopuses appear to employ stereopsis to resolve depth; squids use monocular retinal deformation and blur, and the limited overlap of visual fields from both eyes in octopuses makes the use of stereopsis unlikely. Cuttlefish, however, can produce significant binocular overlap through ocular vergence, though it remained unclear whether they employ stereopsis for their predatory attack. Here we show that cuttlefish (1) use stereovision to resolve the distance to prey, (2) use this information to shorten the time and distance covered prior to striking at a target, (3) likely process visual motion differently to vertebrates, as they can extract stereopsis cues from anti-correlated stimuli, and (4) can switch eye movements from independent to conjugated. These results show that stereopsis has evolved independently in another non-vertebrate group, but with camera-type eyes. Since the organization of the cephalopod brain is considerably dissimilar to that of vertebrates, this finding opens a door for investigating if cuttlefish have evolved alternate processing mechanisms for stereo perception.

131-5 WARGIN, AH*; COMBES, SA; University of California, Davis; *ahwargin@ucdavis.edu*
BEEhavior under pressure: Testing the effects of barometric pressure change on bumblebee foraging behavior
Bumblebees, some of world's most important pollinators, do not store large amounts of food within their hives, so they must respond rapidly to changing conditions in order to survive adverse weather events. Heavy rainstorms pose a particular challenge, as they can prevent foragers from collecting food, and may prove fatal for foragers caught outdoors. Heavy rain is typically preceded by a drop in barometric pressure, and a handful of studies have shown that other types of insects can detect and respond to these changes; however, no previous studies have explored whether changes in barometric pressure affect the behavior of bees. Here, we manipulated barometric pressure in a laboratory setting to investigate how pressure changes affect the foraging and nest activities of bumblebees (*Bombus impatiens*). We placed a hive of bumblebees inside an airtight chamber where they needed to exit the nest box to forage for nectar within the chamber. We pumped air through the chamber continuously, and controlled inflow and outflow rates using proportional valves to produce three different types of 6-hour barometric pressure regimes: constant pressure, rising pressure, or falling pressure. We subjected the hive and foraging chamber to a different pressure regime each day, and recorded foraging activity using motion-triggered image acquisition in the tunnel through which bees exited and entered the nest. Nest activity was recorded by capturing a 10-second video of the entire hive every 10 minutes. Each bee was outfitted with a BEEtag (QR code) on their thorax before trials began so that individual identity and orientation could be extracted from images. Our data show that changes in barometric pressure affect bumblebee activity in several ways, suggesting that bumblebees can not only detect pressure changes but respond behaviorally to prepare for imminent changes in the weather.

P2-33 WATANABE, J; University of Cambridge; *jw2098@cam.ac.uk*
Contingency in the Functional Convergence of the Musculoskeletal System in Wing-propelled Diving Birds
Convergent evolution, independent acquisition of similar traits in distant lineages, is often regarded as a clue to the predictability of evolution. However, there is little understanding on what constitute a predictive framework for trait evolution in individual lineages. In this study, I conducted an anatomical analysis of the musculoskeletal system of wing-propelled diving birds, a classic example of locomotion-associated convergent evolution in birds. Specifically, I reconstructed the wing musculature in two extinct lineages of flightless, wing-propelled auks (*Pinguinus* and Mancallinae, Charadriiformes), and compared it with that of the best-known example of wing-propelled divers, modern penguins (Sphenisciformes). The wings of the flightless auks had numbers of independently derived similarities to those in penguins, including relatively small size, a dorsoventrally flattened profile, reduction of the propatagium, and notably reduced joint mobility. These features have obvious functional advantages for the use of the wings in underwater flight, where the medium is much denser than in aerial flight. However, the stiffening of the elbow joint in the two auk lineages is accomplished by different anatomical configurations from penguins, and even from each other auk lineage to a lesser extent, utilizing unique anatomical structures which were ancestrally present in their own lineages. This is a previously unnoticed instance of incomplete convergence of phenotypic characters in a functionally convergent system, which is seemingly a consequence of differences in ancestral states in different lineages. A potential implication of ancestral-state dependent incomplete convergence would be that lineage-specific ancestral states, and perhaps their variability, may need to be incorporated in the predictive framework of convergent evolution, along with selective regimes.

127-3 WATERS, JS; Providence College; *jwaters2@providence.edu*
Ants of Providence
Biodiversity surveys are critical tools for understanding fundamental patterns and shifts in the distribution of life across the planet. While the ant fauna (Hymenoptera: Formicidae) throughout most of New England has been extensively sampled, relatively few surveys have been conducted in Rhode Island. Working with undergraduate students and members of the community, we surveyed for ant species at two sites in Providence, Rhode Island, from 2015-2019. Manual collection and a 10-week repeated pitfall trap sampling method was used at Providence College and a rapid biological assessment (bioblitz) was conducted at Roger Williams Park. A total of 36 species were identified including the first observations of the introduced Asian needle ant (*Brachyponera chinensis* Emery, 1895) in New England. Twenty-six species identified were new county records and seven species were new state records, representing a substantial update to the list of known ants in Rhode Island, currently totaling 67 species from five subfamilies. These results fill an important gap in our knowledge of New England ant fauna, they are comparable with similarly scaled surveys conducted at parks and cities across the world, and they also question assumptions about the effects of urbanization on species diversity.

P2-29 WATSON, SJ*; EVANS, KM; New Mexico Institute of Mining and Technology, Brown Universtiy; *sara.watson@student.nmt.edu*
Party in the Front, Business in the Back: Mosaic Evolution of Skull Asymmetry in Flatfishes
The cranial asymmetry of flatfishes (Pleuronectiformes: Teleostei) is perhaps, one of the most striking morphological features found anywhere in the animal kingdom. Their unifying and unique characteristic is the migration of one of their eyes to the opposite side of their head during both development and during their evolutionary history. This results in both eyes residing on one side of their body, while fish rests on the opposite side. This orbital migration has been described at the developmental level across several species, and was found to recapitulate the evolutionary transition towards asymmetry in the fossil record. However, the evolutionary tempo and mode of this orbital migration has not yet been examined in a rigorous quantitative and phylogenetic comparative framework. Here we use three-dimensional geometric morphometrics and a phylogenetic comparative toolkit to examine evolutionary patterns of shape variation in these fishes and compare rates of shape evolution between different regions of the skull. We find distinct patterns of variation across the skull with the facial region exhibiting more variation than the braincase region. We hypothesize that the orbital migration (localized to the facial region) experienced by all of these species, is driving the elevated levels of variation in the faces of these fishes.

130-5 WATSON, CM; Midwestern State University; *charles.watson@msutexas.edu*

Comparative Ecology and Physiology of Anoles on Dominica

The Island of Dominica is currently home to two species of anole, the endemic Dominican Anole (*Anolis oculatus*), and the invasive Puerto Rican Crested Anole (*Anolis cristatellus*). While some populations of the native lizard seem to experience minimal deleterious effects of the invasive, others appear to be extirpated from areas where they are present. We measured ecological and physiological variables for these species to determine differences between the two anoles as well as differences among and within populations for each species. Here I discuss variation among different populations of *Anolis oculatus* and how those differences may influence their ability to compete and/or coexist with *Anolis cristatellus*. I also present evidence for local adaptation to temperature by *Anolis cristatellus*, which may allow them to eventually inhabit all but the most extreme environments on the island. While our knowledge of these species' biology remains incomplete, we are beginning to gain a better understanding of underlying factors affecting interspecific interactions, intraspecific variation, and the extent of their ranges on Dominica.

P2-240 WATSON, LAR*; MUSGROVE, CM; HINDS, AD; AMBARDAR, M; CARVALHO, CM; Fort Hays State University; *cmdasilvacarvalho@fhsu.edu*

Investigating the dissemination of antibiotic resistant Enterobacteriaceae microorganisms via a migratory bird species

Antibiotic resistance is a complex and multifaceted problem involving humans, animals, and the environment. Several important antimicrobial resistant pathogens, such as MRSA, vancomycin-resistant *Enterococci* (VRE), *Salmonella* spp., *Vibrio cholerae*, and *Campylobacter* spp. have also been described in wild animals, highlighting the importance and complexity of wildlife, not normally exposed to antibiotics directly, in the transmission of resistant bacteria. However, the role of wildlife in the emergence of antibacterial resistance might be underestimated. This study examined the prevalence of antibiotic resistant *Enterobacteriaceae* microorganisms on House Wrens (*Troglodytes aedon*) in western Kansas. The House Wren is highly social, widely distributed, and often inhabits areas around or within human-dominated centers, making it ideal for studies on transmission of antibiotic resistant bacteria. We swabbed the entire clutch of eggs and the nest cup during incubation. We swabbed individual nestlings when they were 4 days old. Swabs were inoculated on MacConkey media while in the field to select for Gram negative bacteria. Colonies grown on MacConkey media were then selected based on morphology and inoculated on XLD media, a selective and differential media used for the growth of *Enterobacteriaceae* spp. We performed an antibiogram using the Kirby-Bauer method to determine antibiotic resistance. Additionally, selected possible Carbapenem resistant bacterial colonies' identities will be confirmed by 16sRNA sequencing. We discuss our findings to understand the effects of bacterial infection on wildlife health in an evolutionary context and provide a starting point for investigating how migratory wildlife may acquire and transmit resistant bacteria to humans.

107-1 WEAVER, RJ*; GONZALEZ, B; SANTOS, SR; HAVIRD, JC; University of Texas, Austin, Hawaii Baptist Academy, Auburn University, Auburn; *ryan.weaver@utexas.edu*

How does a shrimp become red? From molecules to putative genes underlying variation in red carotenoid coloration of Halocaridna rubra

Variation in coloration within a species can result from selective pressures of the environment, genetic differences, or physiological constraints. The genetic basis for red carotenoid coloration in birds and turtles was recently identified as *CYP2J19*. This gene encodes a cytochrome p450 enzyme that catalyzes the bioconversion of dietary yellow carotenoids to red carotenoids. However, many other animal taxa display red coloration that arises from the bioconversion of yellow carotenoids to red, yet the genetic basis for this conversion remains unknown. Here, we investigated the molecular and genetic basis for population-specific levels of red coloration in the shrimp, *Halocaridina rubra*. *H. rubra* form discrete populations comprised of distinct genetic lineages that range from vibrant red to nearly translucent. We show that variation in red coloration among populations is due to differences in the accumulation of the red carotenoid, astaxanthin. Further, we show that astaxanthin accumulation is heritable and that environmental limitation of dietary carotenoids does not explain population-specific levels of coloration. Our phylogenetic analysis revealed that the transcriptomes of *H. rubra*, other crustaceans, and amphibians do not contain a paralog of *CYP2J19*. Instead, these taxa likely bioconvert carotenoids using a bifunctional hydroxylase like that found in yeast: a cytochrome p450 family 3A-like enzyme. This work is the first step in linking variation in the red phenotype of *H. rubra* to genotypic variation, providing the basis for future work including elucidating genes that function in the absorption, transport, degradation of dietary carotenoids.

105-2 WEBB, JF*; MOLNAR, EJ; NICKLES, KR; JONES, AE; CONWAY, KW; MCHENRY, MJ; University of Rhode Island, Kingston, RI, URI, Kingston, RI, Texas A&M, College Station, TX, University of California, Irvine, CA; *jacqueline_webb@uri.edu*

How to Distinguish Pattern from Chaos: Superficial Neuromasts of the Mechanosensory Lateral Line System in Fishes

The mechanosensory lateral line system (LL) of fishes mediates the detection of low frequency water flows of biotic and abiotic origin. In bony fishes, it is comprised of two types of receptor organs: 1) Canal neuromasts (CNs) in pored canals within a subset of dermatocranial bones and in the LL scales. 2) Superficial neuromasts (SNs) that occur singly, in lines or in clusters on the skin. Several methods have been used to visualize neuromasts, but recently, *in vivo* staining using fluorescent mitochondrial stains (e.g., 4-di-2-ASP) has revolutionized our ability to simultaneously image the distribution of all CNs and SNs on a fish (including dramatic proliferations of 100's - 1000's of SNs). We used 4-di-2-ASP and SEM to document SN distribution and morphology in neon tetras and allies (Fam. Characidae) and in a neon goby (Fam. Gobiidae) and to determine the size, shape and axis of best physiological sensitivity (hair cell orientation) of SNs in these taxa. We also reviewed available data on SN morphology and distribution in a range of fish taxa (Ostariophysi, Salmoniformes, Stomiiformes, Gobiiformes, Pleuronectiformes, Acanthomorpha more generally). We used these data to seek "rules" that define variation in SN morphology and the structural (and functional) organization of the lines, clusters, and large dense fields (patches) of SNs among fishes. Collectively, these data demonstrate that the distribution of SNs has been underestimated among fishes thus demanding a new context in which to address their functional role in flow sensing among fishes. Funded by URI Office of Undergraduate Research and Innovation (EJM), NSF GRFP (AEJ) and NSF Grant 1459224 (JFW).

48-2 WEBB, SJ*; SEBRIGHT, Z; TAYLOR, JRA; Scripps Institution of Oceanography, UCSD; *s3webb@ucsd.edu*
Roles pH and Temperature May Play in the Life History of the Tuna Crab, Pleuroncodes planipes
Tuna crabs, *Pleuroncodes planipes*, are unique crustaceans because adults go through both a partially pelagic phase, then a benthic phase, which occurs once they reach a certain size. This phase transition depends on growth and potentially morphological changes, like increased exoskeleton calcification. For some crustaceans, growth and calcification are sensitive to ocean pH and temperature conditions associated with climate change. Such sensitivity may be impactful for tuna crabs that get transported over long distances, frequently during warm water El Niño events, into habitats that range in these conditions. The main objective of this study was to determine how pH and temperature affect the growth and exoskeleton of *P. planipes*, and consequently their phase transition. A 10 month multi-stressor experiment was conducted on 60 adult animals (24-28mm carapace length) using a full factorial combination of local ambient pH(8.0), reduced pH(7.5), ambient temperature(12°C), and increased temperature(18°C) conditions. Molting, growth and water parameters were monitored throughout the experiment and exoskeleton morphology and composition were analyzed at the end using SEM/ EDX. Intermolt duration was shorter in warm temperature treatments, regardless of pH, but molt increment (carapace length) was greater in the cooler treatments. EDX analysis revealed no differences in %wt Ca or Mg among treatments. These results suggest that tuna crabs are robust to different pH conditions, but ocean temperature (warming) can alter growth and may alter the timing of benthic settlement, thereby impacting the duration of the transient pelagic phase upon which so many organisms depend on for food.

P2-98 WEBBER, RL*; HODGSON, ML; MCGAW, IJ; WYETH, RC; St. Francis Xavier University, Memorial University; *rwebber@stfx.ca*
Lobster Behavioral Responses to Different Prey and Bait Types
The American lobster *(Homarus americanus)* is an abundant benthic marine predator along much of the continental shelf of the Northwest Atlantic. Lobsters are generalists that feed on a variety of vertebrate, invertebrate, and macroalgal species. How lobsters interact with food items and conspecifics around food items are key components in understanding the ecological role of lobsters in the nearshore benthic ecosystem. However, previous research on lobster behavior has primarily occurred in laboratory settings, where behaviours may or may not be similar to what occurs in nature. Our goal is to investigate how lobsters move and behave around food sources in the field and compare responses to different prey and bait items. A set of five downward pointing GoPro cameras attached to tripods with prey or bait secured between the feet were used to record foraging lobster behavior in the field in the Northumberland Strait, Gulf of St. Lawrence. Food items tested were herring *(Clupea harengus)*, redfish *(Sebastes sp.)*, rock crab *(Cancer irroratus)* and mussel *(Mytilus edulis)*. For analysis, we are enumerating lobster appearances in the video, measuring movement directions and speeds relative to water flow directions, and using an ethogram to quantify durations and frequencies of all behaviours recorded in the videos. Collectively, these measures will be used to both describe lobster foraging behaviours and assess the relative attractiveness of different prey and bait items. Our results will improve understanding of lobster foraging, food preferences, and food-related social interactions. Understanding how lobsters forage and what they prefer to forage on may also be useful for improving the efficiency and sustainability of the lobster fishery.

67-2 WEBER, AC*; GUIBINGA MICKALA, A; LIGHTEN, J; VAN OOSTERHOUT, C; ABERNETHY, KA; NTIE, S; MICKALA, P; LEHMANN, D; ANTHONY, NM; University of New Orleans, Université des Science et Techniques de Masuku, University of Exeter, University of East Anglia, University of Stirling, Agence Nationale des Parcs Nationaux du Gabon, University of Stirling; *aweber2@uno.edu*
Characterizing the class II major histocompatibility complex in wild mandrills
The major histocompatibility complex (MHC) plays an important role in adaptive immunity and mate choice in many vertebrate species. Studies in a captive group of mandrills (*Mandrillus sphinx*) have shown that female mate choice is influenced by the MHC, implying that MHC variability may have important fitness consequences. However, nothing is known about MHC variability in natural populations and how this may play a role in female mate choice. Here, we use next generation sequencing to characterize variation in the mandrill MHC class II DRB loci from 192 fecal samples collected from a wild population in Lopé National Park, Gabon. Our study revealed more than three times the allelic richness previously described in captive mandrills with variants forming two monophyletic clades. Variants in clade 1 (n=106 alleles) exhibit signals of balancing selection, as might be expected under parasite-mediated selection or disassortative mate choice. In contrast, variants in clade 2 (n=29) do not show such a signal and may represent a non-functional pseudogene that has not yet been described in non-human primates, although it has some similarity with the human pseudogene DRB9. We also observe trans-species polymorphism between mandrills and other primates, suggesting that balancing selection has maintained functional MHC lineages beyond speciation events. Future work will use these data to assess the role of the MHC in wild mandrill mate choice and fitness.

P3-182 WEBER, AM*; GEORGE, EM; ROSVALL, KA; Indiana University, Bloomington; *abbweber@iu.edu*
Individual changes in conspecific aggression across breeding stages: an exploration into adaptive plasticity
Plasticity can enhance an individual's fitness in dynamic environments. For instance, conspecific territorial aggression may be adaptive during pre-breeding competition for territories or nesting sites, but high levels of conspecific aggression may be more costly to maintain during parental stages, particularly for animals with substantial parental duties. Selection may therefore favor individuals that modulate aggression across breeding stages; however, plasticity is not necessarily infinite. To understand how selection may shape plasticity of aggression across breeding stages, we need to assess the degree of individual plasticity in aggression and how it varies with other life history and fitness correlates. We are exploring these questions using the tree swallow (*Tachycineta bicolor*), a single-brooded species in which females compete for and defend limited nesting sites throughout the breeding season. We performed over 200 simulated territorial intrusions to repeatedly assay aggression across multiple breeding stages. At the population level, we found that average aggression levels decreased over the breeding season, consistent with previous work. However, at the individual level, we found substantial variation in plasticity: some females dramatically reduce aggression as the breeding season progresses while others maintain more moderate levels of aggression. Results will further explore how variation in behavioral plasticity relates to proxies of reproductive success and other life history traits, including age. In doing so, this study will provide a critical first step in understanding the causes and consequences of plasticity in territorial aggression.

P3-102 WEBER, WD*; FISHER, HS; University of Maryland, College Park, MD; *wweber@umd.edu*

Mating system drives the evolution of male and female reproductive traits in Peromyscus mice

Reproduction is arguably the most critical component of an organism's fitness, but mating success does not always translate to reproductive success. In species where females mate with multiple males within a reproductive cycle, males can continue to compete for fertilization after mating has occurred (within the female reproductive tract); this competition can be a powerful driver of reproductive trait evolution. Here we compare six species of *Peromyscus* mice that have evolved under divergent mating systems to examine the evolution of male and female traits shaped by post-mating sexual selection. We find that in species where females that mate multiply, males invest greater in sperm production than in monogamous species, and we predict that higher sperm production gives these males a competitive advantage. Female control of fertilization weakens as sperm competition increases, and this conflict between the sexes can drive the evolution of adaptive changes in female reproductive physiology, either to limit the frequency of polyspermy or to influence the genotype of the offspring resulting from multiple matings. Within females, we compared the oviduct length and changes in the cell population surrounding oocytes that may regulate fertilization. We suggest that increased oviduct length and cumulus cell density may be mechanisms that regulate access to ova during competitive mating events. Together, our study investigates the association between mating system and the reproductive physiology in closely related species with diverse reproductive strategies.

7-3 WEBER, CJ*; ZHOU, Y; LEE, JG; LOOGER, L; QIAN, G; GE, C; CAPEL, B; Duke University, Durham, NC, USA, Zhejiang Wanli University, Ningbo, China, HHMI Janelia Research Campus, Ashburn, VA, USA; *ceri.weber@duke.edu*

Temperature-dependent sex determination is mediated by pSTAT3 repression of Kdm6b

In many reptiles, including the red-eared slider turtle *Trachemys scripta elegans* (*T. scripta*), sex is determined by ambient temperature during embryogenesis. We previously showed that the epigenetic regulator, *Kdm6b*, is elevated at the male-producing temperature and essential to activate the male pathway. Here, we demonstrate that the transcription factor STAT3 is phosphorylated at the warmer, female-producing temperature, binds the *Kdm6b* locus, and acts as a repressor of *Kdm6b* transcription. STAT3 is known to be activated by signaling pathways that respond to environmental stimuli, including temperature. We propose that activation of these pathways at warmer temperatures promotes phosphorylation of STAT3, blocking expression of *Kdm6b*, thus preventing activation of the testis-pathway. Collectively, these data establish a link between temperature and transcriptional regulation of *Kdm6b* during temperature-dependent sex determination.

102-8 WEHRLE, BA*; GONZALEZ, AX; STONE, J; RANKINS, D; VUU, E; HERREL, A; TADIC, Z; GERMAN, D; UC Irvine, MNHN/CNRS, U. Zagreb; *bwehrle@uci.edu*

Do digestive enzyme activities explain increased plant digestibility in a newly omnivorous lizard?

A population of Italian Wall Lizards (*Podarcis sicula*) in Croatia has become primarily herbivorous and morphologically distinct from its source population in ~30 generations, making it a compelling example of rapid evolution. However, it is yet unclear what aspects of these shifts are fixed, and which may be due to phenotypic flexibility. There are few differences in digestive biochemistry in wild individuals measured from these populations. However, during lab feeding trials, lizards from the newly herbivorous population digested plant diets, and specifically the protein in those diets, more efficiently than did lizards from the source population. Fed insect diets, the two populations did not show differences in protein digestibility nor organic matter digestibility as a whole. What mechanism explains the newly herbivorous population's increased digestive performance of plants proteins, compared to their source population counterparts? We are currently measuring digestive enzyme activities in the pancreas and proximal intestine of lizards from both populations that have been kept on experimental diets for up to a month. On the plant diet we expect to find increased protease activity in the in the new lizard population compared to the lizards from the source population, matching the digestibility findings. Our results may shed light on what functional and performance steps can initially lead to herbivory in lizards and the importance of phenotypic flexibility in this dietary shift.

122-5 WEI, L.; REITER, K.E; MCELRATH, T.C; DUNN, A.C; ALLEYNE, M.*; University of Illinois at Urbana-Champaign, Illinois Natural History Survey; *vanlaarh@illinois.edu*

The role of cuticular diffraction gratings in beetle iridescence, wetting and friction interactions

Iridescence is found throughout the natural world, including the cuticle of many beetles (Coleoptera). Iridescence can arise through multiple mechanisms, such as parallel nanoscale ridges, slits, or fringes of the cuticle that diffract light into ordered spectra – called diffraction gratings. This iridescence has been found in many polyphagan families; however, its function in an evolutionary context is still unknown. Some iridescent beetles are known to burrow through different substrates, such as sand, leaf litter, and fungus. For these beetles, it is unlikely that iridescence has an adaptive role in visual cues. We hypothesized that diffraction gratings reduce friction for beetles traveling through various media. The friction coefficients of five pairs of closely related carabid, scarabaeid, and staphylinid, beetles (one species with diffraction grating-induced iridescence and another species without iridescence) sliding against a fibrous countersurface were measured using microtribometry in both wet and dry configurations. Iridescence was quantitatively confirmed using broad light spectroscopy. Coefficients of friction for all species increased by a factor of at least two in the wet versus the dry configuration. Goniometry (hydrophobicity) and cuticle geometry measurements were used as inputs to a friction model. The morphology of the beetle surfaces rather than the presence of a physical diffraction grating determines their wettability and friction behavior when sliding against a wet, fibrous surface. The roughness and orientation of features controls the area in contact, and dynamic changes in the contact give rise to friction.

P3-45 WEIER, D*; RANCHOD, P; STEFFENSON , M; St. Edward's University; *davweier@gmail.com*
The Effect of Colony Relocation Stress on Honeybee Immunity
Honeybee (*Apis mellifera*) populations have been reported to be in decline, the cause of which is not fully known or understood, but the phenomenon has been termed colony collapse disorder (CCD). CCD is characterized as the sudden disappearance of the colony by the worker bees. The awareness of CCD is becoming more widespread due to the help of scientists, corporations, and everyday people warning of the effects of disappearing bee populations which are being felt in both economic and private sectors of human life. By investigating how honeybee populations and their overall immune function change over time post-establishment in a new area from their origin site, we can create a more complete picture of stress responses in honeybees. This idea comes from the assumption and growing body of evidence that supports the idea that immune function and overall health are related to the frequency of CCD. We quantified the immunology of two newly established colonies by measuring protein concentration and prophenoloxidase activity in honeybee hemolymph. Hemolymph was collected twice a week post-relocation and preserved to run later analysis on, including measuring protein concentrations and immune pathways such as the prophenoloxidase pathway and potentially catalase or phenoloxidase. Preliminary results show that colonies went through what appeared to be an "adjustment” period post-establishment in a new area. We believe this to be the case from seeing fluctuations in measured protein concentrations represented as "spikes,” or sharp changes in gathered data between collection days, especially the first few weeks where the colony was establishing itself. Other observational data shows that the colonies would become more agitated on days before or of heavy rainfall which was believed to add more stress to individual bees.

78-6 WEIHS, D; Technion- Israel Institute of Technology; *dweihs@tx.technion.ac.il*
Single Layer Fish Schools- for Hunting and Energy Saving
Single layer fish schools are found in shallow waters and have distinctive features.Several different distributions of individuals can be observed -straight line , parabolic, V-shaped and and diamond formations.The relative advantages to the individual fish and the group are calculated and discussed, and shown to serve different purposes. In most cases, hydrodynamic gains are present, but different configurations result in uneven distribution of these gains. As an example:edge-forward parabolic schools have the lateral ends "working harder" but providing a foraging advantage for the group.

P3-108 WEISS, A*; LAU, B; SPANIAC, M; MONROY, JA; Claremont Colleges, Claremont, CA; *aweiss3617@scrippscollege.edu*
The Effects of Eccentric Resistance Training on History-Dependent and Elastic Properties of Skeletal Muscles from Mice
The purpose of this study was to determine whether five weeks of eccentric resistance training in mice leads to an increase in whole animal performance, muscle stress, and/or an increase in stiffness of leg muscles. Twelve female mice were randomly separated into control and exercise groups. The exercise group received five weeks of downhill ladder training using a progressive overload protocol increasing from 0-15% body mass. Following training, maximum jump height was 1.5-2.5 times higher than before training. Muscles from trained mice generated ~65% greater active stress than control muscles with no difference in passive stress. In addition, on the descending limb of the force-length relationship, trained muscles exhibited ~25% greater force after stretch relative to the isometric reference force compared to control muscles. In both groups, the stress–strain relationship of elastic elements during unloading showed a 2-fold increase in the elastic modulus with activation, but elastic elements in trained muscles developed stress at 4% shorter lengths compared to control muscles. These data demonstrate that elastic properties of muscle are plastic and that eccentric resistance training leads to an increase in muscle stiffness and force enhancement with stretch. The decrease in rest length of elastic elements is consistent with the hypothesis that the elastic titin protein binds to actin upon muscle activation, decreasing titin's free length and increasing its stiffness, potentially contributing to the increase in whole muscle stiffness and force enhancement. Future work on plasticity of titin properties is necessary for understanding how exercise and other factors influence elastic properties of muscle.

77-2 WEITZNER, EL; PEARSON, LE; WHORISKEY, S; HARRIS, HS; WHITMER, E; BRODIE, E; TOMANEK, L; JOHNSON, S; LIWANAG, HEM*; Cal Poly San Luis Obispo, The Marine Mammal Center, The Marine Mammal Center, The National Marine Mammal Foundation; *hliwanag@calpoly.edu*
Development of Diving Capability in Weddell Seal Pups
Weddell seals (*Leptonychotes weddellii*) are among the deepest diving pinnipeds (seals, sea lions, walrus), and adult Weddell seal dive physiology is relatively well understood. However, little is known about their physiology and development as pups during nursing and the transition to independence. The aim of this study was to investigate the development of diving capabilities in Weddell seal pups throughout early ontogeny. We calculated total body oxygen stores (TBO_2) from blood and muscle sampled longitudinally at 1, 3, 5 and 7 weeks of age. These data were correlated with diving behavior measured with time-depth recorders. We found that Weddell seal pups started (at 1w) with mass-specific TBO_2 values (75.43 ± 3.87 mL O_2 kg^{-1}) that were not significantly different from those reported for adults; this is unique among seal species. We hypothesized that TBO_2 would increase with dive experience rather than simply calendar age, but instead found that mass (r^2=0.96) and age (r^2=0.89) were more significantly correlated with total TBO_2 ($P<0.0001$) than time spent in water ($P=0.006$, r^2=0.59) or dive duration ($P=0.007$, r^2=0.38). Pups spent the majority of their time in the water near the surface during dependence; this ‘exercise' may have signaled oxygen store development even though pups were not likely exposed to hypoxia. Relatively high mass-specific TBO_2 values may provide a ‘head start' for diving and facilitate the successful transition to independent foraging in Weddell seals. Later exposure to hypoxia combined with diving experience may be the key to the subsequent increases in total TBO_2 observed in yearlings and juveniles of this species.

84-2 WELLER, HI*; LóPEZ-FERNáNDEZ, H; MCMAHAN, CD; BRAINERD, EL; Brown University, University of Michigan, Field Museum of Natural History; *hannah_weller@brown.edu*
The spandrels of Satan's perches: evidence for the co-optation of feeding traits in the convergent evolution of mouthbrooding in Neotropical cichlids
The co-opting of existing traits for new functions (exaptation) offers an overall pattern in a noisy system: of the many paths evolution can take, exaptation suggests paths of least resistance, where the traits themselves precede their novel functions. Mouthbrooding, or oral brooding of offspring, may be one such function, having evolved independently 10-14 times within cichlids alone. Mechanically, mouthbrooding involves exaptation: a feeding and breathing structure is used in reproduction. While any fish with a mouth is could mouthbrood, certain morphological traits—including some feeding adaptations—might increase mouthbrooding fitness. We hypothesized that mouthbrooding is more likely to evolve in lineages that have feeding adaptations that benefit mouthbrooding. We examined buccal morphologies in Neotropical cichlids, where mouthbrooding has evolved 5 times, 4 within winnowing (substrate sifting) clades. We found that mouthbrooders and winnowers overlapped substantially in buccal morphology. Accounting for phylogenetic and constructional constraints, species that exhibit one or both of these behaviors had larger buccal cavities, curved parasphenoids, and steeply angled vomers, while species that exhibit neither behaviors had narrow buccal cavities and flat parasphenoids. These traits may be developmental consequences of ventral orientation of the mouth for winnowing. We discuss the functional implications of these morphologies for both feeding and mouthbrooding. Our findings support our hypothesis that feeding can select for traits that can be exapted for mouthbrooding, but fully testing this hypothesis will require testing how these buccal morphologies impact both functions.

P3-142 WEST, J*; FARINA, S; GIBB, A; Howard University, Northern Arizona University; *joshua.west@bison.howard.edu*
Preference and Performance in Flatfish Burial
Flatfish burial performance varies based on size of the fish and size of the substrate particles. Additionally, species demonstrate preferences for different grain sizes. In this project, flatfish burial experiments were used to determine if preference for sediment particle size corresponds with the ability to achieve full body coverage. We also examined how preference and performance vary with body size. In the preference tests, we introduced *Parophrys vetulus* individuals representing a large size range to one of four sediment profiles which were arranged in quadrants of a circular tank. Fish show a strong preference for the starting sediment (P=0.000682). However, a slight preference was displayed for the smallest sized sediment (0.125-0.300mm) over the other sizes (0.300-0.589mm, 0.589-0.991mm, and 0.991-2.33mm), after fish had explored the other options (P=0.0366). In the performance tests, we placed the same grain sizes into individual tanks to measure burial performance. Each fish was given a maximum of 15 minutes to bury on one of the four sediments before being transferred to the next, until each fish had the opportunity to attempt burial in each grain size. During the performance trials, fish displayed the ability to completely cover themselves consistently in all but the largest grain size (.991-2.33mm, P=0.000062). In conjunction with one another, the results reveal that *Parophrys* fish prefer to bury on the smaller sediments when given a choice. However, they often choose to bury using whatever substrate is immediately available. This suggests that a fish would rather bury in an "unfavorable" substrate than seek out a smaller grain size, perhaps because extended periods of time moving around to seek a new habitat would potentially leave them at risk of predation.

P1-199 WEST, JV*; LAWING, AM; Texas A&M University; *jvwest25@tamu.edu*
Grab the Lizard by the Horns: Morphological Patterns in Horned Lizard Skulls
Horned lizards of the genus *Phrynosoma* are well known for their iconic horns, a unique trait among North American lizards. Horned lizards share similar body form and dietary specializations but display disparity in size, tail length, and most notably in horn and head morphology. Morphological traits in *Phrynosoma* such as head size and limb length have been shown to be correlated with environmental factors like precipitation and temperature. Evolutionary reduction in horn size has been suggested to co-occur with shifts in life history traits like viviparity and viviparous species tend to occur at cooler, higher elevations. The relationship between environment and head ornamentation in horned lizards is not fully understood. We used micro-computed tomography (micro-CT) scanning to generate volumetric models of skulls across the full range of *Phrynosoma* from 127 specimens across 13 species. Variation in horn and head shape was examined using 3D geometric morphometric techniques. We partitioned this variation into its multiple explanatory components including environmental characteristics, phylogenetic relatedness, and life history traits. Here, we describe preliminary morphometric variation in *Phrynosoma* skulls and compare this to the patterns reported using traditional 2D morphometric methods. Our results improve understanding of how species morphology and specialized defense traits respond to environmental gradients and provide hints on future evolutionary and ecological trajectories under impending climate change.

126-2 WESTERMAN , E.L*; ERNST, D.A; SULLIVAN , T.J; University of Arkansas , University of Arkansas, Gloucester Marine Genomics Institute; *ewesterm@uark.edu*
The genetic basis of mate preference learning in Bicyclus butterflies
Imprinting-like learning, where individuals learn to prefer certain characteristics in future mates based on their juvenile social environment, is pervasive across animal taxa. And, learning ability associated with imprinting-like learning is hypothesized to play a prominent role in mate preference development and sexual ornament evolution. However, the genetics that facilitate imprinting-like learning largely remain unknown. Here we utilized the butterfly *Bicyclus anynana*, a species which exhibits imprinting-like learning and has a published genome, to identify candidate genes associated with imprinting-like learning. We re-sequenced the genome of 84 *B. anyana butterflies*, half that mated with a 4-spot male in choice trials after pre-mating exposure to a 4-spot male, and half that did not. After aligning this genomic sequence to the *B. anynana* reference genome and accounting for relatedness between butterflies, we identified multiple regions in the genome highly associated with imprinting-like learning. One of these peaks of association was substantially larger and more highly associated with learning than the others, and encompasses seven genes, three of which are known to be associated with neural processing. We hypothesize that natural variation in neural processing underlies variation in imprinting-like learning, which has implications for the evolution of mating preference.

42-1 WESTNEAT, MW*; GARTNER, SM; COOPER, WJ; University of Chicago, Washington State Univ; *mwestneat@uchicago.edu*

JawsModel 2020: Tracking the Transmission of Force and Motion in Fish Cranial Linkage Systems Through Phylogenetic History

Fishes use a sensational diversity of jaw mechanisms for feeding, with more than 20 mobile skeletal elements driven by numerous muscles. How can we accurately model these systems so that morphometric data can be used to assess biomechanical traits across phylogeny? Here we integrate biomechanical modeling, geometric morphometrics and phylogenetic analysis to address questions of functional diversification in coral reef fishes. New biomechanical linkage software (JawsModel2020) for analysis of cranial linkages in fishes (from muscle contraction to bite force) allows for simulation of structure-function relationships in a wide range of taxa, using the same coordinate data sets employed for geometric morphometric shape analysis. We present detailed morphometrics, modeling, and diversification of functional traits in two reef fish families, the Labridae (wrasses) and Pomacentridae (damselfishes). Phylomorphospace plots show that damselfishes have evolved largely outside of wrasse morphospace. However, frequent convergences in shape across phylogenetic groupings within families are identified, with evolutionary rates highest in recent crown group wrasses. Linkage modeling leads to several conclusions regarding the evolution of function in reef fishes: (1) Four-bar linkage structure-to-function mapping in fishes is 1-to-1; (2) Novel linkage mechanisms in reef fishes are associated with unique cranial morphospace occupation; (3) Biomechanical traits can diverge and evolve due to linkage changes, or diverge with linkages remaining static, solely due to muscle modification; (4) Multiple mechanical variables and levels of design should be considered when defining convergent or equivalent biomechanical systems. NSF DEB 1541547

P1-74 WESTRICK, SE*; VAN KESTEREN, F; BOUTIN, S; LANE, JE; MCADAM, AG; DANTZER, B; University of Michigan, Ann Arbor, University of Alberta, Edmonton, University of Saskatchewan, Saskatoon, University of Guelph, Guelph, ON; *westse@umich.edu*

Behavioral and Physiological Effects of Variation in Maternal Care and Glucocorticoids

Maternal behavior and physiology play a large role in the early environment offspring experience. These factors hold the potential to contribute to the development of offspring phenotypes that are closely related to fitness. However, maternal behavior is often difficult to observe and measure in wild animals, particularly small mammals. To tackle this problem, with a wild population of North American red squirrels (*Tamiasciurus hudsonicus*) we measured maternal motivation by recording the time until mothers return to their pups following researchers replacing the pups, or a "simulated predator intrusion". This measurement is similar to pup retrieval latencies recorded in laboratory studies. We investigated multiple factors contributing to natural variation in maternal motivation, including the impact of naturally and experimentally elevated glucocorticoids, maternal age, parity status, and amount of food resources. To examine the long-term impact of variation in maternal behavior, we investigated the role of maternal behavior on offspring growth rate and survival. To further explore the impact of the maternal environment on offspring, we test hypotheses about the impact of maternal glucocorticoid levels on offspring behavior and physiology. We provisioned exogenous glucocorticoids to experimentally elevate circulating glucocorticoids in pregnant or lactating mothers. With offspring from these mothers, we conducted behavioral trials to measure personality traits and performed stress hormone challenges to measure HPA axis activity. Through these studies, we expand on our understanding of the impact of variation in maternal behavior and physiology as well as potential fitness consequences in a wild small mammal.

98-5 WHELAN, NV*; WILLIAMS, AS; REDAK, CA; WRIGHT, AA; GARRISON, NL; HALANYCH, KM; JOHNSON, PD; GARNER, JT; US Fish and Wildlife Service and Auburn University, Auburn University, Tuskegee University, Auburn University, Alabama Department of Conservation and Natural Resources; *nathan_whelan@fws.gov*

Habitat Preference and Impoundments Influence Population Genetic Patterns of Freshwater Gastropods

Freshwater gastropods in the family Pleuroceridae are critical components of many freshwater ecosystems in eastern North America. Pleurocerids are important nutrient cyclers and provide essential ecosystem services. As evidence of their importance to many freshwater systems, pleurocerids can comprise over 90% of macroinvertebrate biomass in some streams. Yet, pleurocerids suffer from an estimated 79% imperilment rate, with declines mostly associated with physical and chemical modification of habitats. Aside from instances of complete extirpation, how pleurocerid populations have responded to habitat degradation has been poorly studied. Moreover, we lack data on how genetic patterns differ among species that reside in springs, small streams, and big rivers. Here, we generated datasets containing thousands of single nucleotide polymorphisms (SNPs) with RAD-seq methods to examine historical responses to habitat degradation and provide comparative data for species across habitat types. In total, we sampled 12 species from 63 sites ranging from reservoirs to very small springs. We compared genetic diversity estimates among species with different habitat preferences to better understand mechanisms of genetic variation across the Pleuroceridae and to assess species boundaries of closely related species. We also examined how anthropogenic activities have influenced gene flow and genetic diversity, particularly in the context of large river impoundments. Ultimately, data generated here will aid in prioritizing conservation targets and predict potential for future declines.

116-7 WHELAN, S*; HATCH, SA; BENOWITZ-FREDERICKS, ZM; CHASTEL, O; ELLIOTT, KH; McGill University, Canada, Institute for Seabird Research and Conservation, Bucknell University, CNRS?Universitde La Rochelle, France; *shannon.whelan2@mail.mcgill.ca*

Linking female energy status to timing of reproduction in an income-breeding seabird

Food supply is a major driver of timing of breeding, yet individuals exposed to the same resource environment (e.g. shared feeding areas) often vary in their reproductive phenology. For example, individuals in poor body condition will breed later than those in good condition. At the physiological level, perception of food supply and its environmental correlates can be integrated directly into endocrine axes. Similarly, internal energetic state is incorporated into the endocrine system, inducing foraging behavior when energy levels are low. We hypothesized that if energy status limits reproduction phenology, then individual variation in reproduction phenology should correlate with net energy gains. To test this hypothesis, we conducted an experiment on female black-legged kittiwakes (*Rissa tridactyla*) nesting on Middleton Island, AK, during the prelaying period. Following a 2x2 design, we manipulated energy gains and costs via food supplementation and a short-term weight handicap (alongside controls). We measured baseline luteinizing hormone, testosterone, and corticosterone before and after a four-day GPS-accelerometer deployment, conducting a hormone challenge (luteinizing hormone releasing hormone) at the final recapture. Energy intake (supplementation) but not expenditure (handicap) influenced baseline reproductive hormones. Fed birds were less likely to forage at sea than unfed birds, and we found an interactive effect of food and handicap on at-sea activity budgets. Feeding advanced laying phenology, but short-term handicapping did not delay laying. By integrating endocrinology with movement ecology, we are able to determine how differences in energy status can lead to variation in reproductive phenology.

S5-6 WHITAKER, DL; Pomona College;
dwight.whitaker@pomona.edu
Nature's weapons of mass reproduction: Ballistic dispersal of seeds and spores
Because plants lack locomotion, their only means of colonizing new habitats or escaping disease or predation is through seed and spore dispersal. The most effective methods for dispersal over long distances use a fluid to carry propagules. Examples of extremely long-range dispersal include pollen grains kept aloft in the atmosphere and coconuts riding ocean currents for thousands of kilometers. Despite the efficiency of using a fluid to assist in dispersal, some plants have evolved to ballistically launch their propagules at high speed. In these situations, air resistance works to decrease dispersal distance. Here we will show how the fruits of several Acanthaceae species use a dynamic method to gyroscopically stabilize launched seeds to minimize forces from air drag. We will compare this behavior across a number of Acanthaceae species and show how seed morphology and launch dynamics affect launch ranges. We will also show how this same mechanism of stabilizing disk-shaped seeds with backspin is also employed by the unrelated fruits of *Hura crepitans* (Euphorbiaceae) with a high frame rate video of its explosion. Finally, we will present the spore dispersal of *Sphagnum* moss where a vortex ring is used to efficiently carry high-drag spores to a height where they can be carried indefinitely by wind currents thus employing both low drag and high drag mechanisms to disperse its spores.

123-7 WHITE, HE*; TUCKER, AS; GOSWAMI, A; Natural History Museum, London, King's College London, London;
heather.white.17@ucl.ac.uk
Quantification of Suture Morphology in an Ontogenetic Framework across Laurasiatheria
Cranial variation across mammals is vast and reflects their ecological diversification. Sutures perform many different functions in cranial development and function, from permitting craniofacial growth to facilitating feeding. Diversity of function is reflected in the highly variable morphology and complexity. Phenotypic variation across species is generally only studied at a fully mature ‘adult' state, with limited comparison on how such variation develops. The lack of comparative developmental data, for both cranial and suture morphology, is striking, considering the intrinsic link between evolution and development. As part of a larger study of suture and skull development and morphology in a comparative framework of mammals, we here quantify suture morphology across ontogeny, with microCT scans spanning late prenatal foetuses to adult stages for representative species of Laurasiatheria including *Manis tricuspis* and *Talpa europaea*. A 2D test dataset of extinct and extant mammals (n=79) was created to compare available methods for quantifying suture morphology, by means of complexity. From the 2D suture images, 500 semilandmarks were resampled in the R package Stereomorph to capture suture shape data. Complexity methods (fractal dimension and short-time Fourier transform with power spectrum density) were applied to the test dataset. Both methods were reliable for simpler sutures, but power spectrum density was more sensitive at detecting differences in sutures with complex morphology. Following this result, we quantified suture complexity and morphology across representative species of Laurasiatheria in an ontogenetic framework, by applying the tested power spectrum density method, with the goal to understanding how development generates suture morphological disparity.

120-2 WHITE, CH*; LAUDER, GV; BART-SMITH, H; University of Virginia, Charlottesville, Harvard University, Cambridge;
chw8hq@virginia.edu
Tuna robotics: impact of body flexibility and fin-fin interactions on swimming performance of a new tuna-inspired robotic platform
The performance space of fish-like robotic swimmers is largely confined to tail beat frequencies measuring less than 2 Hz. However, tuna and scombrid fishes are capable of frequencies in excess of 20 Hz. We design a new tuna-like robotic experimental platform that addresses this disparity in frequency and enables testing over a frequency range comparable to biology. The new platform's morphology is closely modeled after yellowfin tuna (Thunnus albacares) by incorporating data from computed tomographic (CT) scans and reference images of yellowfin tuna. Propulsion is provided by a 12V DC motor in a waterproof housing of Nylon PA12 plastic 3D printed using 60μ selective laser sintering (SLS). The motor shaft is waterproofed with a stuffing tube design. Measuring 255 mm in total length, this tuna-like system includes first and second dorsal fins and an anal fin. All fins are removable for testing with a snap-in magnetic design to assess fin-fin interactions between the dorsal/anal fins and the caudal fin. The body is 3D printed with flexible joints that can be varied in number and the extent to which they permit lateral motion to explore the impact of body flexibility on swimming performance. For each joint configuration, the performance metrics measured include swimming speed, power, and thrust. Midline kinematics and flow field analysis from particle image velocimetry (PIV) visualization are also analyzed. These results are compared against biological data to understand the role of body flexibility during high-frequency swimming.

30-6 WHITE, CF*; WHITNEY, NM; WEBER, DN; FRAZIER, BS; Harvard University, Cambridge, MA, New England Aquarium, Boston, MA, Texas A&M, Corpus Cristi, TX, Department of Natural Resources, Charleston, SC; *connor_white@fas.harvard.edu*
Survival and Swimming Behavior of Red Drum (Sciaenops ocellatus) Following Recreational Capture and Release
Red drum (*Sciaenops ocellatus*) is a highly targeted recreational species, with 95% of captured individuals released alive. However, it is uncertain how many of these released fish survive, as many experience barotrauma as part of capture. Thus, we replicated recreational practices to (1) estimate post-release survival and sub-lethal impacts of capture on red drum and (2) experimentally test the effect of common release practices on survival and behavior. To do so, captured individuals (n=54, TL = 93 ± 7.3 cm) had an acceleration data logger(monitoring duration 39 ± 24 hr) affixed to their dorsal musculature and their physiological status was assessed using an iStat blood gas analyzer in the field. Individuals were then released by one of three treatments: a descending device (SeaQualizer, n=13), venting their swim bladder (n=18), or a control of no treatment (n=23). Of the 46 recovered data loggers, only two fish experienced mortality events; a gut-hooked fish that received no treatment (moribund: 102min PR) and a descended fish that likely was predated upon 124 minutes after release. However, recreational capture was stressful for fish, as longer fight times were associated with higher lactate concentrations (p=0.01) and lower blood pH (p=0.022). Upon release individuals had 60% higher activity levels (p=0.001) and displayed twice as much vertical displacement (p=0.001) compared to 24 hours after release. Both vertical displacement and activity level displayed similar patterns, decreasing over the first 10 hours after release before reaching a baseline level. Release treatment also had no apparent sublethal effects on fish, as activity level (p = 0.17) or vertical displacement (p = 0.14) remained the same between treatments.

P3-198 WHITE, KJ*; Starkey, JM; SAH, S; PRADHAN, DS; Idaho State University; *vanlkatr@isu.edu*

Different Aggressive Intensities Within Two Social Contexts in a Hermaphroditic Fish

Conspecific aggressive encounters are highly dynamic, involve a spectrum of behavioral traits, and largely based on reciprocated interactions between or among individuals. The challenge hypothesis has long been the predictor of circulating androgen levels during male-male aggression. Females also display these behaviors, but the associated hormones are not widely studied. Bluebanded gobies, *Lythrypnus dalli*, are bidirectionally hermaphroditic fish, in which sex change occurs due to a change in social structure. In stable groups, *L. dalli* live in harems, such that one male dominates over many females and defends a nesting territory. Upon male removal (MR), the most dominant female exhibits rapid increases in rates of aggressive and territorial behavior. Little is known about the behavior exhibited by a resident male during territorial intrusion from another male. *L. dalli* is ideal for exploring the challenge hypothesis in both sexes, due to the plasticity of life history transitions. This study compares the behavioral and hormonal changes that occur amongst the group hierarchy, between MR groups and groups that have a male added (MA). We found that overall, the competition for dominance was similar across MA and MR groups, such that they all demonstrated spatial aggression, by competing for the nest. However, the aggressive intensity was different across the two contexts. In MA groups, the resident male and the intruding male showed high rates of aggression through physical contact inside the nest tube, whereas in MR groups, the most dominant female demonstrated high rates of approaches and displacements and prevented subordinates from entering the nest. Waterborne hormones were collected from fish in stable groups and from MA and MR groups 30 min after the aggressive change, to be analysed at a later date.

3-6 WHITEHEAD, JG*; WORRELL, TA; SOCHA, JJ; Virginia Tech; *whijo23@vt.edu*

Influence of approach trajectory on water landings in mallards

Studies of landing in birds have focused on perch landings involving short flights within a controlled laboratory. However, birds demonstrate the ability to land under a diverse set of conditions, including the ability to land on water, a fluid substrate. Landing on water enables birds to dissipate the energy of collision through skimming after impact. In this study, we examined the relationship between distance skimmed and impact speed, impact angle, and mean approach angle (the mean trajectory angle from a given landing). Landing mallards were recorded in the wild with a three-camera array (GoPro HERO4 Black) with 4k resolution at 30 fps. The array was calibrated with a 0.94 m wand and an audio synchronization through Argus 3D tracking software. Filming was conducted with wind speeds less than 3.3 m/s, in the months of October through May, 2017-2019. From 177 digitized landings, a diverse range of kinematics was documented, with impact speeds of 5.02 ± 1.36 m/s (mean ± SD) [range, 1.76 m/s, 8.48 m/s], impact angles of 14.8 ± 10° [0.6°, 59.9°], and mean approach angles of 8.6 ± 6.3° [-0.4°, 36.7°]. After impact, mallards skimmed a distance of 2.17 ± 1.36 m [0 m, 6.04 m]. Impact speed, impact angle, and mean approach angle are all significantly correlated to the distance skimmed after impact. However, a general linear regression model utilizing those kinematic features only accounts for approximately 25% of the variation seen in the distance skimmed, with impact speed accounting for the greatest portion (22%). This low value for the sum of the coefficients suggests much of the variation observed is the result of other factors including rotational movements of the body on impact, which may change the drag profile of the duck at the air-water interface.

P3-222 WHITENACK, LB; Allegheny College; *lwhitena@allegheny.edu*

Insights from a five-year partnership between Allegheny College and local STEM teachers

Standardized testing links K-12 student mastery of state educational standards to school funding, teacher job security, and student graduation. This can leave teachers little time to try out or refine new methodologies, including active learning practices. These challenges also effect undergraduate education, as students enter their courses with an ever-changing set of skills and competencies. A partnership between Allegheny College and local high school STEM faculty ran from 2014-2018 to address these challenges. Educators from Allegheny and local schools were paired together each summer to develop curriculum and pedagogy in line with state standards and to inform Allegheny faculty about current issues in our local school system. In some cases, Allegheny undergraduates were also matched with these educator pairs. Based on participant assessments, the partnership program was largely successful. Participants found it useful and enjoyable, and new collaborations spanning teaching and research sprouted between some participants. Successful partnerships occurred when partners were well-matched by topic interest and personality, and when partners were truly on equal footing. To reinforce the latter, professors and teachers were paid equally for their time, were asked to determine their goals for the summer together, and were asked to articulate how their planned work would specifically benefit each partner. Challenges included difficulty in finding partners for interested potential participants and finding undergraduate participants, largely due to the difference in collegiate and K-12 academic calendars and the limited number of potential teacher partners in small school districts.

P1-10 WHITESEL, CA*; BARONE, V; LYONS, DC; UC San Diego; *cwhitese@ucsd.edu*

Studying Neuroanatomy in B. Stephanieae through Immunohistochemistry

The use of nudibranchs as experimental species for adult neuroethology has been pivotal to elucidating the basis of animal behavior.. These shell-less molluscs are particularly suited to such investigations, given their distinguishable swimming and crawling behaviors and accessible sensory organs. However, little is known about early life stages: how the neural system controls their behavior during embryonic, larval, and juvenile stages remains unclear, mostly due to the intractability of embryos in species currently used for behavioral studies. Understanding the link between neuronal development and animal behavior at early life stages is essential to comparing juvenile and adult behaviors. Therefore, we have established the aeolid nudibranch, *Berghia stephanieae*, as an experimental system; this species' embryos are accessible, enabling us to study all stages of its brain's development. We report on methodology for labeling the central nervous system with various antibodies that recognize neurotransmitters, and describe the expression patterns of neurotransmitters in the brain during the early juvenile stage. We found that the post-metamorphic juvenile brain is organized similarly to the adult brain of nudibranch neuroethological models. The cerebropleural ganglia are positioned dorsally to the pedal and buccal ganglia. Acetylated Tubulin-Like Immunoreactivity localizes in neurons connecting the oral tentacles, buccal ganglia, and rhinophores to the anterior end of the cerebropleural ganglion, and in neurons extending posteriorly to the ciliated foot. These neurons are visible under differential interference contrast microscopy. These results provide a starting point for building a clearer picture of the neuroanatomy of post-metamorphic *B. stephanieae*, and allow for future neuroethological studies.

11-5 WHITFORD, MD*; FREYMILLER, GA; HIGHAM, TE; CLARK, RW; San Diego State University, University of California, Riverside; *mwhitford@ucdavis.edu*

The Effects of Temperature on the Predatory and Defensive Strikes of Rattlesnakes

Locomotor performance is heavily influenced by body temperature due to the link between temperature and muscle physiology. As temperature influences the performance of endotherms and ectotherms asymmetrically, temperature can play an important in role in determining the outcome of predator-prey interactions. Rattlesnakes (*Crotalus* spp.) are a widespread genus in North America and are active during day or night, so their strike performance may vary substantially across seasons and time of day as available environmental temperatures change. Additionally, as rattlesnakes are an abundant meso predator, being a major predator of small mammals and prey resource for many large endothermic predators (large mammals and birds), temperature can influence both their ability to capture prey and their ability to avoid predators. Here, we studied the effects of temperature on the predatory and defensive strikes of rattlesnakes. We found that the kinematics of defensive strikes were positively correlated with body temperatures, however, temperature was less influential in modulating the kinematics of predatory strikes both in the field and the lab. This research provides valuable insight into the potential for temperature, and possibly climate change, to influence large-scale ecological processes that are mediated by endotherm-ectotherm predator-prey interactions.

P3-4 WHITLOCK, JR*; VO, CP; STAHLSCHMIDT, ZR; U Pacific; *j_whitlock1@u.pacific.edu*

Glyphosate in a warming world: Effects on lifespan, feeding, and food conversion efficiency in a field cricket, Gryllus lineaticeps

The use of the herbicide glyphosate (GLY, the active ingredient in Roundup®) in the U.S. has increased over 200-fold since its introduction in the 1970s, and U.S. farmers now spray enough GLY to apply 1 kg onto every hectare of cropland. Historically GLY was marketed as non-toxic to animals, but recent work indicates acute and chronic toxicological effects of GLY across animal taxa—from insects to humans. Along with increasing GLY exposure, animals are expected to experience warmer temperatures due to climate change. Therefore, we studied the independent and interactive effects of GLY and warming on lifespan, food intake, and food conversion efficiency during adulthood in the variable field cricket, *Gryllus lineaticeps*. Half of the crickets were provided with GLY in drinking water (5 mg / l H_2O as in other insect studies) while the remaining were provided with normal (GLY-free) drinking water. Crickets' thermal environments were also manipulated—that is, crickets underwent a 2 × 2 factorial manipulation of GLY and temperature treatments. Half of the crickets experienced a control temperature cycle (19°C - 38°C each day), which averaged rearing temperature and fluctuated similar to microhabitats used by adult *G. lineaticeps* in the field. The remaining crickets experienced a warming temperature cycle (23°C - 42°C each day), which had the same thermal variation as the control temperature treatment but with a 4°C higher mean temperature to reflect projected warming. Ours is the first study to examine interactions between GLY and warming in an insect thereby providing critical insight into understanding the complex dynamics among herbicides, plants, and herbivores in the context of climate change.

97-4 WHITLOW, KR*; ROSS, CF; WESTNEAT, MW; University of Chicago; *kwhitlow@uchicago.edu*

Strike biomechanics in Polypterus bichir described with XROMM: implications for actinopterygian feeding evolution

Our understanding of the evolution of skull kinesis in fishes requires detailed analysis of feeding in living polypterids, a key lineage due to their phylogenetic position as the earliest-branching extant actinopterygian group. *Polypterus* skulls contain an upper jaw fused to the neurocranium, eliminating one axis of cranial kinesis utilized by teleosts and *Amia* in generating suction. However, their skulls remain highly kinetic, using dorsal, ventral, and lateral expansion to generate suction. Additionally, mechanisms of lower jaw depression and the degree to which pectoral girdle and ceratohyal retraction are transferred to the lower jaw through the mylohyoid ligament are poorly understood in this species. This study describes the major patterns of 3D mechanics driving buccal expansion and suction feeding in *Polypterus bichir* using X-Ray Reconstruction of Moving Morphology (XROMM). Cranial elevation peaks early in the strike, followed shortly by maximal lower jaw rotation, then cleithral and hyoid rotation, which occur nearly synchronously when variables are measured relative to the body axis. As in many other suction feeding fishes, opercular abduction undergoes the final kinematic peak of the cranial elements, maintaining the anterior to posterior movement of water into and through the mouth. Results show substantial cleithral rotation, largely concurrent with ceratohyal rotation and jaw opening, suggesting a central role of the pectoral girdle in jaw opening and suction generation. This pectoral girdle – hyoid bar – lower jaw depression mechanism is likely driven by the hypaxial musculature and may be the ancestral condition for ray-finned fishes.

P3-10 WILBURN, PA*; MANESS, TJ; Louisiana Tech University; *paw019@latech.edu*

Liver lead concentration is unrelated to presense of lead shot in waterfowl gizzards

Studies of lead exposure in waterfowl have used presence of lead shot in the gizzard to identify birds for tissue metal analysis. We examined waterfowl donated to us by hunters at Catahoula Lake, Louisiana for lead and mercury liver concentration, presence of metal/lead shot in the gizzard, and intestinal parasites. Catahoula Lake has been under a mercury advisory for fish consumption for a number of years. In addition, sediments across the lake contain approximately 2 lead shot/ft2. Sixty-six percent of gizzards contained metal/lead shot and 60% had intestinal parasites. Liver lead concentration ranged from 0.0 - 29.7 ppm and 33% of ducks had lead concentrations greater than a lethal level. Mercury in liver ranged from 0.4 - 3.97 ppm and 0% of ducks had mercury concentrations greater than a lethal level. Both presence of metal/lead shot in the gizzard and parasite infection were unrelated to liver lead or mercury concentration. Our results indicate that waterfowl exposed to mercury and lead are not more prone to intestinal parasite infection and that presence of lead shot in the gizzard is unrelated to liver lead burden.

112-1 WILCOXEN, TE; SPENCE, JM*; Millikin University ; *twilcoxen@millikin.edu*

Effects of cypermethrin on neurophysiology, development, and behavior of Cuban treefrog (Osteopilus septentrionalis) and American bullfrog (Lithobates catesbeiana) tadpoles.

Cypermethrin is a pesticide designed to disrupt the nervous system of invertebrates, though vertebrates may also be affected. We exposed Cuban Treefrog (*Osteopilus septintrionalis*) and American Bullfrog (*Lithobates catesbeiana*) tadpoles to cypermethrin at two different concentrations and recorded neurophysiological and behavioral metrics among groups. We also measured plasma corticosterone levels in the bullfrog tadpoles at two time points. Tadpoles exposed to cypermethrin were found to be smaller, less developed, and hyperactive compared to a control group, despite showing no signs of altered acetylcholinesterase levels. The behavioral differences combined with elevated corticosterone levels in the bullfrog tadpoles exposed to cypermethrin demonstrate that cypermethrin is a stressor for these animals even though it may not have direct impacts on the nervous system.

99-6 WILKEN, AT*; MIDDLETON, KM; SELLERS, KC; COST, IN; HOLLIDAY, CM; University of Missouri; *atwxb6@mail.missouri.edu*

Functional Morphology of the Palate of Varanus exanthematicus and its Significance for the Evolution of Cranial Kinesis

Although many species of vertebrates evolved feeding behaviors that employ cranial kinesis, little is known about the loading environment of the palate and other parts of the suspensory apparatus responsible for this movement. Additionally, the role protractor muscles play in controlling palatal excursion or insulating the braincase and sensory capsules via palatocranial joints is challenging to test in vivo and equally unclear. We explored the morphology of jaw musculature, kinetic joints and cranial bones using diffusible iodine-contrast CT and histology of *Varanus exanethematicus*, a modestly kinetic anguimorph lepidosaur. DiceCT imaging and fiber tracking analysis shed new light on the muscular anatomy and architecture of these muscles. Finite Element Modeling was employed to test the effects of muscle activation and joint material properties on the loading environment of the palate, braincase, and skull. We found different joint material properties have only minor effects on the loading environment of the skull. Complex interactions between m. levator pterygoideus and m. protractor pterygoideus work to stabilize the palate about the palatocranial joints and ultimately diminish the strains experiences by the braincase. The tubular cross-section and second moment properties of the pterygoid bone reflect l the bending and torsional environment developed during biting. These data will inform future studies of cranial function and illustrate how morphological complexity of cranial bones, joints, and muscles evolve in different lineage of lepidosaurs and reptiles in general. New understanding of the biomechanics of the jaw muscles, bony linkages and connecting joints reveals a better understanding of skeletal adaptation, physiology and evolution.

P1-267 WILLIAMS, CE*; KUENEMAN , JG; MCMILLAN , WO; COX, CL; LOGAN, ML; Northeastern Univ., Smithsonian, Georgia Southern Univ. , Univ. Nevada, Reno; *williams.cla@husky.neu.edu*

The response of the gut microbiome to climate warming in a vertebrate ectotherm: A field-transplant experiment in the Panama Canal

The planet is projected to warm through the end of the century and beyond. Ectothermic organisms in tropical rainforests, which were historically thermally stable, are particularly sensitive to the effects of warming. In order to understand and accurately predict how these organisms will respond, researchers are increasingly focusing on animals as meta-organisms, taking into account the microbial communities that reside in and on these species. The interactions between the genes of organisms and the genes of their microbial symbionts may mitigate or exacerbate vulnerability to climate warming. We combined a controlled greenhouse experiment with a large-scale field-transplant experiment to determine how the gut microbiome of a tropical lizard responds to habitat change and warming. For the greenhouse experiment, we collected 40 lizards from a mainland site in Panama. Lizards were then maintained in either control or warm temperatures (+2°C) for 28 days. For the field experiment, 70 lizards were transplanted to two islands in Gatun Lake (Panama Canal) that are 2°C hotter than the mainland, on average, and allowed to evolve for three generations. Lizards were dissected following each experiment and their intestines removed for sequencing of the bacterial 16S V4 region. Using QIIME2, sequences will be analyzed to determine changes to bacterial community richness, evenness, beta diversity, and composition in the gut microbial communities of these lizards. Our results will help inform projections of how climate warming will impact the fitness and performance of organisms by providing insight into stability and adaptability of symbiotic microbial communities.

133-5 WILLIAMS, CD*; KNIJNENBURG, TA; Allen Institute for Cell Science; *cdavew@alleninstitute.org*

Spatial reorganization and clustering during the formation of myofibrils

Muscle cells generate an entirely new organelle as they differentiate from their stem cell precursors. The structures that emerge from this process are responsible for the production and transmission of force from the molecular to the organismal scale, and for the specialized adaptation of the resulting fibers. The transition from pre-myofibril to developing and mature myofibril is mechanically regulated. The mechanical context, e.g. surrounding tissue stiffness and active forcing of cell edges as surrounding cells contract, partially control the reorganization of the actin/myosin/cross-linker bundles. The ordering of these pre-fibrils is in contrast to similar structures present in other load-bearing or motile cells. Non-muscle stress-fibers contain many or most of the same constituent proteins but never transition to the stable crystalline order seen in developing myofibers. The Allen Institute for Cell Science is producing a high-throughput dataset that explores these transitions as human induced-pluripotent stem cells differentiate into derived-cardiomyocytes. We develop and present a spatial model, parameterized by this high-throughput imaging, that tracks the force and diffusion mediated rearrangement of proteins within a developing myofibril. This model treats each protein as an object with distinct dimensions, stiffnesses, energy-dependent kinetics, and connectivities. Comparison of large-scale runs to structure-organization metrics derived from the Allen Institute for Cell Science's growing muscle-differentiation image corpus allows us to characterize the emergence of sarcomereic organization.

110-1 WILLIAMS, KL*; EVANS, KM; SIMONS, AM; University of Minnesota and University of Minnesota Bell Museum, Brown University; *will5761@umn.edu*

The morphology of tooth replacement in Salariin Combtooth Blennies (Blenniiformes: Blenniidae: Salariini)

Historically, modes of teleost tooth replacement are classified as either intraosseus, wherein replacement teeth develop in sockets within the bone of attachment, or extraosseous, where replacement teeth develop within soft tissue outside the bone of attachment. However, recent work suggests that these modes of tooth replacement are extremes on a continuum and therefore understate the complexity of teleost tooth replacement. Salariin combtooth blennies (Blenniiformes: Blenniidae: Salariini) are a clade of teleost fishes that demonstrate an unusual mode of tooth attachment in which functional teeth are attached via loose connective tissue that may extend laterally beyond the jaw margins. Although tooth attachment has previously been described, these studies were limited by available technology. We use a range of methods including histology, SEM, microCT scanning and clearing and staining to ask two questions: **1)** How are functional teeth replaced in the salariin blennies? **2)** Do salariin blennies provide further evidence for a continuum of teleost tooth replacement modes? We find that replacement teeth develop and move labially through a matrix of highly vascularized epithelial and connective tissue, via a permanent, discontinuous dental lamina, to the functional tooth position. Most species exhibit teeth that at no point in development make contact with the oral jaw bones, and in some species, teeth are replaced within lip tissue lateral to the oral jaws. Salariin teeth are replaced extraosseously but their mode of attachment is unique, providing further evidence for a continuum tooth replacement classification model for teleost fishes.

P1-162 WILLIAMS, MD; MOOSAVI, SK; HUTCHINS, CE; ROBERTO, DP; BREEN, MK; AHMED, ZB; SULLIVAN, TJ; JABIR, AH; KOLONKO, KJ; HARBISON, CW*; SIENA COLLEGE; *charbison@siena.edu*

Pheromone Communication and Aggregation Behavior in a Bird Ectoparasite

Lice are a well-known and diverse (>5000 species) group of ectoparasites that infest mammals and birds. However, their ability to communicate using pheromones has remained unstudied. Here, we explore the possibility of pheromone communication in a model system consisting of feather-feeding wing lice (*Columbicola columbae*) and their Rock Dove hosts(*Columba livia*). First, we determined that louse distributions on flight feathers were highly aggregated, suggesting the possibility of pheromone communication. Next, using a Y-tube olfactometer, we demonstrated that lice readily responded to volatile pheromones produced by nearby conspecifics, and likely used multiple sex-specific pheromones. SPME (solid phase microextraction) and GC-MS were then used to identify a number of candidate pheromones emitted by lice and by bird feathers. Finally, *in vitro* and *in vivo* bioassays showed that lice responded to a number of potential pheromones and host-generated volatile compounds.

25-6 WILLIAMSON, CJ; SPELT, A; WINDSOR, SP*; University of Bristol; *cara.williamson@bristol.ac.uk*

Are complex wind fields beneficial for soaring? An urban gull's perspective

Wind interactions in urban spaces generate complex flow patterns that are difficult to predict, however these heterogeneous wind fields may offer considerable opportunities for energy harvesting for flying animals. Applying Cost of Transport (CoT) theory to flight dynamics equations for flight through a wind field indicates that with the right airspeed and trajectory adjustments it is possible to harvest energy from spatiotemporal wind gradients. We tracked 11 urban nesting lesser black-backed gulls, *Larus fuscus,* using GPS units over 2 years as they flew through urban environments. The loggers collected a GPS fix up to every 4 seconds along with a 1 second burst of acceleration data; allowing us to determine the gulls' trajectories and flight modes. Our initial studies found the gulls flew at velocities predicted by CoT theory in flapping and soaring flight. Furthermore, we observed the gulls perform a soar strategy not explained by static soaring techniques and hypothesized that the gulls were taking advantage of spatiotemporal gradients to soar. We tested this hypothesis using a 4D path planner in CFD generated city wind fields. A cost function was used that combined CoT velocity optimization with a flight dynamics model which included energy expenditure estimates based on Basal Metabolic Rate ratios for flapping and soaring flight. The simulated commuting flights gave trajectories with gradient soaring flight traits which corresponded to those seen in the gull flight paths. This suggests that complex wind fields, such as those present in urban environments, could provide ample opportunities for energy harvesting, and that soaring is not just limited to more structured wind fields, such as thermals or shear layers. This offers inspiration for the development of wind-aware flight control schemes to increase the range and endurance of unmanned air vehicles.

S9-4 WILSON, RS*; PAVLIC, T; WHEATLEY, R; CAMERON, SF; The University of Queensland, Arizona State University; *r.wilson@uq.edu.au*

Using performance to predict the survival of threatened mammals

More than a third of all modern extinctions have occurred in Australia and the ongoing loss of these distinctive species threatens to diminish global biodiversity. Half of Australia's endemic land mammal species are now threatened or extinct, and most ecologists agree that this is due mainly to an interaction between habitat simplification and introduced predators. Understanding and predicting extinction risk relies on our ability to identify when, where and how predators attempt to capture their prey, and how and whether prey can escape them. When predators encounter prey, the success of each (i.e. capture versus escape) is defined by the physical and performance attributes of both, including traits such as body size and speed or agility. However, most studies of performance focus on the physiology and biomechanics of movement of species' in isolation rather than relative performances between predators and their prey. Therefore, conservation ecologists and managers lack the ability to predict which animals are likely to survive encounters with predators and why. Our work is attempting to address this gap by developing and testing a mathematical framework that predicts the survival of prey, based on their capacity to escape specific predators in different habitats. In this talk I will discuss the development of our model and progress with the testing of the model at our northern Australian field site on Groote Eylandt using studies of two marsupial species (northern brown bandicoot and northern quoll) that have undergone extensive decline across their range.

23-5 WILSON, LE*; CURLIS, JD; LONSDALE, G; COX, CL; Georgia Southern University, University of Michigan, University of Plymouth, Florida International University; *lw16271@georgiasouthern.edu*

The role of sympatry on predator-based selection on coral snake mimicry components in the montane tropics

A fundamental goal of biological research is to understand the forces that drive the evolution of phenotypic diversity such as in mimicry systems. In particular, understanding how selection acts upon the signal components of mimicry can give insight into how mimicry has evolved. We study coral snake mimicry, where brightly colored and venomous coral snakes are imitated by harmless snakes. Previous research in temperate zones has 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, we know relatively little about the evolution of signal components in montane tropical ecosystems, which are ideal for studies of sympatry and allopatry because elevation creates a mosaic of sympatry and allopatry. We tested which mimetic signal components are important for deterring attacks in sympatry and allopatry with coral snakes in a tropical cloud forest in Honduras. We placed 240 plasticine models that were either brown, white and black, red and black, or white, red, and black (mimetic) in sympatric and allopatric sites. We found that attacks by birds, but not mammals, were highest at the two sympatric localities. Models with either bands or red color were attacked with less frequency by birds, but not mammals, than other models at one sympatric site. These results lend insight into how geographic range and elevation may alter selection for signal components of coral snake mimicry systems in the tropics as well as affect the broader processes that generate and maintain phenotypic diversity.

P1-50 WILSON, EJ*; DELICH, C; TOBLER, M; LEE, STM; ZEGLIN, LH; Kansas State University; *libbywilson719@gmail.com*

Host-Microbiome Associations in Livebearing Fishes Adapted to Sulfidic Environments

In metazoans, complex microbial communities are found throughout epithelial tissues and influence host growth rate, life history, metabolism, ecology, and immunity. Furthermore, the host's microbiome can mediate tolerance to environmental stress and facilitate adaptation. Despite the well-established functional importance of vertebrate microbiomes for host physiology and fitness, the putative role of symbionts mediating adaptation in vertebrate extremophiles remains unstudied. We are utilizing a system of a livebearing fish (*Poecilia mexicana*) that repeatedly colonized toxic sulfide springs in southern Mexico to explore how host-microbiome associations change upon colonization of extreme environments. This study system is excellent for understanding mechanisms of adaptation due to both strong sources of selection (hydrogen sulfide and hypoxia) driving adaptation and the naturally paired sulfidic and nonsulfidic populations that allow for comparative analyses. We collected skin, gill, and gut samples of *P. mexicana* across multiple sulfidic and nonsulfidic habitat pairs, as well as sediment and water samples, and used 16S rRNA amplicon sequencing to characterize the environmental and tissue microbiomes. This approach helps disentangle the evolutionary and environmental factors that shape host microbiomes, and it establishes a core extremophile microbiome consisting of taxa that are unique to—and consistently present in—fish from sulfide springs. Analyzing microbiomes within an evolutionary framework provides opportunities to understand how host-microbe associations arise and what role they play in adaptation.

136-5 WINCHELL, CJ*; LEE, DT; REYES-RIVERA, J; RODRIGUEZ, A; TORRES, MM; WEISBLAT, DA; UC Berkeley; *cjwinchell@berkeley.edu*

Functional analysis, by CRISPR mutagenesis, of genes in the atomized Hox cluster of the leech Helobdella austinensis

Leeches are active epibenthic predators or ectoparasites; in contrast, their ancestors and close extant relatives (oligochaetes) are infaunal detritus feeders. In the transition from oligochaetes, leeches evolved novel features, e.g., determinate growth (32 segments, all arising in embryogenesis), anterior and posterior suckers, and a specialized midgut with segmental ceca. Leeches and oligochaetes also exhibit massive genomic changes (gene loss & duplication, loss of macrosynteny) relative to other animals. For example, the leech Hox cluster is highly atomized, and has multiple gene losses and duplications relative to the ancestral lophotrochozoan. Has Hox cluster disorganization enabled new regulatory interactions and functions for these transcription factors? Do these molecular novelties contribute to the morphological novelties in leeches? We use the tractable leech species *Helobdella austinensis* as a model in which to characterize the expression, function and regulation of duplicated and single-copy Hox genes. In contrast to arthropods and vertebrates, CRISPR-induced Hox mutants in leech do not show overt homeosis (altered segment identity). Rather, we observe: defects in gut and sucker formation (for *post2a*, *post2c*, *lox4b*); late-embryonic edema (for *lox5*), possibly due to a failure in kidney development; an embryonic-lethal phenotype during epiboly (for *hox3*), perhaps caused by duplication of segmentation stem cells (teloblasts); and new gene expression patterns and regulatory interactions compared with those known in polychaetes. Our results reveal how Hox-related developmental mechanisms may have contributed to annelid body plan diversification.

26-1 WINGFIELD, JC*; REID, AMA; PEREZ, JH; BISHOP, VR; KRAUSE, JS; MEDDLE, SL; University of California, Roslin Institute University of Edinburgh, University of Glasgow, University of Nevada Reno; *jcwingfield@ucdavis.edu*

Divergence of Hypothalamic-pituitary-gonadal (HPG) Axis Gene Expression and Testosterone in Migrant and Resident Female White-crowned Sparrows

Photoinduction of the hypothalamic-pituitary-gonadal (HPG) axis in seasonally breeding animals activates the reproductive system but precise timing of breeding and sex steroid production are controlled by local environmental information. We aimed to understand functional regulation of the HPG axis by changes in gene expression and synthesis of testosterone in female migrant and resident subspecies of white-crowned sparrow. We hypothesized that regulation of the HPG axis would differ between residents and migrants during breeding and molt, but not during winter. Plasma testosterone was higher in migrants compared to residents during egg lay and incubation. Hypothalamic expression of estrogen receptor α was down-regulated, while androgen receptor, gonadotropin inhibitory hormone (GnIH), aromatase and 5α-reductase were up-regulated in migrants compared to residents. No differences were observed between subspecies in gene expression for luteinizing hormone receptor, follicle stimulating hormone receptor, side chain cleavage enzyme, steroidogenic acute regulatory protein, 3β-hydroxysteroid dehydrogenase, or aromatase. Ovarian gene expression associated with inhibiting the reproductive axis. GnIH, mineralocorticoid receptor, glucocorticoid receptor and 11β-hydroxysteroid dehydrogenase 2 were higher in migrants but not residents during breeding. These data suggest nesting onset may result in increased plasma testosterone regulated by differential gene expression in the hypothalamus and increased sensitivity to stress at the gonad level.

P1-160 WISER, SD*; MARKHAM, MR; University of Oklahoma;
shannonwiser@ou.edu

Electrosensory and metabolic responses of weakly electric fish to changing water conductivity

South American weakly electric fish use self-generated electric fields, known as electric organ discharges (EODs), to navigate their environment and communicate. These fish are categorized either as wave-type fish that produce EODs at continuous frequencies of ~100-2000 Hz, or as pulse-type fish that generate EODs at low intermittent rates of ~10-100 Hz. EOD production incurs significant metabolic costs, as high as 30% of the daily energy budget in wave fish and 20% of the daily energy budget in pulse fish. Water conductivity in some Neotropical habitats varies with natural seasonal rainfall/drought and human inputs (e.g., agricultural runoff, industrial waste disposal). Changing water conductivity alters the fish's electric field volume (EFV). Increased conductivity shrinks the EFV, while decreased conductivity expands the EFV. The resulting changes in EFV likely affect sensory and communication performance. We have found that, following a conductivity increase, some species compensate by increasing the EFV over the course of a week possibly by increasing the EO power output. Here we investigated whether this compensation impacts metabolic investment in EOD production. We used intermittent-flow respirometry to measure metabolic rate across different conductivities in both pulse-type and wave-type fish. Metabolic rate increased in both wave-type and pulse-type fish within days of exposure to increased water conductivity. Preliminary results indicate that pulse-type fish increase the EFV after exposure to high-conductivity water, but wave-type fish do not.

25-7 WISSA, A/A; University of Illinois Urbana-Champaign;
awissa@illinois.edu

Aerodynamic Characterization of a Leading-Edge Alula-Inspired Device

Even though Unmanned Aerial Vehicles (UAVs) operating at low Reynolds numbers are becoming common, their performance and maneuverability are still greatly limited due to aerodynamic phenomena such as stall and flow separation. Birds mitigate those limitations by adapting their wings and feather shapes during flight. Equipped with a set of small feathers, known as Alula, located near the leading edge and covering 5% to 20% of the span, bird wings can sustain the lift necessary to fly at low velocities and high angles of attack. In this presentation, an alula-inspired leading edge device is installed on a high-lift airfoil and a moderate aspect ratio wing. Wind tunnel experiments are conducted at post-stall and deep-stall angles of attack and at Reynolds numbers of 100,000 and 135,000. Experimental results including integrated force measurements and hot-wire anemometry are presented. The presentation examines the distinctive effects of the geometric parameters of an alula-inspired leading-edge device (LEAD) on the aerodynamic performance of both the airfoil and the finite wing are discussed. Results show that the LEAD affects the airflow in two fundamental ways. First, it increases the capability of the wing to maintain higher pressure gradients by modifying the near-wall flow close to the leading-edge. Second, it generates tip vortices that modify the turbulence on the upper-surface of the wing, delaying flow separation. Post stall lift improvements of up to 32% are reported, confirming that the LEAD is a post stall and a three-dimensional device. Results show that these lift improvements are more sensitive to the LEAD relative angle of attack and root location than to the LEAD tip deflection angle.

P1-61 WITTMAN, TN*; COX, RM; University of Virginia;
tw9jj@virginia.edu

Experimental evidence that parasites alter patterns of phenotypic selection in a wild lizard population

Parasites impose substantial fitness costs on their hosts. Accordingly, parasitism is predicted to be an important selective force shaping the evolution of host phenotypes. While there is a substantial literature exploring the impact of parasitism on host fitness, less is known about their role as an agent of selection. To address this question, we developed a method for the long-term removal of nematode parasites from the brown anole, *Anolis sagrei*, an abundant lizard that is ideally suited for studies of natural selection. Using an island population of *A. sagrei*, we captured adult males (n = 178) and females (n = 177) at the onset of the breeding season (March 2019) and treated half of the individuals of each sex with an injection of a sustained-release formulation of the drug Ivermectin (I), while the other half received the vehicle as a control (C). Prior to release, we measured individuals for snout-vent length, mass, limb length, head width, head length, and area, hue, brightness, and saturation of the dewlap, a sexually dimorphic ornament. We recaptured survivors two months later to estimate natural selection on these phenotypes. Although parasite removal only slightly improved the survival probability of males (C = 0.54, I = 0.60) and had no effect in females (C = 0.60, I = 0.60), it significantly reduced the strength of selection experienced by males. On average across all traits, the absolute value of linear selection gradients was 2.9-fold greater in C males relative to I males ($P < 0.001$), and the absolute value of nonlinear selection gradients was 3.2-fold greater ($P < 0.01$). Neither linear nor nonlinear selection differed between C and I females. Our results indicate that parasites are important mediators of phenotypic selection and that their effects on selection may be sex-specific.

126-3 WOFFORD, SJ; Behavioral and Sensory Ecology Laboratory, Dept of Biology, Jacksonville State University; *swofford@jsu.edu*

Urine for a fight: Sex-based differences in crayfish contest signaling

Competition for resources can result in physical contests which are energetically costly and potentially injurious. Organisms with a strategy to assess when costs of a contest have outweighed the benefit of a resource can minimize overall costs that could negatively impact fitness. Males and females of a species incur different types of fitness costs due to reproductive differences, and evidence suggests that these differences can influence contest behavior and persistence. Longer contests equate to greater energy expenditure and risk of injury which could be more costly to female opponents. Consequently, male and female differences in assessment strategies present an ecologically relevant exploration of the context dependence of assessment. Using crayfish as a model organism, we have found that male and female crayfish likely differ in the information used to determine contest persistence and intensity. We first explored the assessment strategy in place for same-sex and mixed-sex dyads and found that mixed-sex contests differed from same-sex contests. While both male and female same-sex contests showed strong evidence for a self-assessment strategy, mixed-sex opponents had no obvious strategy in place. Subsequent trials limited the availability of a chemical signal during mixed-sex contests and revealed varied impacts for males and females. While contest outcome was simply a function of size, contest duration was dependent on both opponent size and the accessibility of chemical information. We suggest that chemical information is equally important for male and female crayfish in contest assessment but the information contained in or conveyed by the signal likely differs.

P2-235 WOHLLEBEN, AW*; FOSTER, SA; BAKER, J; Clark University, Worcester MA; *Awohlleben@clarku.edu*

The infection of young-of-year threespine stickleback by a cestode parasite

Infection rates often vary substantially among host populations, both on local and global scales. Here, we take advantage of the freshwater adaptive radiation of the threespine stickleback (*Gasterosteus aculeatus*) in southcentral Alaska following the last glacial maximum. Oceanic stickleback independently colonized freshwater habitats where they encountered *Schistocephalus solidus*, a trophically transmitted cestode that has a long evolutionary history of parasitizing freshwater stickleback but that is not viable in marine environments. Initial work in British Columbia suggests, as expected, that oceanic stickleback exhibit little resistance to infection, whereas freshwater populations exhibit lower infection rates under experimental conditions, suggesting evolved resistance. Population differentiation of *S. solidus* is unlikely due to a highly mobile definitive host (piscivorous birds). Some stickleback populations have persistently low parasite loads, some have consistently high loads, and some exhibit extreme fluctuations in parasite loads and stickleback population sizes across years. In a first step toward understanding the interaction of such systems, we looked at the timing of infections by *S. solidus* in four Alaskan stickleback populations with different *S. soldius* frequencies. Our goal was to pinpoint the timing of the first exposure of the stickleback to *S. solidus* and to determine the course of infection over the winter.

75-3 WOLD, ES*; ROBERTS, TJ; SLEBODA, DA; Brown University, Providence RI; *ethan_wold@brown.edu*

Osmotic engine drives shortening in passive skeletal muscle

Skeletal muscle, like most biological tissues, is primarily made up of fluid. This fluid is rarely considered a mechanical component of muscle, but recent work suggests that it may be a determinant of basic muscle properties. We have shown previously that an isolated muscle bathed in dilute solution takes on water and swells. If held at constant length during this process, it develops greater passive tension over time. This phenomenon can be replicated by a model of a fluid-filled cylinder surrounded by a fiber-wound matrix, and we have proposed that a similar interaction of fluid pressure and the collagenous extracellular matrix influences passive force development in muscle. We explore this hypothesis further by measuring shape changes in isolated bullfrog semimembranosus muscle held at constant tension by a servomotor. When bathed in hypotonic solution 20% of isotonic, muscles swelled (as measured by an increase in muscle width) and shortened. Over time, shortening was proportional to the increase in width. Although the work done was small compared to an active muscle, the forceful shortening demonstrates that passive skeletal muscle is capable of acting as an osmotic engine, converting osmotic potential to mechanical work. Returning muscle to an isotonic solution reduced muscle width and was associated with re-lengthening. Length changes observed in muscle that was held at a low force were greater than those at high force, and a mathematical model inspired by human-engineered McKibben pneumatic actuators yields similar outcomes. These results suggest another parallel between biological muscle and McKibben actuators, and give support for the notion that muscle shape change is influenced interactions between extracellular matrix collagen and intracellular fluid.

P2-197 WOLDT, K/M*; SUSTAITA, D; Department of Biological Sciences, California State University San Marcos; *woldt002@cougars.csusm.edu*

Preliminary analysis of climbing morphology and performance of the salt marsh harvest mouse and co-occurring species in the Suisun Marsh, California

As the only terrestrial mammal entirely restricted to coastal marshes, the salt marsh harvest mouse (*Reithrodontomys raviventris*) occupies an environment that is subject to tidal flooding on a daily and seasonal basis. Thus, specifically how mice endure or avoid high tides has been a subject of interest amongst salt marsh harvest mouse researchers and wildlife managers. Previous researchers have indicated that salt marsh harvest mice tend to climb onto to taller vegetation during high tides, moving vertically onto emergent vegetation rather than horizontally toward uplands away from water. As a corollary, salt marsh harvest mice tend to have relatively longer and thicker tails compared to other co-occurring species. However, the extent to which these morphological differences affect their locomotor abilities is unclear. To this end, we measured climbing-related morphology (tail and foot pad dimensions) and performance (forelimb grasping forces and climbing behavioral assays) of salt marsh harvest mice, in comparison to those of co-occurring western harvest mice and house mice. Our preliminary results suggest differences among species, primarily with regard to the salt marsh harvest mouse's relatively more extensive use of the tail as a tactile or prehensile organ. Because natural selection acts directly on morphological and performance traits, these measurements of their abilities to move during high tides are critical for understanding and predicting the success of salt marsh harvest mouse in its dynamic wetland environment.

92-3 WOLF, SE*; BELTRAN, SE; SANDERS, TL; ROSVALL, KA; Indiana University, Dominican University, Oklahoma State University; *wolfsae@indiana.edu*

Telomere protection mechanisms and adaptive organismal responses to early postnatal stress

Telomeres are the guanine-rich, protective ends of chromosomes that shorten with exposure to stressors and consequently, may link early life stress with long-term effects on phenotypic qualities. However, recent findings highlight gaps in our understanding of telomere protection mechanisms (e.g., antioxidants, DNA-binding proteins) and their role in minimizing stress-induced telomere loss. Here, we ask how an acute stressor influences physiology and telomere dynamics in free-living nestling tree swallows (*Tachycineta bicolor*), with a focus on molecular mechanisms that protect telomeres from shrinkage or promote recovery (i.e., elongation) following stress. During the peak of nestling growth, we injected mothers with lipopolysaccharide, which led to a temporary (~24h) decrease in chick provisioning. 24 hours and 1 week following treatment, we sampled chicks to quantify acute and lasting effects of food limitation on telomere-related processes in a select set of neural and peripheral tissues. One week after treatment, we saw changes in telomere dynamics, stress reactivity, and gene expression of telomere regulatory processes (i.e., antioxidants, POT1) in blood. Now, we explore how telomere regulatory mechanisms respond immediately after 24 hours of fasting, and the degree to which protection mechanisms vary by tissue. Results will shed light on the causes and consequences of variation in telomere dynamics and emphasize the potential role of telomere protection mechanisms in adaptive responses to stress.

106-8 WOLF, CJ*; CHEVIRON, ZA; University of Montana, Missoula, MT; *colejwolf@gmail.com*
Seasonal Variation of Body Composition in Deer Mice (Peromyscus maniculatus)
Body condition, an estimate of an animal's fat reserves, is frequently used to assess population health and habitat quality, but few studies have attempted to link condition to individual survival. In deer mice, cold-induced summit metabolic rate is positively correlated with survival. Because fats are the primary fuel source for thermogenesis in rodents, an individual's fat reserves (i.e., condition) may also be related to survival. We used a mark-recapture study to examine: 1) the relationship between condition and survival and 2) seasonal variation in body condition, activity levels, and field metabolic rate. We surveyed deer mouse populations on two 1-hectare grids in western Montana for four nights each month from May through November in 2018 and 2019. Body composition (percent fat and lean mass) was assessed via quantitative magnetic resonance (QMR). We did not find any association between percent body fat and survival rates over the sampling period. Female mice had higher percent body fat than males, but both sexes carried significantly less fat in August and September than in other months. Since this period represents the peak and tail of the dry season, this pattern may be linked to the hot and dry conditions of late summer. Deer mice are known to reduce aboveground activity when conditions are unfavorable, which could force individuals to rely on fat reserves in lieu of foraging. However variation in nightly movement rate was not significantly associated with month or percent fat – suggesting a different mechanism may be driving this seasonal reduction in fat reserves.

S4-5 WOLFNER, MF; Cornell University; *mfw5@cornell.edu*
The female side of the male x female interactions that modulate sperm competition and reproduction
Reproductive interactions between males and females integrate molecules, cells, behaviors, and physiology from both partners. In sperm competition, attention has been paid to the evolution of male features to improve their success, such as faster sperm, more sperm, and composition of seminal plasma. Although the female is not ‘passive' in the outcome of sperm competition, the nature of her genes and molecules that regulate sperm outcome is unknown. By a GWAS based on variation in Drosophila female contributions to sperm competition outcomes, we (Chow et al., 2013 Genetics) identified SNPs whose presence in the female genome modulated the outcomes of sperm competition. Recently, we (Chen, Delbare, White et al., 2019 Genetics) tested directly for the action of genes defined near those SNPs in sperm competition outcome. Eight genes showed such effects, and five of these are neurally-expressed. I will describe these results, and recent data from D. Chen that show that at least one of these neural classes participates in modulating sperm competition outcomes. Another phenomenon involving female-male cross-talk concerns how seminal proteins interact with females' physiology in Drosophila and mosquitoes; examples will be presented. These interactions are often discussed in terms of the male ‘manipulating' the female. I will suggest that in some cases one could consider that the female is, instead, ‘using' the male to activate certain of her physiological pathways, when it is beneficial to her that they be activated. [Sperm-competition work is in collaboration with A. Clark, mosquito work is in collaboration with L. Harrington; all studies described were funded by NIH.]

46-1 WOLLESEN, T*; MUSSER, J; BERTUCCI, P; ARENDT, D; European Molecular Laboratory, Heidelberg, Germany; *tim.wollesen@embl.de*
Single Cell RNA-sequencing reveals molluscan cell types and sheds light on the evolution of a complex bilaterian body plan
How did the vast diversity of cell types arise during evolution and how are cell types related to each other? Addressing these questions, we study representatives of the phenotypically diverse superphylum Lophotrochozoa with clades as different as mollusks or annelids. The polyplacophoran mollusk *Acanthochitona crinita* exhibits ancestral molluscan and bilaterian traits. Its trochophore larva is a mosaic of embryonic and adult features such as seven shell plates, an apical organ, a ciliary band, a creeping foot, and a differentiated nervous system. In order to investigate the cellular organization of these ancestral traits we have conducted whole-body single cell transcriptomics on trochophore larvae using 10x genomics and Next-Seq technology. Approximately 8000 cells with 8000 mean reads per cell were obtained and more than 60 different cell types revealed which were localized via *in situ* hybridization experiments. Besides endodermal clusters, we identified mesodermal cell types giving rise to the complex polyplacophoran musculature. In addition, several ectodermal cell types including sensory cells, other neurons, and epidermal cells were found. Notably, cell types forming the shell fields and the surrounding spicules cluster together with neuronal cell clusters suggesting a shared evolutionary history. By comparing our data to those of other lophotrochozoan representatives we reveal putative homologous cell types. Our data lay the foundation for tracing the evolution of cell types and cell type families across Lophotrochozoa and Bilateria.

S10-11 WOMACK, MC; National Museum of Natural History, Washington, DC; *molly.womack@usu.edu*
Disentangling intrinsic and extrinsic factors underlying anuran postcranial skeleton evolution
Many extrinsic factors (habitat, biotic interactions, etc.) and intrinsic factors (phylogenetic history, size constraints, etc.) affect the morphological evolution of a lineage, making it difficult to disentangle the effects of any particular factor on trait evolution. Frogs and toads (anurans) present a unique opportunity for studying how intrinsic and extrinsic factors contribute to morphological and functional diversity because they are specious (over 7,000 species), distributed worldwide, vary in body size, and have frequently and independently invaded various microhabitats (aquatic, arboreal, terrestrial, etc.). Using microCT data from over 250 species across all families, we first correlate postcranial skeleton evolution with phylogeny, body size, and microhabitat at a macroevolutionary scale spanning 200 million years. We then use existing performance data to pinpoint skeletal features affecting locomotion and other functions. Finally, we lay out hypotheses to be tested via developmental studies, mechanical modeling, and performance data that will inform why skeletal evolution varies among clades and how skeletal variation promotes functional and ecological diversification in anurans.

P1-207 WOMBLE, AL*; CLARK, AJ; UYENO, TA; Valdosta State University, Valdosta, GA, College of Charleston, Charleston, SC; *alhoburn@valdosta.edu*

The Functional Morphology of the Hagfish Feeding Apparatus Dental Plate Complex

Hagfish are benthic marine craniates that have not evolved opposable jaws. Despite this, hagfish are capable of powering a "bite" that is strong enough to utilize food materials that range from marine worms to giant vertebrate carcasses. Rather than biting using an opposing pincer action, hagfish use a rasping motion of a tongue-like dental plate that is armed with keratinous teeth. The dental plate is protracted and retracted using a complex series of cartilages, muscles, and connective tissues that are collectively known as the hagfish feeding apparatus. Rigid elements of the feeding apparatus can be visualized using microCT scans, however, the organization of soft tissues can often remain more difficult to describe. In this study, we characterized the muscle and connective tissues that join and actuate the more rigid elements of the feeding apparatus through the use of traditional paraffin histological techniques. We used frontal, transverse, and parasaggital serial sections to create a three-dimensional interpretation of morphology. This analysis indicated that the cartilaginous plates of the anterior feeding apparatus are connected using thin connective tissue strap hinges that are likely formed of collagen and, in some places, cartilage. The musculature of the feeding apparatus is complex and are variously organized as antagonistic groups, that function to protract and retract the dental plates, and as muscular hydrostats that are used to provide structural support and stabilize the various rigid cartilaginous plates during movement.

P3-143 WONG, JCM*; JOSHI, V; JAIMAN, RK; ALTSHULER, DL; University of British Columbia, Vancouver, BC; *jwong@zoology.ubc.ca*

Wing Morphing During Avian Flight Induces Changes in Local Wing Stiffness Which Affect Aeroelastic Response

As the variety of uses for aircraft increases, so too does the need for flight structures that are robust and adaptable to unforeseen circumstances. Birds achieve this adaptability to variable flight conditions by actively changing wing shape ("wing morphing") during everyday flight. By rearranging flexible components, such as feathers, relative to each other, changes to wing shape may also modulate the wing's mechanical properties, and thus aeroelastic responses and flight performance. We first sought to determine how changes to wing shape affect local wing stiffness in anesthetized pigeons *(Columba livia)*. In each of two extreme wing positions (extended and folded), we calculated stiffness by measuring the force resisting an oscillatory position change actuated near the base of select flight feathers. To test whether stiffness is more significantly affected in some areas of the wing during morphing, stiffness measurements were acquired near a distally-located leading-edge primary flight feather (P9) and a proximally-located flight feather near the wrist joint (P1). We then performed these measurements with and without the neighboring feathers present to test whether changes in stiffness were due to feather-feather interaction. We found that wing folding changes stiffness most significantly in areas near the wrist joint through an increase in feather-feather interaction. The effects of these changes in wing stiffness on fluid-structure responses and aerodynamic performance were then evaluated using computational fluid modeling. Our findings provide insight in the design of multi-component structures capable of modulating aeroelastic responses, thus increasing the performance envelope of aircraft.

20-5 WONG, S*; BIGMAN, JS; DULVY, NK; Simon Fraser University, Burnaby, Canada; *serenaw@sfu.ca*

Ontogenetic scaling of gill area and brain size between two populations of blacktip shark (Carcharhinus limbatus)

Temperature underlies physiological and ecological variation among populations. For example, temperature is a key determinant of water oxygen availability, affecting metabolism, life histories, and morphology in fishes. Since gill area (GA) relates to oxygen diffusion and brains are one of the most metabolically costly organs, we hypothesize that populations at higher environmental temperatures will have faster life histories, larger GA relative to body size, and smaller brains relative to body size. Here, we ask whether GA and brain size vary between two populations of blacktip sharks (*Carcharhinus limbatus*) living in different environmental temperatures. However, because GA and brain size change with body mass throughout sharks' lives, these traits must be studied in a scaling context. We predicted that the slope values for both GA and brain size would be similar for the two populations, but that the warmer population would have a larger GA and a smaller brain for a given body size. Gill area and brain mass were measured on individuals from the cooler South Atlantic Bight and the warmer Gulf of Mexico. We found that the Gulf population had a smaller relative brain size than the Atlantic population when we compared immature individuals, but also a smaller relative GA. Finally, both brain mass and GA scaled more steeply with body mass in the Gulf population. These results suggest that temperature influences the scaling of GA and brain mass between populations of blacktips. Investigating how GA and brain size scale between populations with different life histories and environments helps provide a better understanding of the evolutionary effects of environments on two key organs, as well as how environment and physiology impact metabolism and life histories.

P2-143 WONG, BH*; KAYE, RJ; CHRISTIE, AE; DICKINSON, PS; Bowdoin College, Brunswick, ME, University of Hawaii Manoa; *bhwong@bowdoin.edu*

Differential modulation of pattern generating networks by multiple members of a single neuropeptide family

Neuropeptides are important modulators of neural activity, allowing neural networks, such as the central pattern generators (CPGs) that control rhythmic movements, to alter their output and thus generate behavioral flexibility. Isoforms of a neuropeptide family vary in physical structure, allowing potentially distinct functional neuromodulatory effects on CPG systems. While some familial neuropeptide isoforms can differentially affect a system, others in the same family may elicit indistinguishable effects. Here, we examined the effects elicited by members of a novel family of six peptide hormone isoforms (GSEFLamides: I-, M-, AL-, AM-, AV-, and VM-GSEFLamide) on two CPG systems in the American lobster, *Homarus americanus*. The cardiac CPG drives rhythmic, neurogenic heart contractions, while the stomatogastric nervous system controls the gastric mill and pyloric filter regions of the foregut. Five of the six GSEFLamides elicited similar increases in contraction amplitude when perfused through the isolated lobster heart, while one (AVGSEFLamide) had virtually no effect. Although none of the peptides elicited a significant change in contraction frequency in pooled data, most of the isoforms caused changes that varied across individuals; the smallest range of changes was elicited by AVGSEFLamide. Using extracellular recordings, we found that the same five GSEFLamide isoforms enhanced the activity of the gastric mill pattern, while AVGSEFLamide did not alter the output of the gastric mill CPG. In contrast, the pyloric CPG was not modulated by any isoforms of this family.

91-2 WOOD, T/C*; MOORE, P/A; Bowling Green State University and University of Michigan Biological Station; *tcwood@bgsu.edu*
Chemical Landscapes of Fear: Crayfish can Determine the Degree of Predatory Threat by Olfaction Alone
Encounters between predators and prey lead to capture and consumption of the prey or a nonlethal avoidance response when the prey changes its behavior to evade the threat. Either outcome is costly for prey. However, not all predators represent equal threats, especially when predators are gape limited. Prey solve this problem by obtaining information about a predator from a variety of sensory cues that they use to assess risk, to avoid responding to nonthreatening predators. Chemical cues in the form of predator odors provide information about the predator's species identity, health, satiation state, and previous dietary components. Odors also indicate the size of the predator, which could inform prey if a predator poses a threat relative to their own body size . Rusty crayfish (*Faxonius rusticus*) were exposed to odor cues produced by two gape limited predatory fish, Largemouth Bass (*Micropterus salmoides*) and Rainbow Trout (*Oncorhynchus mykiss*) across a gradient of relative size relationships. Crayfish consumed more macrophytes when exposed to odors from bass that were large relative to the crayfish. There was no change in macrophyte consumption by crayfish exposed to trout odors along the same relative size gradient. Foraging effort and shelter use behaviors of the crayfish were also impacted by odors from predators that were large relative to the size of the prey. Thus, crayfish can extract size information from predator odor cues and use this information to determine if the predator represents a threat relative to their own body size. However, the responses are also species specific, which further supports the hypothesis that prey assess risks relative to the threat posed by individual predators.

90-6 WOOD, H.; Smithsonian Institution; *woodh@si.edu*
Reverse engineering the "trap-jaw" mechanism in spiders (Araneae, Mecysmaucheniidae)
Trap-jaw spiders (Mecysmaucheniidae) have been shown to have ballistic, high-speed "jaw" movements that are the fastest known arachnid movements to date. Within the family there is considerable interspecific functional diversity, with the fastest species moving their "jaws" two orders of magnitude faster than the slowest species. Phylogenetic analysis has revealed that the four fastest lineages do not form a monophyletic group but instead have evolved in parallel. The tiny size of these spiders (carapace length ranges from 0.8 – 3.0 mm) precludes in vivo manipulations. Instead, I use micro-CT scanning techniques, histology, and high-speed videography to reverse engineer the trap-jaw mechanism. I compare and contrast the functional morphology of two different mecysmaucheniid lineages, both from New Zealand, that are each other's closest relative, with one lineage capable of ballistic, high-speed "jaw" movements and the other with slower movements. Based on differences in muscle morphology and anatomical shapes between the two sister-lineages, I develop a hypothesized mechanism for the trap-jaw strike. Finally, I test this mechanism by 3D printing a scaled-up model of different structures and use string and elastics to replicate "jaw" function, thereby demonstrating proof of mechanical concept. This research highlights the morphological steps that were taken to evolve a ballistic, complex, structural mechanism.

38-3 WOOD, LJ*; TOBALSKE, BW; ALTSHULER, DL; University of British Columbia, Vancouver, University of Montana, Missoula; *leo.w@zoology.ubc.ca*
A Specialized Muscular System Enables Highly Dynamic Wing Motions in Passerine Birds
Previous work indicates that strong coupling of elbow and wrist motion in birds results in an outsized influence of elbow angle on overall wing morphing. The muscular morphology of the avian wing that controls elbow flexion is highly unique. In addition to the biceps, there are two muscles unique to birds with attachment points and tendinous properties that are highly unusual relative to other vertebrates. This elbow flexion system has no parallel in other vertebrates, is highly diverse across avian species, and yet has not been studied in close detail. We sought to answer fundamental questions on what roles each muscle performs in flight, how the muscles in this system interact in different modes of flight, and what possible scaling relationships may bound and drive the morphological variation of this system. We collected *in vivo* electromyography and kinematics measurements on European Starlings in wind tunnel flights designed to elicit both gliding and level flapping behaviors. These investigations were coupled with isolated muscular studies to characterize the activation dynamics, force production, and torque production of the wing muscles of interest. We show that the three passerine elbow flexors exhibit a robust pattern of sequential activation that is closely rooted to their anatomical arrangement and muscular dynamics, and that the specific flexor muscles unique to birds utilize favorable lever arms to generate higher torques from comparatively lower muscle masses than traditional elbow flexors. This study provides a view of the interrelation between muscular morphology and coordination, and how a highly specialized avian muscular system is used to generate and control flight.

45-1 WOODLEY, SK*; MOORE, IT; Duquesne University, Virginia Tech; *woodleys@duq.edu*
Introduction to Celebrating the scientific contributions of Rosemary Knapp: hormones and alternative reproductive tactics
On February 3rd, 2019, Dr. Rosemary (Roe) Knapp, Professor at the University of Oklahoma, passed away after a long courageous battle with breast cancer. Roe was a dedicated member of SICB and DCE, serving as DCE program officer multiple times and was a longstanding active member since the early 1990s. She was a role model, mentor, colleague, and friend to many in the SICB community and beyond. Along with her bright smile and gracious attitude, she was highly regarded for her sharp intellect, her scientific rigor, and her high standards. Roe exemplified integrative and comparative biology through her published studies of ecology to neurobiology using many species, including caterpillars, mice, lizards, birds, and fish. Roe was best known for her studies of the behavioral neuroendocrinology of alternative reproductive tactics. Starting with aggression in male lizards with her PhD, she expanded into male parental care, aggression, and reproductive physiology in fish. Most recently, she was an integral member of the team that compiled HormoneBase, a valuable data repository that has allowed testing of broad hypotheses about patterns and functions of circulating steroid hormones in free-living vertebrates. Along with her scientific contributions, she was a caring mentor to students and colleagues alike and was the beloved graduate director at her home institution. Today, we celebrate and honor her influence on SICB and her impact on the field of hormones and alternative reproductive strategies with a series of talks by her friends and colleagues.

65-6 WOODLEY, SK*; CASCIO, M; KOLBER, BJ; MIHAILESCU, MR; TIDGEWELL, KJ; Duquesne University; *woodleys@duq.edu*

Community-engaged Learning in a Summer Undergraduate Research Program

Scientists are essential for communicating scientific concepts, the social relevancy of science, and the excitement of science and related fields to the public. However, scientists are rarely trained in how to effectively engage with the public. To address this gap, we incorporated community-engaged learning into the 10-week immersive summer undergraduate research program of Duquesne University. Students were funded by Biology NSF REU or NIH R25 grants. The summer research students developed and shared science activities with children at a summer day camp located in an underserved neighborhood in Pittsburgh. Undergraduate students worked in teams to develop science enrichment activities that they shared with 25 middle school-aged campers one morning each week for 4 weeks. The experience culminated in a visit by campers to Duquesne University where the undergraduate students described their background and research projects to the campers. An average of 12 hrs total was spent on community engagement activities. Assessment was via a retrospective post-test. The undergraduates reported statistically significant gains in communication, professional, and civic skills. At the same, Pittsburgh youth were exposed to hands-on science enrichment to increase their understanding and enthusiasm for biology. In sum, community-engaged learning via sharing science with children is a meaningful addition to a summer undergraduate research program. By giving scientists-in-training opportunities to share science with the non-expert public, we hope they will become better communicators and more receptive to civic engagement in the future.

P1-48 WOODMAN, TE*; EMBERTS, Z; MILLER, CW; University of Florida, University of Florida ; *tamsin.woodman@ufl.edu*

A high quality diet leads to improved puncture resistance of a weapon in the leaf-footed cactus bug (Narnia femorata)

Across taxa, males use sexually selected weapons in competition for access to a mate. A sub-optimal diet can cause a reduction in the size of these weapons, and lead to lower fitness. As well as size, the structural properties of the weapon should be important in its effectiveness. For example, if the cuticle is too thin, it might be more likely to be damaged during combat. However, not much attention has been given to how diet affects the structural properties of the weapon, especially in invertebrates. We investigated this question using the leaf-footed cactus bug, *Narnia femorata (Hemiptera: Coreidae)* which uses its hind leg as a weapon in competition for access to females and also has a diet that can change in quality throughout the year. We measured the amount of force it takes to puncture the surface of the weapon in individuals on high and low quality diets and found that a high quality diet leads to significantly better puncture resistance, while those on the low quality diet punctured more easily. Variation in fighting behaviours throughout the year could possibly be explained by cuticle properties, something that has received very little attention. More generally, these results could provide insights into the effects of environmental stresses on skeletal properties in invertebrates.

P1-245 WOODRUFF, MJ*; SERMERSHEIM, LO; ROSVALL, KA; Biology, Indiana University, Center for the Integrative Study of Animal Behavior, Indiana University; *woodrufm@iu.edu*

Do endotherms acclimate to heat? Physiological responses to a simulated heat wave in free-living birds

Anthropogenic climate change is dramatically altering conditions across the globe, but there is still much to learn about the physiological mechanisms that facilitate thermal tolerance, particularly in endotherms. Animals may respond to heat by regulating heat shock proteins (HSP), which combat stress-induced cellular damage. Thermal challenges may also alter corticosterone (CORT) secretion, thereby mobilizing resources during metabolically challenging conditions. We explored these mechanisms by which developing birds may acclimate to a naturalistic thermal challenge. Specifically, we exposed free-living tree swallow (*Tachycineta bicolor*) chicks to an experimentally mimicked 6-day heat wave using disposable air-activated shipping warmers, which elevated nest temperatures by at least 2°C during the period of rapid postnatal development (6-12 days post-hatch). To assess physiological acclimation to heat, we quantified HSP gene expression in the blood across various time points during heat exposure, including 4 hours, 3 days, and 6 days after the onset of heat. We measured baseline and stress-induced CORT secretion at the end of the treatment period. Experimental heating did not affect nestling growth or parental visitation, but initial analyses suggest that nestling behavior was affected. Here we describe both initial and delayed effects of heat on HSP gene regulation and the degree to which HSP expression is correlated with CORT signaling. Heat may be particularly relevant in this system because tree swallows are currently undergoing a unique southward range shift and are breeding in warmer climates. Furthermore, this experiment informs our understanding of how birds respond to climate change and lays the foundation for future work exploring the evolution of thermal resilience.

S1-12 WOODS, HA*; MORAN, AL; University of Montana, University of Hawai'i at Mānoa; *art.woods@mso.umt.edu*

Reconsidering the oxygen-temperature hypothesis of polar gigantism: successes, failures, and nuance

‘Polar gigantism' describes a biogeographic pattern in which ectotherms in polar seas tend to have larger body sizes than do their warmer-water relatives. Although polar gigantism has been ascribed to a variety of mechanisms, one idea—the oxygen-temperature hypothesis—has received significant attention in the past twenty years. The idea is that low temperatures in polar seas depress metabolic demand for oxygen more than they depress supplies of oxygen to and within organisms. This shift, releases polar organisms from oxygen-based constraints on body size. In this talk, we review evidence for and against the hypothesis. Although some data suggest that larger-bodied taxa live closer to an oxygen limit, or that rising temperatures can challenge oxygen delivery systems, other data provide no support. We propose that these findings can be reconciled, in part, by recognizing that the oxygen-temperature hypothesis, in its simplest incarnation, focuses on *passive physical transport* of oxygen, which implicitly ignores other important processes, including ventilation of respiratory surfaces, internal transport of oxygen, and behavioral choices about positioning within environmental mosaics. Indeed, the oxygen-temperature hypothesis may apply most meaningfully to organisms that are sessile (e.g., nudibranch egg masses, sessile adults) or that have poorly developed physiological and behavioral systems (eggs and embryos). Finally, most tests of the oxygen-temperature hypothesis have involved short-term experiments. Although most complex organisms can mount effective responses to physiological challenges over such time periods, doing so may incur negative energetic consequences that become apparent only over much longer time scales. We therefore advocate a renewed focus on long-term studies of temperature-oxygen interactions.

P2-122 WOODS, CE*; PADILLA, G; TODD, K; Westminster College, Salt Lake City, Utah; *sew0307@westminstercollege.edu*
Behavioral and Electrophysiological Response of Medicinal Leeches to UV Light
There is a great deal known about leech neuronal circuitry, however, their visual system has not been thoroughly studied. European medicinal leeches, *Hirudo verbana*, have 5 pairs of cephalic eyes and an additional 7 pairs of sensillar eyes along the surface of each mid-body segment. These cephalic eyes and sensilla contain photoreceptors that allow the leech to sense and respond to light. Recent work has shown that medicinal leeches display negative phototactic behavior when exposed to UV light—a portion of the electromagnetic spectrum between 395 and 405 nm— with a difference in the behavioral response of the leech depending on if the light was applied to the head or tail. Application to the head causes shortening and backward locomotion, while exposure to the tail causes forward locomotion. The circuitry and how UV light information is encoded underlying this negative phototactic response remains to be determined. We first characterized the animal's behavioral response to varied intensities of UV light ranging from about half their normal environmental exposure to 4 times greater. Further, we recorded electrical activity resulting from the same light intensities applied to the sensillar photoreceptors. Raw data indicates a more negative phototactic response to higher intensities of UV light. In addition, there seems to be a difference in the electrical activity between different intensities of UV light as well.

P3-168 WORRELL, TA*; WEISS, TM; GONZALEZ, MG; WHITEHEAD, JG; SALCEDO, MK; PULLIAM, JN; GRAHAM, M; SOCHA, JJ; Virginia Tech; *terrew7@vt.edu*
Development of a multi-camera array to study gliding in flying snakes
Flying snakes (genus: *Chrysopelea*) glide using unique morphological and behavioral adaptations to generate lift while undulating in the air. After a jumping take-off, flying snakes pass through a ballistic phase, and as speed increases, the trajectory becomes increasingly shallow. The orientation of the snake's body changes throughout a glide, subjecting the snake to a continuously shifting balance of forces and torques. Understanding how aerodynamic and inertial forces influence gliding requires a precise knowledge of body orientation, but we lack an understanding of the snake's complete body posture in the shallowing phase of the trajectory. To address this problem, we built an array of 23 cameras (Hero 4 Black and Silver, GoPro), which were synchronized using custom electronics (MewPro Illiad, Orangkucing Lab). *Chrysopelea* snakes launched from a mechanical lift (600AJ, JLG) from heights greater than 13 m. The camera array was positioned to capture the late portion of the snake's trajectory near landing, representing the shallowing phase of the glide. White marks painted along the dorsal surface of the snake enabled post-hoc photogrammetric reconstruction of body landmarks using Argus software. For each trial in which the snake passed through the field of view of the array, a calibration was conducted using a ~1 m wand. Results from this study will be used to inform future computational fluid dynamics modeling of the snake to test hypotheses of morphology, posture, and movement on force generation and stability in gliding. Funded by NSF 1351322 to J.J.S.

68-1 WRIGHT, RM*; NUTTALL, M; DAVIES, SW; Smith College, Northampton MA, Flower Garden Banks National Marine Sanctuary, Galveston TX, Boston University, Boston MA; *rwright@smith.edu*
Gene Expression in Response to Experimental Low Dissolved Oxygen Supports the Hypothesis that Hypoxia Contributed to a Natural Coral Mortality Event
In July 2016, the East Bank of the Flower Garden Banks (FGB) National Marine Sanctuary experienced a localized mortality event (LME) of multiple invertebrate species that caused unprecedented reductions in coral cover for the reef. Abiotic data collected after the LME suggest that hypoxia driven by freshwater run-off and stratification contributed to the mortality. Yet, little is known about the molecular responses of corals to low oxygen. Gene expression samples from affected and unaffected coral colonies revealed physiological consequences of the event on the coral host and its algal symbiont from two congeneric coral species (*Orbicella franksi* and *Orbicella faveolata*) from both East (affected) and West (unaffected) Banks. Affected colonies differentially regulated genes involved in mitochondrial components and oxidative stress, suggesting a response to hypoxia. To test this hypothesis, we measured coral host and algal gene expression in response to experimentally induced low dissolved oxygen (control = 6.9 ± 0.08 mg/L, hypoxic = 0.083 ± 0.017 mg/L) in replicate fragments of three healthy *O. faveolata* colonies from the FGB. This controlled experiment also revealed differential regulation of mitochondrial components and oxidative stress response mechanisms. The delta ranks of enriched gene ontology terms were significantly positively correlated between the responses to the natural LME and in response to the controlled hypoxic challenge, providing further support that hypoxia contributed to the LME at FGB. These *in situ* and experimental data highlight the diagnostic power of an affordable sequencing methodology using ecological samples. Furthermore, our results shed light on the molecular responses of corals to hypoxia.

P1-33 WRIGHT, AD*; WILLIAMS, AS; GARRISON, NL; WHELAN, NV; Tuskegee University, Tuskegee, AL, Auburn University, Auburn, AL; *awright1863@tuskegee.edu*
Population Genetics of the Critically Imperiled Oblong Rocksnail Leptoxis compacta
Many freshwater systems in the eastern United States rely on pleurocerid snails as important nutrient cyclers that have an outsized influence on community structure. Yet, many pleurocerids are critically imperiled, and almost all are understudied.One such understudied species is *Leptoxis compacta*, a species endemic to the middle and upper Cahaba River in central Alabama. *Leptoxis compacta* was previously thought to be extinct but was rediscovered in 2011. With a current range that is 90% less than its historical range, genetic data is needed to improve our understanding of *Leptoxis compacta* biology, inform future listing decisions, and ensure effective management efforts. Here, we performed field surveys across the range of *Leptoxis compacta* and generated genome-scale data for population genetic analyses. In total, we collected 80 specimens of *L. compacta* from four sites, including one site that increases the upstream extent of the known distribution by over 4 km. This nearly doubles the known range of *L. compacta*. Single nucleotide polymorphism data (SNPs) were generated with a 2bRAD approach and Illumina sequencing. We modeled migration and gene flow patterns among populations to understand species resilience and potential for natural population and range expansion. The results from this research will be used by the US Fish and Wildlife Service in future listing decisions for *Leptoxis compacta*.

P1-241 WRIGHT-LICHTER, JX*; GORMALLY, BMG; ROMERO, LM; Tufts University; *jessica.wright_lichter@tufts.edu*

Feather corticosterone concentrations not related to DNA damage in house sparrows

The goal of this study was to determine if there is a relationship between feather corticosterone levels and DNA damage in domestic house sparrows (*Passer domesticus*). Molt was induced in 20 birds by plucking 4 primary feathers per bird. Half of the birds were subjected to a chronic stress protocol for the duration of feather regrowth. The remaining birds were not exposed to the chronic stress protocol. Regrown feathers were then plucked. Blood samples were collected immediately after induced molt and, again, when regrown feathers were collected from both groups. Feather cort levels were measured using a radioimmunoassay. DNA damage was assessed by comet assay with DNA extracted from red blood cells. Feather corticosterone levels did not differ either in initial feathers (grown in the wild) or in feathers regrown either with or without chronic stress. In contrast, DNA damage significantly decreased over time, but chronic stress negated this effect. When combined, these results indicate that there is no correlation between feather corticosterone concentrations and DNA damage in birds exposed to a chronic stress protocol.

132-7 WU, C*; HOWLE, LE; MCGREGOR, AE; MCGREGOR, R; NOWACEK, DP; Marine Science and Conservation, Duke University, Mechanical Engineering and Materials Science, Duke University, School of Life Sciences, University of Glasgow, HiDef Aerial Surveying Ltd; *chen.yi.wu@duke.edu*

Computational Fluid Dynamics Analysis of Gliding North Atlantic Right Whale Models with Variable Body Shapes

The streamlined body shapes of cetaceans delay the separation of flow, create lower drag when they swim, and therefore decrease their locomotor cost in terms of energetics. However, previous studies show that body shape of the North Atlantic right whale (*Eubalaena glacialis*; hereafter right whale) changes with life stages, reproduction status, nutritive conditions, and the effects of entanglement. Accordingly, we aimed to investigate the changes in drag on right whales with variances in body shapes and estimate any associated kinematic costs. We hypothesized that emaciated right whales, which have a less-streamlined body configuration, suffer higher drag when swimming and consequently need longer time to replenish their energy reserves. This fact is likewise crucial for pregnant females because their energy budget for migrating to breeding grounds may increase due to having an enlarged girth for their abdomen. To obtain measurements of drag over right whales under various body conditions, we undertook computational fluid dynamics (CFD) simulations on several static right whale models reflecting different body fitness (e.g., normal condition, emaciation, and pregnancy, etc.) and measured multiple fluid dynamics parameters such as characteristics of boundary layer and hydrodynamic forces on the animals. Our results reveal that drag on right whales fluctuates across its body and varies between models of different body fitness, suggesting that the kinematic energy expenditure of right whales is indeed affected by its body shape.

P2-228 WUNDERLICH, RE*; ORLANDI, D; TONGEN, AL; James Madison University; *wunderre@jmu.edu*

The effect of enclosure type on locomotion and energy expenditure in captive lemurs

The extent to which captive environments facilitate physically similar experiences to those in the wild is important to health and husbandry decisions and to the interpretation of captive behavioral and experimental studies. We examined locomotor behavior and overall dynamic body acceleration (ODBA) in two lemurs in different cage environments at the Duke Lemur Center in order to assess the extent to which available space and substrate variety influence locomotor behavior and energy expenditure. *Propithecus verreauxi* and *Lemur catta* are primates endemic to Madagascar that live sympatrically in some areas yet are very different in terms of group size, substrate use (*L. catta* are the most terrestrial of lemurs while *P. verreauxi* are primarily vertical clingers and leapers), and life history patterns. We predicted that in both species, animals would exhibit more leaping and higher ODBA in the larger natural habitat enclosures (NHEs) than in the caged enclosures (CGEs). We attached inertial sensors to 7 *P. verreauxi* and 4 *L. catta* as they moved both in their CGE and their NHE environments. We used a custom Matlab program to quantify leaping bouts and ODBA and validated the program using focal animal behavioral sampling. Our results indicate that, contrary to expectations, animals used more leaps per hour, higher ODBA, and more activity in the CGEs than NHEs. We suggest these differences were a result of the relative complexity of the CGE enclosure as well as the spacing tendencies of the animals. These data suggest that animals do behave differently in different captive environments (and captive vs. wild) but that these differences cannot be predicted by space alone, and factors influencing these behaviors are species-specific.

115-4 WYETH, RC*; UCCIFERRI, C; YOUSSEF, K; STEVENS, H; St. Francis Xavier University; *rwyeth@stfx.ca*

Environment- Dependent Switching of Odour-Based Navigation Strategies by the Freshwater Gastropod, Lymnaea stagnalis

Many aquatic animals use olfactory-based navigation to move relative to prey and predators. Two common navigation strategies are used, depending on the flow in the animal's environment. To move towards or away from odour sources, either in no flow or laminar flow, chemotaxis can be used (moving up or down a chemical gradient), while in turbulent flow, odour-gated rheotaxis is used (moving up or downstream in the presence of an odour). Moreover, searching-for versus avoidance-of odour sources are distinct goals which need not require a simply inverted navigation strategy (there is only one odour source location, but many locations which could be sufficiently far from an odour source). Few studies have tackled this full complexity in one species. Navigation by the great pond snail, *Lymnaea stagnalis*, presents an interesting case in that they can experience both kinds of flow environments with both attractive (prey) and aversive (predator) odour sources. In a series of behavioural experiments, we are testing whether the snails can switch between chemotaxis and odour-gated rheotaxis, and how navigation differs relative to prey and predator odour sources. The results indicate that *L. stagnalis* can use either chemotaxis or odour-gated rheotaxis when moving towards at least some prey odour sources. Navigation relative to predator odour sources is categorically distinct, and seems to primarily involve upwards movement rather than horizontal movement away from the odour source. Other interesting results include diminished navigation success relative to plant prey versus greater success relative to protein-based odour sources and evidence that vision is integrated with odour-based navigation, at least in environments without flow.

P1-180 WYND, BM*; UYEDA, JC; NESBITT, SJ; Virginia Tech, Blacksburg, VA; *bmwynd@vt.edu*

Allometric growth and shifting diet in the large-bodied traversodontid cynodont, Exaeretodon argentinus, with implications for modeling growth in distorted specimens

Post-natal growth in vertebrates reflects repositioning on the trophic scale, whether through changes in size or diet. Dietary shifts through growth are reflected in changes in cranial morphology accommodating differing proportions of musculature, reconstructed via allometry. Although allometric growth is readily measurable in extant taxa, fewer extinct taxa are represented by sample sizes that allow for study of allometric shifts. Furthermore, most fossils are either fragmentary or deformed during the fossilization process, making comparable measurements across specimens difficult. Here, we describe allometry in the cranium of the large-bodied herbivorous stem mammal, *Exaeretodon argentinus*. Nearly all specimens were deformed, and not typically useful in studies of allometry. To combat this, we simulated distorted and normal data, under a known allometric coefficient, and tested model fit of a simple linear regression and a mixed effects model, which can incorporate additional sources of variation. We simulated differing sample sizes, and found that across all sample sizes, a mixed effects model is better able to predict the allometric coefficient, given deformed data. Under a mixed effects model, we find that through growth *E. argentinus* reduces snout length, widens the back of the skull, and expands the masseter attachment site while reducing the temporalis attachment site. These shifts suggest chewing-dominated feeding in adults, which indicates that smaller individuals had a more crushing feeding style, consistent with a lower proportion of plant material in the diet and a shift from omnivory to herbivory during ontogeny.

S9-5 WYNEKEN, J*; SALMON, M; Florida Atlantic Univ; *jwyneken@fau.edu*

Science, Sea Turtles, and Links to Conservation Management

Fundamental and applied studies of protected species require governmental permissions. Permitted studies often have components directed to address conservation data gaps as defined in species recovery plans. Accurate guides for species identification and gross morphology are critical for managers so that subjects are correctly identified. Descriptive and experimental studies that distinguish normal vs. abnormal development, growth, or behavior are knowledge gaps commonly studied by biologists, but not regularly by managers. When declines occur, managers must understand if such changes result from natural or anthropogenic causes. Mistaken blame may result in ineffective management strategies. Several studies link fundamental science and management. Hatchling marine turtles migrate out to sea; how this migration is done differs among species. Some species swim briefly then allow currents to promote offshore displacement; others swim continuously for days. Differences also correlate with contrasts in hatchling size, shape and flipper morphology. Species also differ in visual perception manifested by contrasting structural organization of their retinae, sensitivity to light wavelengths, how visual information is processed during orientation, prey recognition, and other essential functions. Recognition of such differences has helped regulators better address problems associated with artificial lighting at nesting beaches and lights placed on fishing lines and nets that may attract turtles. Recent studies of nest environments improved understanding of the drivers of hatchling sex determination and thus contribute to population sex ratios. Collectively, the studies demonstrate how relationships in structure, function and behavior contribute fundamental knowledge as well as assist in development of better conservation/management strategies.

51-1 WYNNE, NE*; FRYZLEWICZ, LH; VINAUGER, C; Virginia Polytechnic Institute and State University, Blacksburg, VA; *nwynne@vt.edu*

Navigating Towards Defensive Hosts: Mosquito Visual Avoidance Behavior

In order to produce progeny female mosquitoes require proteins and nutrients found in our blood. This food is hidden under the skin of mobile and defensive vertebrate hosts. In response, mosquitoes have evolved the ability to navigate around hosts at close range while avoiding their defensive and antiparasitic behaviors. It is well known that invertebrates display escape behaviors in response to visual, predator-like, looming stimuli. In locusts and fruit flies a subset of neurons are specialized in the encoding of looming stimuli and descending pathways control these escape responses. However, in spite of great epidemiological relevance, very little is known about how mosquitoes evade their predators, as well as swatting from their hosts. As a first step towards bridging this knowledge gap, we combined behavioral and molecular approaches to analyze the responses of *Aedes aegypti* females to looming visual stimuli. In a first set of experiments we used an LED arena to introduce looming, predator-like stimuli to mosquitoes that were either landed, in free flight, or in tethered flight. Results from these experiments allowed us to characterize mosquitoes' escape responses and determine the angles and distances to the stimuli most likely to trigger an escape response under different behavioral contexts. Next, we relied on molecular and imaging approaches to investigate the underlying neural mechanisms supporting this behavior. The significance of these results will be discussed relative to the design of control tools.

132-6 XARGAY, E*; BARTON, K; GOUGH, W; ADAMS, D; FISH, F; ANTONIAK, G; SHORTER, KA; UMich, SU, CU, WCU, UM; *kshorter@umich.edu*

Inverse Dynamics Analysis of Dolphin Swimming

This work uses a physics-based model of a swimming bottlenose dolphin to investigate thrust production and propulsive efficiency. The model captures critical features such as body posture, fluke flexibility, and delayed fluke stalls, and integrates findings from previous research on small odontocetes, including body morphometry, fluke morphology and elasticity, gait and swimming stability. The modeling framework is based on a mixed Newtonian-Lagrangian formulation and brings together tools and concepts from multi-body dynamics, plate theory, hydroelasticity, and unsteady hydrodynamics. The head, torso, caudal peduncle, and pectoral fins are modeled as a set of interconnected rigid bodies subject to a prescribed kinematic gait profile relative to the torso. Gait kinematics are extracted from video data of bottlenose dolphins swimming over a range of speeds. The fluke, on the other hand, is modeled as a flexible plate, whose deformation evolves in response to hydrodynamic, elastic, and inertial forces acting on the fluke. Because hydrodynamic loading over the fluke is in turn affected by its deformation state, the model incorporates results from unsteady thin-airfoil theory and unsteady lifting-line theory to predict lift and drag distributions over the deforming body. An inverse dynamics analysis is used to estimate forces, moments, and power required to move elements of the model during the experimentally derived motion. We show that the swimming kinematics resulting from our model are in good agreement with kinematic data previously reported in the literature. We also present estimates of swimming energetics over a wide range of speeds, and compare these results with estimates obtained from previous work on cetacean swimming performance and oscillating hydrofoil propulsors. Finally, we discuss discrepancies between our findings and existing knowledge of the hydrodynamic performance of a swimming dolphin.

P3-58 XAVIER, C*; BERGEY, L; RITCHIE, L; JEAN-PAUL, J; Centenary University; *clerson.xavier@centenaryuniversity.edu*
Differences in reproductive efforts in the invasive grass shrimp, Palaemon macrodactylus over gravid native Palaemon shrimp.
Studying invasive species is important because they can have far reaching impacts on ecosystems. Grass shrimp are an important ecological species in food web dynamics in estuarine systems. Local fish species, crabs, and wading birds all feed on these small shrimp. Palaemon macrodactylus, an invasive species of grass shrimp was examined to determine if there were any differences in reproductive output when compared to three native species of grass shrimp in New Jersey waters. A total of 88 shrimp were collected from seven sites from April 2018 to September 2018. Larger body sizes of females has been correlated to larger production of eggs. The number of gravid females collected from each of the seven sites of each species was recorded. The size of each of the gravid females were recorded. Eggs were examined to confirm that they were viable eggs. The distributions of morphological size for Palaemonetes pugio, Palaemonetes vulgaris and Palaemon intermedius were not significantly different from being normal ($p > 0.05$). While the distribution for Palaemon macrodactylus was significantly different from normal ($p = 0.001$). The Shapiro-Wilks test was used to help with the normality of the size distribution for each species, the differences between the means of sizes for all species, P. pugio, P. vulgaris, P. intermedius, and P. macrodactylus was not statistically significant, Welch's $F(3, 29.350) = 1.740$, $p = 0.181$. Additional analysis is being conducted looking at egg mass, individual egg count and morphological size ratios. This study has confirmed that the invasive species has a larger body size overall compared to the native species and has a potential to outcompete the native species in reproduction.

P1-187 XIONG, D*; CHURCHILL, M; University of Wisconsin, Oshkosh, WI; *xiongd67@uwosh.edu*
Prey Capture Strategy is Correlated with Temporalis Muscle Size in Toothed Whales (Odontoceti)
Temporalis muscle size is influenced by diet and method of food processing in terrestrial mammals. The correlation between the size of this muscle and feeding behaviors in whales has yet to be tested. The purpose of this study was to quantify the size of the area of attachment on the skull for the temporalis muscle, a proxy for the size of the muscle, for 209 specimens of 72 odontocete whales. The temporal fossa area was calculated using measurements of the temporal fossa height and width, with body size removed by dividing each measurement by the occipital condyle breadth, a correlate for body size. We used ANOVA statistical tests to determine if differences in temporal fossa area were present, and if they relate to diet (generalists vs fish vs squid, vs higher vertebrates dominant diets) and prey capture and processing strategy (suction vs snap vs ram vs. grip-and-tear feeding styles). Significant differences in the temporal fossa area were found between all feeding strategies except between grip-and-tear verses snap feeding. Grip-and-tear feeders along with snap feeders encounter a substantial amount of strain while feeding and would need a larger temporalis muscle to accommodate the higher bite force needed for their feeding style. Whales using the grip-and-tear feeding method had the largest temporal fossa area followed by snap feeding, ram feeding and suction feeding. The only significant differences in temporal fossa area in relation to diet were differences between consumers of bird and marine mammals versus those which fed on fish or squid. This study provides evidence that the temporal fossa of extant whales strongly associated with prey capture strategies and can be used as a tool to examine the feeding behaviors of fossil whales.

5-5 XU, NW*; DABIRI, JO; Stanford University, California Institute of Technology; *nicolexu@stanford.edu*
Metabolic costs of enhancing propulsion in live biohybrid robotic jellyfish
Robotic control of animal locomotion can potentially address questions about organismal biology and animal-fluid interactions, which are otherwise limited to observations of natural behavior. This work demonstrates a biohybrid robot that uses a low-power, wireless microelectronic system to induce forward swimming in live jellyfish, *Aurelia aurita*. When bell contractions are externally driven at a frequency range higher than observed in natural behavior, swimming speeds can be enhanced nearly threefold. This microelectronic system was also used to determine the metabolic response of the jellyfish over this optimal frequency range, which was only a twofold increase in cost of transport to the animal compared to unstimulated swimming. These experimental results are consistent with an adapted hydrodynamic model, developed to characterize enhanced propulsion and match more biologically relevant kinematic and body morphological parameters. Thus, jellyfish can sustain the associated higher metabolic costs of increased swimming speeds. This capability can possibly be leveraged in applications such as ocean monitoring and robotic sampling for ecological uses, and to enable more user-controlled studies of swimming organisms in lab and in-situ experiments.

87-4 XUAN, Q*; LI, C; Johns Hopkins University; *qxuan1@jhu.edu*
Template model reveals mechanism of wing and leg coordination during self-righting of a cockroach-inspired robot
Self-righting is a critical ability that terrestrial animals must have to survive. The discoid cockroach can push its wings against the ground to somersault and dynamically self-right. However, because this maneuver is strenuous, the animal often cannot build up sufficient kinetic energy to overcome the large potential energy barrier required to pitch the body. In this case, the animal often flails its legs, which adds kinetic energy to help overcome the barrier by body rolling. Our recent study using a cockroach-inspired robot showed that self-righting requires good coordination (good phases) between wing pushing and leg flailing. Here, we further understand the mechanism of phase dependence by developing a template model. Our planar template model rotates in the sagittal plane and has two massless wings and a flailing leg with mass at its end. Applying the similar geometry size, mass distribution, and actuation profile, the model also struggled to self-right and relied on a good coordination of body parts. We first validated the model against a multi-body dynamics simulation. Then, we used the template model to calculate mechanical energy injection by the wings and leg, mechanical energy dissipation due to collision and friction, and potential energy barrier. Our model revealed that, although phase affected energy injection and dissipation in complex ways, good phases resulted in mechanical energy accumulation that exceeded the potential energy barrier, whereas bad phases did not do so. Our study elucidated the mechanism of coordination between thrusting and perturbing appendages to cumulate energy to overcome the barrier during strenuous maneuvers such as self-righting.

S6-3 YACK, JE; Carleton University, Ottawa, Ontario, Canada; *jayneyack@cunet.carleton.ca*
What does a Butterfly Hear? Neurophysiological and Behavioural Responses to Predator Sounds
Butterflies are among the most extensively studied insects, and research on their behaviour has contributed to our understanding of animal territoriality, migration, conservation biology and climate change. A full appreciation of an animal's behaviour includes knowledge of its sensory ecology, and whilst visual, chemical, and tactile senses have been widely studied in butterflies, the auditory system is poorly understood. Recent work from my lab shows that many species of diurnally active butterflies possess tympanal ears on their forewings that are sensitive to low frequency sounds (best sensitivity ~1-6 kHz). Yet, a key question remains unanswered: What is the adaptive significance of their hearing? Most species are diurnally active and do not produce sounds, so bat detection or conspecific communication are unlikely. Birds are a primary predator of butterflies and we pose the hypothesis that butterflies (and other insects) use their ears as ‘bird detectors'. We provide evidence that insectivorous birds produce broadband sounds as byproducts of flight that these sounds overlap with insect hearing. We show that butterfly ears respond neurophysiologically to predator sounds. Additionally, sounds of approaching predators evoke escape responses. Results to date support the hypothesis that the ears of butterflies, like those of many vertebrate prey such as some rabbits and lizards, function in predator risk assessment. We propose that the function of low-frequency hearing for predator risk assessment is underappreciated for both invertebrate and vertebrate prey, and warrants further investigation.

P2-150 YAMADA, KYH*; ZIKELI, SL; YAP, KN; ZHANG, Y; KIARIS, H; KAVAZIS, AN; HOOD, WR; Auburn University, Alabama, University of South Carolina, Columbia; *kyy0003@tigermail.auburn.edu*
The relationship between the unfolded protein response and mitochondrial performance in deer mice maintained in a natural context
Individuals often display considerable variation in how each responds to stressors. The stress response has historically been evaluated by quantifying circulating levels of glucocorticoids. Yet, this approach has had limited value in understanding why two individuals would have different physiological responses to the same endocrine signal. One variable that could contribute to this variation is the unfolded protein response (UPR). The UPR is activated by accumulation of misfolded proteins, which often result from environmental stressors. The UPR affects the cells' physiological function and secretory activity. In this study, we evaluate the relationship between the UPR, corticosterone levels, and mitochondrial physiology in deer mice (*Peromyscus maniculatus*). Mitochondrial physiology provides a strong indicator of the condition and energetic capacity of the individual and may be impacted by exogenous and endogenous stressors. Ear punches were collected and relative responsiveness of cultured fibroblasts to tunicamycin, a compound stimulating protein unfolding, was quantified by evaluating the expression of different chaperones. The mice were then released into seminatural enclosures where they will be maintained in a natural social structure for 6 months. After that period, mitochondrial respiratory capacity and reactive oxygen species production will be evaluated in liver and skeletal muscle. Mice with a higher UPR and lower corticosterone level are predicted to display higher mitochondrial performance than mice with a lower UPR.

63-1 YANG, Y*; RICHARDS-ZAWACKI, CL; University of Pittsburgh, Pittsburgh, PA; *yusan.yang8@gmail.com*
Male Contest Limits Assortative Female Preference in a Color Polymorphic Poison Frog
Assortative mate preferences (i.e. the tendency to mate with phenotypically similar individuals) are widespread in animals and are hypothesized to facilitate speciation by limiting gene flow among diverging populations. However, male-male competition can either reinforce or suppress the expression of mate preferences. Therefore, it is essential to quantify the combined effect of both mate choice and intrasexual competition on mating patterns when studying the evolution of reproductive isolation. The strawberry poison frog (*Oophaga pumilio*) is a highly color polymorphic species at an early stage of divergence. Females generally prefer males of the same color morph, and this assortative pattern has been interpreted as a support for speciation via sexual selection. However, this inference does not account for male-male competition. We experimentally tested the relative importance and interaction of female preference and male-male competition. Females were housed with two size-matched, differently-colored males. We manipulated male territoriality so that the female's preferred phenotype is either the territory winner or the loser in the enclosure. These trios were kept together until one pair produced tadpoles, which we then genotyped to reveal paternity as direct evidence of reproductive success. Females mated assortatively when her preferred phenotype was the territory winner, but not when her preferred phenotype was the loser. This supports the hypothesis that male territorial status is a stronger driver of mating pattern than female color preference. Our results highlight the interaction between mate choice and intrasexual competition, and the importance to consider the combined effect of both selective forces in shaping phenotypic divergence and speciation.

134-6 YANG, DY*; GAMEL, K; FLAMMANG, B; SHORTER, KA; University of Michigan, Ann Arbor, MI, The University of Akron, Akron, OH, New Jersey Institute of Technology, Newark, NJ; *yangyayu@umich.edu*
Modeling and Experimental Evaluation of Traditional and Remora-inspired Suction Cups
Bio-logging tags enable behavioral studies of marine mammals and are often secured to the animals using suction cups to minimize impact. A secure attachment that does not interfere with locomotion or influence animal behavior is a key element of the tag system. Cup performance is dependent on the mechanics of the attachment surface. Marine mammal skin is made up of an anisotropic nonhomogeneous distribution of integrated tissue layers that possess variable viscoelastic properties which exhibit a nonlinear stress-strain relationship during loading and unloading processes. Current understanding of the biomechanical interface between the skin and cup is limited, and the experimental evaluation of suction cup performance on soft tissue is lacking. In this study, a specifically designed test setup that incorporates a uniaxial tension test machine, a pressure transducer and a camera is used to record the force, elongation, pressure differential, and deformation of a suction cup on a soft surface during controlled loading. Data from the experiment are used to create a simplified model of the coupled system that is used to examine design parameters and performance trade-offs between cup designs. These design tools are then used to refine and experimentally evaluate a remora-inspired suction cup design. These results provide an improved understanding of the coupled cup/skin system, as well as facilitating bio-inspired suction cup design.

102-1 YANG, ZY*; EASY, RH; AVERY, TA; Acadia University; *jacksonyang@acadiau.ca*

Identification and quantification of Atlantic Salmon Salmo salar, Arctic char Salvelinus alpinus, Cod Gadus morhua, and Capelin Mallotus villosus in Striped Bass diets in Labrador

In 2017, Striped Bass were found for the first time along the coast of Labrador, Canada. The presence of Striped Bass in Labrador can potentially affect local fisheries because it is a piscivorous predatory fish. Striped Bass may feed on commercially fished and 'at-risk' species such as Atlantic Salmon, *Salmo salar*, Arctic char, *Salvelinus alpinus*, Cod, *Gadus morhua*, and Capelin, *Mallotus villosus*. Our objective was to use traditional and molecular tools to identify and quantify Striped Bass diets. Three methods of diet analysis were chosen for this study: traditional analysis (TA) through dissecting stomachs and counting identifiable prey using morphological methods or examination of otoliths, molecular analysis (MA) whereby gastric DNA was used to identify prey to species, and stable isotope analysis (SIA), which was used primarily to identify diet trophic level. In general, TA identifies prey within a few days of being eaten, whereas MA widens this window to perhaps a week. SIA provides a diet indicator on a local trophic level perhaps reflecting several weeks. Stripe Bass carcasses were collected from recreational anglers, and from commercial fisher bycatch. The current focus is to develop the MA method. MA uses quantitative PCR to identify target species and provide a proportion of different prey species in the overall diet. The method relies on species-specific primers targeting conserved genes in suspected prey. Using various diet analysis methods may provide a more reliable and robust picture of these large predators.

6-4 YANG, Y*; PAN, Y; UYANIK, I; COWAN, NJ; Johns Hopkins University; *yyang138@jhu.edu*

The Selection of Stimuli Affects Non-parametric System Identification for Refuge Tracking Behavior in Eigenmannia virescens

Mathematical models are widely used to study animal behaviors. But for high-level tasks like sensorimotor processing, dynamics cannot be easily predicted by simple physical models. In these cases, data-driven system identification techniques are essential. This study focuses on system identification of refuge tracking responses in weakly electric glass knifefish, *Eigenmannia virescens*. During refuge tracking, fish swim forward and backward to track the movement of an actuated refuge. In these experiments, we command the refuge to follow one of two predefined input signals tuned to have similar overall signal power: (1) a sum of sinusoids comprising 13 single sine components with frequency of 0.1 Hz-2.05 Hz and (2) noise, filtered to 0 Hz-2.5 Hz. We use real time image processing software to record digitized refuge and fish trajectories. Given these input-output data, we use non-parametric system identification techniques to estimate the Frequency Response Function (FRF) of refuge tracking responses. To investigate how input signal selection affects FRF estimation, we performed an Empirical Transfer Function Estimate (ETFE) of the FRF. Preliminary results for N=2 fish suggest that ETFE performs reasonably well for the sum-of-sines stimulus, likely due to the high signal-to-noise ratio at a small number of frequencies, but produces erratic estimates for the pseudorandom input. Fortunately, FRF estimation for the noise stimulus is dramatically improved by introducing overlapped hamming windows to smooth time domain data. We find the improved noise input FRF estimation is similar to the result of deterministic input case, a critical validation that refuge tracking dynamics are approximately linear in this regime.

34-2 YAP-CHIONGCO, MK*; VARNEY, RM; KOCOT , KM; University of Alabama, University of Alabama , University of Alabama and Alabama Museum of Natural History ; *mkyapchiongco@crimson.ua.edu*

What the Shell-less Aplacophorans Can Tell us About Molluscan Biomineralization

The great diversity and success of molluscs can partially be attributed to their ability to secrete diverse biomineralized structures. Aplacophora is a group of vermiform molluscs that lack a shell but are instead covered with calcareous scales or spines called sclerites. Aplacophoran sclerites are composed of calcium carbonite polymorphs like conchiferan (e.g., gastropod and bivalve) shells, but homology of these different biomineralized structures has not been tested. Transcriptomic and proteomic approaches have provided insight into the genes and proteins responsible for patterning the shells of conchiferan molluscs. These studies have shown the expression of both highly conserved and lineage-specific genes in mantle transcriptomes of distantly related mollusc species. Investigation into the biomineralization toolkit of aplacophoran is needed. Here, we present an ongoing project aimed at addressing these questions focusing on draft assemblies of the solenogaster aplacophorans *Neomenia megatrapezata* and *Epimenia babai*. Our sequencing strategy combined Illumina HiSeq X paired-end reads and multiple flow cells of Oxford Nanopore GridION long reads to produce hybrid assemblies using MaSuRCA. Assemblies will be scaffolded with optical mapping and subsequently annotated to identify genes involved in biomineralization. Proteomics will be used to confirm protein products within the sclerites and expression patterns will be examined in larvae using *in situ* hybridization. This work will shed light on the formation of sclerites, their homology to conchiferan shells, and the biomineralization toolkit of the last common ancestor of Mollusca.

39-5 YARGER, AM*; SMITH, AJ; RAZMI, AN; FOX, JL; Case Western Reserve University, Cleveland, OH; *amy9@case.edu*

Haltere synchrony in flies

The ability of dipteran insects (flies) to perform complex acrobatic maneuvers while maintaining stability in flight is due in part to specialized sensory organs called halteres. Halteres are modified hind-wings that oscillate in antiphase with the fore-wings during flight and detect inertial forces produced by body rotations (Nalbach 1993). The halteres are coupled with the wings during flight through mechanical linkages in the thorax (Sane et al. 2015). How is the synchronization between the two halteres maintained and are they synchronized during other behaviors? Is the connection between the left and right haltere purely mechanical or is there a sensory component to their synchronization as well? Here we show that the halteres are not synchronized during walking and flight initiation behaviors. Halteres are only reliably synchronized when flies flap their wings at high frequencies with the wings intact. Flies with clipped wings flapping at high frequencies or intact wings that are either stationary or flapping at low frequency do not oscillate their halteres in synchrony. This suggests that sensory input from the wings may contribute to haltere-haltere synchronization.

20-6 YEGHISSIAN, TG*; DARNELL, MZ; University of Southern Mississippi; *talene.yeghissian@usm.edu*
Impact of Thermal-Hydric Stress on Surface Activity and Waving Behavior of Fiddler Crabs
Social and environmental factors influence the behavioral decisions of all animals. Behavioral choices require time and energy investment, and tradeoffs occur when critical behaviors must be performed in specific habitats. Ectotherms in thermally stressful environments reduce stress by altering microhabitat use, yet behavioral thermoregulation using shade or burrows can lead to missed opportunities if functions like reproduction must occur in stressful areas. Fiddler crabs mate in high intertidal areas, where males perform a claw-waving display. Courting behavior is limited by heat and desiccation stress, which is ameliorated by retreat into cool moist burrows. Yet this burrow retreat requires a cessation of mating behavior and thus a potential fitness cost. We examined impacts of thermal-hydric stress on surface activity and waving behavior in the fiddler crab *Uca pugilator*, an abundant sandy-shoreline species extending from Massachusetts to the Bahamas. The present study focuses on three sites along the species latitudinal-thermal range: Panacea, FL (30.0159°N), Beaufort, NC (34.7115°N), and Stony Brook, NY (40.9357°N), allowing for the examination of the trade-off between thermal-hydric stress and mating success under different thermal regimes. Operative body temperatures were quantified using physical models and compared to preferred temperatures to assess thermal habitat quality at each site. Simultaneously, body temperatures and hydration states of surface-active males in the high-intertidal breeding area were measured. In order to evaluate the impact of thermal-hydric stress on surface activity and waving behavior, video footage was used to quantify activity budgets (including time on the surface and time in the burrow) across a range of thermal conditions.

P1-92 YEH, S/Y*; MEADE, M/E; ROGINSKY, J/E; SCHULZ, J/R; Occidental College; *syeh@oxy.edu*
Primary Cell Culture of Adult Zebrafish Spinal Neurons for Electrophysiological Studies
Zebrafish *(Danio rerio)* have increasingly become a popular organism in biological research fields, especially in neuroscience, as a paradigmatic vertebrate model. The mature adult zebrafish model can be used to study neural circuits and the physiological processes within the spinal cord. Building upon previous zebrafish research regarding the spinal cord, we developed a novel *in vitro* primary cell culture for spinal neurons from adult zebrafish. After dissecting and isolating neurons from an intact spinal cord, we cultured robust cells displaying distinct neuronal morphology and behavior with large cell somas, long axons and dendrites, and highly active growth cones. To characterize cells in culture as neurons, immunofluorescence labeling, calcium imaging, and patch clamping were performed. The staining of the cells with NeuN antibody, neuronal nuclear marker, and axonal marker acetyltubulin confirmed neuronal characteristics. Morphologic analysis was supported by calcium imaging which confirmed an excitable cell type. Lastly, analysis from the recordings of whole cell patch clamping revealed strong voltage-dependent currents, both inward and outward, as well as tetrodotoxin-blocked sodium conductance, consistent with a neuronal phenotype. Altogether, these tests successfully and effectively differentiated the spinal neurons from adult zebrafish from other surrounding cells in culture confirming successful isolation. The cultured neurons represent a powerful new system to investigate modulators of endogenous ion channel targets in the zebrafish model system.

16-2 YEN, J*; LI, W; Georgia Tech, School of Biol.Sciences, Atlanta, GA, Georgia Tech, School of Industrial Design, Atlanta, GA; *jeannette.yen@biosci.gatech.edu*
Bio Inspired Design: translating biology to engineering and design
Biologically inspired design takes superlatives of Nature and translates into designs and engineering processes. Bio inspired design avoids design fixation by starting off with multiple sources of bio inspiration. In our class, each student searches for phylogenetically related, convergently evolved and champion adaptors for a function of interest, e.g. capability to stick and detach or be seen or unseen. Often, design rules in nature are found using phylogenetic and convergent evolutionary analyses to find common patterns leading to similar functions for deep bio inspired designs. Once key articles are found for each organism, the student performs a functional decomposition to define how the behavior of interest occurs. Then - as a team of 5 interdisciplinary majors, they have a total of at least 25 sources of bio inspiration. To organize the information into a useful format, a species x function matrix is constructed where each function is linked to the functional decomposition that details how that function is achieved. To invent a new bio inspired design requires the students to find key patterns and abstract that to an application. Evaluation of designs based on creativity and analogical goodness-of-fit will be examined. Some tricks of the trade that promoted interdisciplinary learning and engagement in education include: cognitive dissonance, functional matrices, pattern abstraction, identification of key levers. Consideration of performance and scalability are applied to test credibility vs technology readiness level [TRL] of the final designs. Teaching this course gives value to Nature through this education and research avenue.

P2-12 YEO, AC*; RICHARDSON, EL; DEAKER, D; GARCIA, A; BYRNE, M; ALLEN, JD; William and Mary, Monash University, University of Sydney, Université Libre de Bruxelles, University of Sydney; *acyeo@email.wm.edu*
Effects of gamete age on development in broadcast spawning marine invertebrates
For broadcast spawning organisms like echinoderms, the timing of gamete release is essential for successful fertilization. However, synchronous release of gametes does not always occur. Delayed fertilization due to asynchronous gamete release or delayed contact between sperm and eggs could potentially have a large impact on the successful development of broadcast spawning organisms, but few studies have tested the effects of egg age on development beyond fertilization. Prior studies have focused on the presence of a fertilization envelope as a marker of successful development, however, the presence of a fertilization envelope alone does not necessarily indicate whether the fertilized zygote will develop into a normal larva and therefore may be a misleading indicator of successful development. We tested the effects of egg age on fertilization and early development in two species of asteroid echinoderms: *Asterias forbesi* and *Acanthaster cf. solaris.* We found that both species exhibited similar developmental responses to delayed fertilization. Fertilization was consistently high (90-100%) within 30 minutes of gamete release and/or egg maturation, but declined variably after that among different females. Importantly, we found that the frequency of normal development drops dramatically at each stage of development (blastula, gastrula, bipinnaria), with fewer than 30% of offspring developing to normal bipinnaria if fertilized more than an hour after gametes have been released. Our work suggests that researchers should carefully monitor gamete maturation and release in asteroid echinoderms, and likely other marine invertebrates, to avoid artifacts of gamete age on experiments with marine invertebrate eggs, embryos and larvae.

P1-71 YERGA, KM*; GAMS, HC; YOUNG, VKH; Saint Mary's College, Notre Dame, IN; *kyerga01@saintmarys.edu*

Body mass in female and male fox squirrels (Sciurus niger) at Saint Mary's College

Urbanization can affect native species by altering their food availability, habitat structure, and other factors of survival, such as predation. An urban environment provides species with increased anthropogenic food sources that can affect body condition. The Saint Mary's College campus in Notre Dame, IN is an urban environment that supports a robust fox squirrel population (*Sciurus niger*). This arboreal squirrel relies heavily on campus resources for food, breeding grounds, and shelter. Our study focuses on the differences in scaled body mass between female and male fox squirrels (*Sciurus niger*) captured on campus during the months of June and July 2019. Previous work on sexual dimorphism in small mammals has found that males usually weigh more than females for purposes of mate competition and defense. We collected measurements of body mass, body length, tail length, ear length, and hindfoot length. These values were used to generate scaled mass indices for male and female fox squirrels. Each individual was sexed and tagged with a stainless steel ear tag for identification purposes. Scaled body mass is indicative of body condition, which is a more accurate way to assess the health of an individual compared to mass alone. Our results indicate that there is no significant difference in female and male scaled body mass and body condition. Failure to detect differences in scaled body mass between female and male fox squirrels may be attributed to the timing of data collection and small sample size. Future work will include additional year-round data collection over the course of several years to generate a long-term profile of body mass trends within the Saint Mary's College squirrel population.

P3-138 YOHANNAN, K*; NARICI, V; MASS, S; MASS, Spe; SUNY New Paltz; *yohannak2@hawkmail.newpaltz.edu*

Further studies of axolotl and tiger salamander kinematics

Axolotls (*Ambystoma mexicanum*) are neotenic salamanders that do not typically complete metamorphosis and remain aquatic when they reach sexual maturity; however, some axolotls may undergo spontaneous metamorphosis. Tiger salamanders (*Ambystoma tigrinum*) are non-neotenic terrestrial salamanders that normally complete metamorphosis and are within the same genus as axolotls. These studies investigate kinematics in order to compare movement of the metamorphosed axolotl to the tiger salamander during walking. By digitizing the movements of these salamanders with slow-motion video, the motion and position of specific body parts were tracked, measured and compared.

P1-116 YORK, JM*; ZAKON, HH; University of Texas at Austin; *juliayork@utexas.edu*

Identifying potential molecular thermosensors in Antarctic notothenioid fishes

Notothenioid fishes are the primary taxon of fishes in the Southern Ocean. The Southern Ocean surrounds Antarctica and is isolated by topography, currents, and thermal environment: the water is generally stable between -1.9 and +1°C. Notothenioids have a variable but limited ability to acclimate to temperatures as low as +4°C, therefore, we would expect their nervous system to be sensitive to temperatures in this range. Most putative molecular thermosensors in vertebrates belong to the transient receptor potential (TRP) family of ion channels, but the most cold-sensitive TRP channel thus far characterized activates above +14°C, far above any ecologically-relevant temperatures for notothenioids. We expect molecular thermosensors to be expressed in the trigeminal ganglion because it is the sensory ganglion that innervates the head. To identify candidate molecular thermosensors we dissected the trigeminal ganglion and whole brain from five *Harpagifer antarcticus*, a notothenioid in the family Harpagiferidae. We extracted the RNA and conducted TagSeq to identify which TRP channel genes were highly expressed in the trigeminal ganglion, and we normalized expression relative to the whole brain to eliminate genes that were generally expressed. We found high relative expression of TRPV1 and TRPM1. TRPM1 has not previously been identified as a thermosensor, but appears to have a gene duplication in notothenioids that could enable evolutionary novelty. TRPV1 is a noxious heat sensor in other vertebrates, sensing in the range of >25°C, a range never experienced by notothenioids. Thus, TRPV1 might be tuned to much lower noxious heat sensation in these fish. Future directions include characterizing the thermosensitivity of this channel using electrophysiology.

139-7 YOUNG, JW*; WILSON, A; PHELP, T; DUNHAM, N; NEOMED, Cleveland Metroparks Zoo; *jwyoung@neomed.edu*

Effects of support diameter on vertical leaping performance in tree squirrels (Sciurus carolinensis)

Leaping is common in small-bodied arboreal tetrapods, where acrobatic locomotion is often required to move among the three-dimensional substrates of the canopy. However, the narrow diameters of arboreal substrates may constrain leaping performance by comprising mechanical work production during the push-off phase of the leap - i.e., the period prior to aerial take-off when the animal is accelerating the center of mass (CoM) by pushing against the substrate. We used high-speed video and force platforms to investigate the mechanics of three squirrels (*Sciurus carolinensis*) leaping vertically from flat substrates and poles 9.1, 4.9, and 3.5cm in diameter. Contrary to our hypothesis, leaping performance was not compromised by substrate diameter. Projected leap height (calculated using ballistic equations) did not significantly differ among substrates ($p=0.18$). However, squirrels used different mechanical strategies to produce the mechanical work required to accelerate the CoM on flat and cylindrical substrates. For a given level of performance (i.e., terminal CoM velocity at the end of push-off), squirrels emphasized greater force production on flat substrates versus increased CoM displacement on cylindrical substrates (all $p\leq0.001$). Our results have implications for understanding leaping adaptations in arboreal animals, suggesting that adaptations to maximize CoM displacement (e.g., greater hindlimb lengths) maybe be more critical for increasing performance than adaptations to maximize force production (e.g., increased hindlimb muscle mass). Future work should investigate how other aspects of arboreal substrate variation, such as angular orientation and compliance, affect mechanical work production during leaping. Supported by NSF BCS-1126790 and NEOMED

22-2 YOUNG, R/L*; HOFMANN, H/A; University of Texas at Austin; *youngrl@utexas.edu*

Leveraging Network Analysis to Study the Evolution of Sociality in Vertebrates

Recent comparative studies of complex behavioral phenotypes find evidence that homoplasy, or the evolution of similar phenotypes in unrelated species, is often associated with similar transcriptomic patterns even across vast phylogenetic distances. However, comparing complex phenotypes fairly across distantly related species requires the development of rigorous, quantitative metrics, which have been elusive for the study of social evolution because behavioral phenotypes represent emergent properties of the organism and integrate multiple organismal systems (e.g., sensory and motor systems). Here, we introduce a quantitative approach to characterize diverse forms of sociality and compare independent evolutionary transitions to social dominance. Social dominance systems – where some individuals are dominant over subordinate group members, control access to resources, and attain more reproductive opportunities – have evolved repeatedly across vertebrates and beyond. In such groups, individuals may assume a specific set of behavioral characteristics – such as social polymorphisms or reproductive tactics (or "types") – because of genotype, developmental events, individual condition, and/or social or ecological opportunity. Using a quantitative social network modeling approach, we compare attributes of social status and network position across types in independent evolutionary transitions to social dominance systems. We ask how components of social dominance vary, whether similar social and reproductive types emerge, and how types vary in social status attributes and network properties across vertebrates. Finally, we discuss the implication of our approach for identifying the evolutionary origins and underlying neuromolecular mechanisms of social dominance systems.

P2-195 YOUNG, VKH*; STARNER, MK; BAEZA, JA; BLOB, RW; Saint Mary's College, Notre Dame, IN, Clemson University, Clemson, SC, Clemson University, Clemson, SC; *vyoung@saintmarys.edu*

Comparative Limb Bone Scaling and Shape in Emydid Turtles

Limb bone morphology often correlates with functional demands placed on animals by the environment. Recent studies of limb bone allometry that compared functionally divergent turtle taxa showed that highly specialized lineages like sea turtles exhibit extensive flattening of the humerus that contributes to the development of flipper-shaped forelimbs, allowing for lift-based swimming (i.e. underwater flight). In addition, terrestrial tortoises showed more robust humeri and femora, potentially reflecting specializations for resisting high torsional loads during terrestrial walking and digging behaviors. However, whether such morphological distinctions might be found within clades that encompass species with diverse ecological habits has not been tested. Emydid turtles represent such a clade, with both semi-aquatic and fully terrestrial representatives. To test whether limb bone size and shape varies among closely related taxa with divergent ecological habits, we assessed scaling patterns and overall morphology of the humerus and femur of 23 turtle species representing four emydid genera: *Graptemys* (semi-aquatic), *Pseudemys* (semi-aquatic), *Trachemys* (semi-aquatic), and *Terrapene* (terrestrial). Our analyses indicate that in general, emydid taxa scale isometrically for most length-diameter and length-mass relationships. However, interestingly, *Graptemys* exhibit long and robust humeri (relative to body mass), as well as femora that are long relative to body mass. The robust forelimbs of *Graptemys* might provide advantages in handling robust, shelled food items attached to the substrate, such as mussels and gastropods, or assist as the turtles pull themselves out of the flowing water to bask.

S1-9 YOUNG, JN*; DAWSON, HM; RUNDELL, SM; University of Washington; *youngjn@uw.edu*

Responses of Antarctic Microalgae to Seasonal Shifts in Temperature and Salinity

Microalgae in polar oceans possess a number of physiological adaptations that allow them to thrive under extreme conditions. These include adaptations to low light, cold temperatures and fluctuating salinity. Here, I will show results from two experiments testing how Antarctic microalgae respond to seasonal shifts in temperature and salinity. In the first experiment we use metabolomics to explore how axenic laboratory cultures of the sea-ice diatom, *Nitzschia lecointei*, respond to a matrix of temperatures (-1C, +4C) and salinities (32, 41). While there was only a small effect on overall growth rates and photophysiology, we observed large shifts in the metabolome, particularly in the regulation of compatible solutes. For the second experiment, natural phytoplankton communities from the Western Antarctica Peninsula are incubated at three different conditions: sea ice (-3C, salinity 50), seawater (0C, salinity 32) and melt (+3C, salinity 20). Here, we saw clear differences in net community production and composition over a 10 day period. We will discuss how seasonal changes in temperature and salinity impacts cellular composition and health and how responses at a cellular level could have far reaching impacts on larger scale polar ecology and biogeochemistry.

1-3 YOUNG, BA; Kirksville College of Osteopathic Medicine; *byoung@atsu.edu*

CSF flow dynamics in Alligator mississippiensis: The role of the myodural bridge

Despite its clear clinical significance, the underlying flow dynamics of the CSF remain poorly understood. The study was intended to quantify some of the physiological features that contribute propulsive force to the CSF. Juvenile American alligators (*Alligator mississippiensis*) with a body length of approximately 180 cm were physically restrained on an inversion table. Using a cuffed tracheal tube the animal was connected to a mechanical ventilator and anesthetized with Isoflurane. Fluid pressure catheters were surgically implanted into the spinal and cranial subdural spaces. Surface EKG electrodes were placed on the ventral scalation on either side of the heart. The suboccipital muscles of the myodural bridge were surgically exposed on one side, implanted with bipolar EMG electrodes, and activated with a stimulating probe. In the first round of the experiment CSF pressure was recorded simultaneously with heart rate, ventilatory airflow, myodural bridge contraction, while the animal was exposed to varying gravitational gradients. FFT analysis of the pressure recordings was used to examine the relative contribution of the ventilatory movements and arterial pulsations. During the second round of the experiment ultrasonography was used to test for displacement of the dural sheath during contraction of the myodural bridge. During the third round of the experiment, artificial microspheres were introduced into the CSF and their pattern of movement studied using laser Doppler ultrasonography. All three rounds of the experiment provided support for the hypothesis that the myodural bridge functions as a CSF pump.

P3-159 YOUNG, BA*; ADAMS, J; KNOCHE, L; CRAMBERG, M; KLASSEN, M; Kirksville College of Osteopathic Medicine; *byoung@atsu.edu*

Regulation of Narial Patency in Alligator mississippiensis

Terrestrial and amphibious tetrapods have developed a variety of means of regulating the patency of the external nares. Crocodilians have smooth muscles associated with the external nares and nasal vestibulum. There is a distinct narial dilator that attaches to the caudal surface of the narial vestibulum and nares. Though previous descriptions vary, there is a narial constrictor that, rather than encircling the nares, wraps around the dilator muscle. Narial closure is achieved when the relaxed narial dilator is protracted against the caudal surface of the nares and narial vestibulum by the compressive force of the narial constrictor. In this way, the narial dilator functions as its own antagonist, performing opposite roles depending on whether it is in an active or passive state. Anatomical analyses included dissection, histology, and a variety of imaging techniques (CT, MRI, and 3-D reconstruction of micro-CT imaging). We explored this unusual system using sub-adult (approximately 180 cm in total length) American alligators (*Alligator mississippiensis*). The animals were restrained without chemical sedation or anesthesia, in a way that did not impede normal ventilator movements. A Hall effect sensor was placed on the dorsolateral surface of the animal to document the movements of the ribs. A fluid-filled soft latex catheter was inserted into one nares and connected to a fluid pressure transducer. Bipolar EMG electrodes were inserted using hypodermic needles. There was no clear temporal pattern between ventilation and narial closure, and the force of the ventilatory airflow was highly variable. The nares were patent at rest. The dilator and constrictor muscles had distinct, non-overlapping activity pattern, the amplitude of which correlated with the strength of the ventilator airflow.

P3-195 YOUNG, R/L*; WEITEKAMP, C/A; TRIKI, Z; BSHARY, R; HOFMANN, H/A; University of Texas at Austin, USA, University of Neuchatel, Switzerland, University of Neuchatel, Switzerland; *youngrl@utexas.edu*

Comparative Transcriptomics of Cooperative Behavior in Cleaner Wrasses

The neural transcriptome is closely tied to behavior. Still, high variability of gene expression – even among members of the same population – poses a challenge for linking expression patterns with specific behavioral outputs. Phylogenetic comparative methods provide a powerful tool to identify molecular pathways repeatedly associated with similar phenotypes across species. Combined with the ever-increasing accessibility of transcriptomes obtained from diverse species, comparisons of neural transcriptomes across species can serve as natural experiment to test evolutionary hypotheses of behavioral evolution. However, phylogenetic relatedness can confound associations between expression and phenotypes and appropriate, phylogenetically-informed transcriptomic analyses are still debated. Here, we take a comparative transcriptomic approach to identify neuromolecular correlates of a fascinating example of interspecific cooperation, cleaning behavior in coral reef wrasses. Multiple species of Labridae wrasses have independently evolved cleaning behavior, where cleaners remove ectoparasites, mucus, and damaged tissue from larger, often predatory "client" fish. We combine multiple comparative approaches with standard transcriptomic analyses including differential gene expression and dimensionality reduction to compare the forebrain transcriptomes of six wrasse species. We characterize neural gene expression diversification across species and identify robust correlates of cleaning behavior and other behavioral and ecological phenotypes. Our results provide insights into the evolution of the neuromolecular basis of cooperative behavior.

P3-21 YOUSEFELAHIYEH, M*; MILLER, DR; KIM, H; PARKER, J; California Institute of Technology; *myousefe@caltech.edu*

Dalotia coriaria as a genetic model system of animal symbiosis

Interactions between species are a fundamental feature of the natural world, occurring among organisms. A major domain which is less understood in modern biology is how animal species at the molecular and neurobehavioral levels interact with each other. In Parker lab, we propose to study a new model system, rove beetle that has evolved to live symbiotically inside colonies of social insects. This model organism can be exploited to address mechanistic questions. How does one species evolve the means to recognize and interact effectively with another species? Are there neural circuits for perception of other organisms? Does evolution co-opt pre-existing circuits to foster interspecies recognition and behavioral interactions? To answer these questions, we apply new technologies to the Greenhouse rove beetle, Dalotia coriaria. Dalotia embodies the free-living groundplan that has repeatedly spawned symbiosis in a family of rove beetles, Aleocharinae. Dalotia can serve as a recipient organism for the introduction of exogenous genes and modifications with genetic materials.Experimental approach of this research follows two main aims: 1) Engineering gene manipulation in Dalotia. The goal of this project is to determine how specific genes influence rove beetle's brain and behavior, gland development and defensive compound biosynthesis. ¸ Engineering gene knockouts in Dalotia. To develop method for CRISPR/CAS9 gene editing via non-homologous end joining to make single gene knockouts in Dalotia. 2) Optimizing introduction of exogenous DNA into the Greenhouse rove beetle. A method was developed in Dalotia to transform the genome via transposon-mediated transgenesis. The goal of this project is to generate a transgenic toolkit for Dalotia neurobiology and chemical ecology.

123-1 ZACHOS, LG; University of Mississippi; *lgzachos@olemiss.edu*

Matrix Models for Logistic Plate Growth in Sea Urchins

The coronal skeletons of modern sea urchins comprise 20 columns of plates, of two basic types (ambulacral and interambulacral), in five paired sets. Following an initial plate configuration derived from the rudiment, plates are added to each column over the lifetime of the animal. The growth of individual plates of a sea urchin can be accurately modeled by logistic functions. The addition and growth of plates in a single column can be envisioned as a stage-structured density-dependent Markov chain, where stages represent plate cohorts. The parameters of the Markov model, represented on a life cycle graph, can be used to define a tridiagonal transition matrix. Inclusion of density-dependent factors results in a model of logistic growth. The model has the general form $\boldsymbol{X}(t+1) = \boldsymbol{QAX}(t)$ where $\boldsymbol{X}(t)$ is an n-dimensional size vector at age t, $\boldsymbol{A}$ is an $n \times n$ tridiagonal transition matrix, and $\boldsymbol{Q}$ is an $n \times n$ density-dependent damping matrix. The model thus assumes that the growth of a plate at a given stage is dependent on the state of the previous plate stage and some function of plate density. The transition matrix and damping coefficients are unknown *a priori* and require solution of an inverse model using a Monte Carlo approach. The inverse models are derived from estimated plate growth series (beginning with the classic Deutler model of *Echinus esculentus*) and adult plate size distributions measured from 3D scans of species representative of major clades of regular sea urchins. The Markov model is shown to generate the stable plate size distributions of these different clades of sea urchins. This offers a new approach to quantifying the growth of these organisms.

110-2 ZACK, EH*; SMITH, SM; ANGIELCZYK, KD; University of Chicago, The Field Museum of Natural History , The Field Museum of Natural History, University of Chicago; *ehzack@uchicago.edu*

Zoo Versus Wild: Trabecular Bone Architecture in Captive and Wild Xenarthra

Captive (zoo) specimens in natural history collections allow researchers to inspect the morphologies of rare or CITES-listed taxa, but the lifestyles, diets, and lifespans of captive animals differ from those of their wild counterparts. To quantify these differences, we compared trabecular bone architecture (TBA) of dorsal vertebrae in captive and wild specimens of xenarthran mammals (anteaters, armadillos, and sloths). Because TBA develops following in-vivo bone force regimes, it reflects ecology and behavior, but this also means that it may differ between captive and wild specimens of the same species. We collected µCT scans of the last six presacral vertebrae in 15 species of fossorial, terrestrial, and suspensorial xenarthrans ranging in body mass from 120g (*Chlamyphorus*) to 35kg (*Myrmecophaga*). For each vertebra, we measured bone volume fraction (BVF), trabecular number (TbN), mean trabecular thickness (TbTh), degree of anisotropy, and trabecular orientation. We found that wild specimens generally have a greater BVF, TbN, and TbTh than captive specimens, but that these metrics differ by species, vertebral position, ecology, and pathology. Wild specimens of *Dasypus* have greater BVF, TbN, and TbTh than captive specimens in the three most posterior lumbar vertebrae, but have much closer metrics in the anterior three vertebrae. In *Choloepus*, BVF, TbN, and TbTn are greater in wild specimens in the anterior vertebrae and more similar in the posterior vertebrae. Arthritis in captive *Tamandua* increased BVF and TbTh, whereas wild specimens had greater TbN. Our results add to overall understanding of variation in mammalian vertebral trabecular bone, and suggest caution when including captive specimens in research on the relationship between TBA and ecology.

112-7 ZAHOR, DL*; GLYNN, KJ; CHIPARUS, S; CORNELIUS, JM; Eastern Michigan University, Oregon State University; *dzahor@emich.edu*

Bioaccumulation of lead (Pb) in songbirds following the Flint, Michigan drinking water crisis

Pollutants, including heavy metals, can interact with animal physiologies in ways that negatively impact fitness. Human activities emit unnatural levels of metal pollutants such as lead into the environment in various ways, including historical use of leaded gasoline, current vehicular emissions, industrial production and other types of catastrophes. Lead is a neurotoxin that is highly persistent in the environment and is thus of particular concern for humans as well as wildlife. From 2014 to 2017 the Flint, Michigan drinking water crisis caused lead to leach from pipelines into the drinking water in some neighborhoods. While human residents were belatedly alerted to avoid ingestion of lead-contaminated water, there was not a similar caution taken when watering lawns or otherwise allowing the drinking water to exit Flint homes and enter the environment. Although water levels are now reduced, lead is highly persistent and tends to remain in the upper layers of soil where it is bioavailable to wildlife. Foraging differences, however, may drive patterns of lead exposure across species and may influence bioaccumulation despite the fact that species may forage in the same site. Omnivorous songbirds forage for invertebrates by digging into the soil, potentially exposing them to soil lead, while granivores forage at the tops of plants for seeds or in feeders. This research explores bird blood lead levels of both omnivores and granivores in Flint, MI in watered and unwatered sites in comparison to reference sites within southeast MI. This study investigates the impact of the Flint, MI water crisis on lead exposure of urban songbirds, as well as how diet impacts lead accumulation.

P2-75 ZAHRA, E; GRIFFIN, L; MINICOZZI, M; MASS, M*; SUNY New Paltz, Minnesota State University, Mankato; *masss@newpaltz.edu*

Endocrine disruption and planarian regeneration

Environmental xenoestrogens such as Bisphenol-A (BPA), BPS, and Octyl-phenol have been shown to depress and delay regeneration in a variety of flatworms at high doses, and to work in a non-monotonic fashion and stimulate regeneration at very low doses. These compounds are environmental pollutants used in the manufacture of polycarbonate plastics, thermal printing systems, detergents, health and beauty products, food packaging, epoxy resins and other industrial processes. Prior work in our lab has suggested that bisphenol compounds are interacting with an ER-like pathway in planaria. In vertebrate systems, weak estrogen receptor (ER) agonists like BPA are known to repress ER responses at high doses and increase ER responses at low doses in a manner very similar to the decrease and increase in growth we observe in regenerating planaria. Since regeneration involves both proliferation and cell movement, we hypothesized that cytoskeleton may be one of the mechanisms by which endocrine disruptors are affecting regeneration in flatworms.

58-3 ZAKAS, C*; ROCKMAN, M; North Carolina State University, New York University; *czakas@ncsu.edu*

How Maternal Genetic Effects Shape Developmental Evolution

Phenotypic evolution in animals is constrained by the mechanics of early development. Large-scale evolutionary changes are initially shaped by developmental program, where simple trade-offs can ultimately result in a vast spectrum of physiological, morphological, and ecological differences. Because early development is strongly influenced by maternal effects, we focus on finding the genetic contribution of maternal background to developmental phenotypes. The polychaete *Streblospio benedicti* provides a unique opportunity to address this issue because it has two types of mothers who produce distinct offspring that differ in egg size, early development, and larval morphology. It is an ideal genetic model for understanding how transitions in developmental program evolve. Using crosses between these types, we reveal the distribution of genetic factors affecting a suite of developmental phenotypes. Our cross design further isolates the role of maternal genetic effects on development. By identifying the loci responsible for early developmental phenotypes, we begin to uncover how major transitions in development evolve.

P3-217 ZALOGA, AR*; NEAL, S; KOENIG, KM; Harvard Univerisity, Harvard Univeristy, Harvard University; *arzaloga@college.harvard.edu*

Axon Guidance Cues in the Visual System of the Cephalopod Doryteuthis pealeii

Cephalopods have a highly-acute, image-forming camera-type eye and a large, complex nervous system. Essential to building this nervous system is the process of axon pathfinding, where neurons extend axons toward their target cells, form synapses and build a precise network. While axon guidance molecules and mechanisms of axon pathfinding have been studied in vertebrates and *Drosophila*, very little is known about this process in cephalopods. Many proteins have been previously shown to play a role in axon pathfinding in vertebrates and *Drosophila* and include members of highly conserved families of axon guidance molecules: Semaphorins, Netrin, DCC, Slit, ROBO, Eph, and Ephrin. These proteins are the attractive and repulsive cues that guide axons as they grow toward their target cells and often work in pairs. As a model to study axon guidance in the squid, we focus on a step during visual system development when photoreceptors in the cephalopod eye extend their axons to synapse on the outer nuclear layer of the optic lobe, where visual processing occurs. Our goal is to better understand which guidance cues may be important during this process. We have used the squid *Doryteuthis pealeii* as an embryological model to characterize the spatiotemporal expression of 12 candidate genes during visual system development. The expression patterns of these genes give insight into their function during cephalopod neurodevelopment and the process of photoreceptor axon growth and synapse formation in the optic lobe. This work is the first investigation of the role of canonical axon guidance molecules during nervous system development of any cephalopod.

S8-9 ZAMORE, SA*; ARAUJO, N; SOCHA, JJ; University of Colorado Boulder, Virginia Tech; *sharri.zamore@colorado.edu*

Visual behavior in flying snakes: measurement and exploration with virtual reality

Flying snakes (genus *Chrysopelea*) are highly visual animals that climb, jump, and glide while navigating through tropical rainforests. These arboreal behaviors likely produce different visual problems than terrestrial locomotion. For example, gliding requires visual assessment to determine position, distance, and speed. To wit, flying snakes have large eyes, and perform visually-guided behaviors, such as tracking birds that are flying overhead. While some visual behaviors in arboreal snakes are well-described, their visual capabilities and its role in decision-making remains largely unknown. The visually sensitive flying snake is an ideal model to explore this relationship.

The use of closed-loop stimuli—stimuli that is modified based on behavioral output—has proven to be a useful tool for exploring visually-guided behaviors. To test the functionality of closed-loop systems on visually-guided limbless locomotion, we developed an Immersive Virtual Visual Arena (IVVA). The arena is a 3-foot cube with translucent walls onto which images were back-projected from LCD projectors. The projected visual stimuli were created with Unity 3D game development software. We tracked a marker on the head of the snakes using a Leap Motion Sensor, d its position using OpenCV, and updated the stimuli in Unity. The snakes were placed on an air table inside the cube, which inhibited translative locomotion, while allowing them to freely move.

Preliminary results show that behavioral responses in the virtual arena approximate those seen in an "analog" setup. This talk will 1) review previous visual research on the flying snake (*Chrysopelea paradisi*) that contributed to the specifications of the IVVA, and 2) discuss the design and development of an affordable IVVA, and its performance when exploring visually guided behaviors.

27-6 ZANG, H*; NAGAYASU, N; Lyon College, University of Arkansas ; *hannah.zang@lyon.edu*

The evolution of novel neuropeptides in Cnidaria: investigating the function of a lineage-specific neuropeptide RPamide during sea anemone development

Understanding how new neuropeptides become functionally integrated into the pre-existing nervous system during evolution is important for understanding the mechanism by which neural function evolves. In Cnidaria, novel neuropeptides known as RPamides likely emerged in the sea anemone lineage, but little is known about their function. To bridge this fundamental knowledge gap, we examine the expression pattern of RPamides during development of the sea anemone *Nematostella vectensis*. We show that RPamide precursor transcripts first occur during gastrulation in scattered epithelial cells in the aboral ectoderm. These RPamide-positive epithelial cells then extend basal neuronal processes toward the aboral pole, forming an aboral sensory nerve net of the planula larva. During planula development, several RPamide-positive sensory cells become part of the aboral apical organ, and a subset of endodermal sensory cells begin to express RPamides. During metamorphosis into a polyp, RPamide-positive sensory cells in the aboral ectoderm disappear via apoptosis, and RPamide-positive ectodermal sensory cells develop in growing oral tentacles. These expression data strongly suggest a role of RPamide in sea anemone development and/or larval behavior. Interestingly, the developmental expression pattern of RPamide differs from those of RFamide and GLWamide - ancient families of neuropeptides thought to have been present in the last common ancestor of Cnidaria and Bilateria – indicative of distinct functions. Thus, during cnidarian evolution, RPamides may have acquired new function that pre-existing neuropeptides did not have; alternatively, RPamides may have inherited old function that pre-existing neuropeptides subsequently lost. We are currently taking a CRISPR-Cas9-mediated gene knockout approach to directly test RPamide function during *N. vectensis* development.

10-3 ZAPFE, KL *; LAROUCHE, O; PRICE, SA; Clemson University; *kzapfe@g.clemson.edu*

Macroevolutionary Relationships Between High Contrast Patterns and Body Shape in Teleost Fishes

Visually striking animals are found across the Tree of Life, but we are still untangling the story behind bold color pattern displays. Color patterns can help animals achieve crypsis or communicate with conspecifics and other species. Bold patterns such as stripes (horizontal linear patterns), bars (vertical linear patterns) and contrasting spots can also help animals avoid recognition by visually disrupting a recognizable body outline. Further, some disruptive patterns are hypothesized to combine with movement to create erroneous speed and direction signals (motion dazzle), or redirect attacks towards the anterior (motion redirection). Such misleading signals are hypothesized to help thwart predation. While studies continue to resolve the proximate drivers of color pattern evolution, the influence that they have on broad taxonomic and time scales remain much less resolved. We employ phylogenetic comparative methods to explore the evolutionary history of color pattern traits across a diverse radiation of vertebrates: teleost fishes. Additionally, we assess the potential coevolutionary relationship between bar and stripe patterns and body streamlining in fishes. Consistent with early observational work on fish depth and stripe orientation on the body, our quantitative macroevolutionary analysis reveal that fishes with different orientations of linear patterning (i.e. barring, striping) possess differing body shapes. Fishes with bar patterns have less streamlined body shapes while striped fishes have more streamlined shapes. These results suggest that predation predation pressure may drive coevolutionary dynamics between color pattern traits and morphology over macroevolutionary scales.

118-3 ZELDITCH, ML*; SWIDERSKI, DL; University of Michigan, Ann Arbor; *zelditch@umich.edu*
An Incisor Runs Through It I. Variational modularity of the squirrel mandible
Modularity enables complex morphologies to evolve, by coordinating variation of functionally coupled traits within modules, which, being quasi-autonomous, can vary independently of other modules under stabilizing selection. Consequently, modular complexes can be optimized without interfering with adaptations of other modules. The rodent mandible has long served as a classic example of modularity, but the hypothesis of modularity for the mandible is of two "functional modules": the tooth-bearing front and the muscle-bearing back. That is difficult to reconcile with the idea that the mammalian mandible can be modeled as a beam because a beam is not divisible into two functional complexes along its length. It is even more difficult to reconcile with the rodent mandible because the incisor runs through it, well past the boundary between the modules, and the masseteric muscle overlaps the border in the other direction. The question is: why would the front/back model fit so well, if it does? We find, using the Covariance Ratio, that it does fit well in eight species of squirrels from both tree- and ground-squirrel lineages. However, if we extend the beam of the horizontal ramus posteriorly through the back (to the bases of the posterior processes), and analyze correlations between the shapes of those regions, we find a high correlation between that posterior segment and the anterior (diastema) and/or middle (molar) in most of the species we analyzed. The exceptions are species that have high correlations between those anterior regions and at least one posterior process. On average, regions of the front may be more highly integrated than they are with the back but in no case are front and back even quasi-autonomous.

P3-212 ZELLER, KR*; MARSHALL, CA; GHALAMBOR, CK; Colorado State University; *kyndall_zeller@sbcglobal.net*
The effects of local adaptation and rearing salinity on sustained swimming performance in freshwater estuary dwelling Trinidadian guppies
Salinity tolerance is thought to play an important role in defining range limits for many aquatic species. Yet, the degree to which distribution patterns are determined by local adaptation versus acclimation remains unknown for most aquatic organisms. In Trinidad, the euryhaline guppy (*Poecilia reticulata*), behaviorally avoids brackish and saltwater. We thus hypothesized that guppies experience some decline in fitness upon entering brackish water. In fact, previous lab work suggests acute exposure to brackish water causes a reduction in activity levels, reaction times, and metabolism. To investigate if long-term acclimation could overcome these challenges, we conducted a common garden experiment. We reared out wild-caught guppies to the second generation (F2) and looked at the effects of developmental plasticity due to salinity rearing conditions on fitness. We split F2 broods at birth and raised them in either fresh (0ppt) or brackish (30ppt) water. Sustained swimming performance was measured in adults under various treatments: their rearing condition and several away environments, mimicking swimming up or down a salinity gradient. Performance was recorded in terms of critical swimming velocity (U_{CRIT}), the maximum swimming velocity a fish can withstand for a given period of time. If populations are locally adapted to freshwater, we predict that guppies reared and tested in freshwater will do better than their counterparts, reared and tested in brackish water. If developmental plasticity can overcome salinity challenges, we predict no difference in performance between fish reared and tested in brackish water and those reared and tested in freshwater.

P2-114 ZENG, R*; BROWN, A; SISNEROS, J; University of Washington ; *zengr@uw.edu*
Age-related change in the auditory sensitivity of zebrafish (Danio rerio)
Vertebrate animals can undergo changes in sensory physiology due to aging. Despite our increased knowledge regarding the underlying mechanisms of aging, we still have a limited understanding of how senescence (aging process) affects hearing across different vertebrate taxa. In our project, we aimed to characterize the effects of aging on the auditory sensitivity of zebrafish (*Danio rerio*). Zebrafish have become a valuable model system for studying the effects of aging because of their availability in large numbers, ease of manipulation, and relatively short lifespan (~40 months on average for wildtype zebrafish). In addition, research on the zebrafish auditory system may eventually provide insight into conserved molecular and genetic mechanisms of age-related hearing loss across multiple taxa. Previous observations in mammals have shown that age-related hearing loss has the most impact on encoding high frequency sounds. We test the hypothesis that zebrafish undergo age-related changes in auditory sensitivity such that the higher frequencies in the zebrafish hearing range are more greatly affected by senescence. We characterize the auditory sensitivity of three zebrafish age groups: 12-month-old, 20-month-old and 36-month-old. We used AB/WIK zebrafish from each of the age groups and applied the auditory evoked potential (AEP) recording technique for measuring the sensitivity of the zebrafish auditory periphery (i.e., the combined auditory evoked response of the inner ear, auditory nerve, and brainstem). We found that the oldest age zebrafish group (36 months of age) had the poorest auditory sensitivity across the five tested frequencies (115Hz, 800Hz, 1850Hz,3700Hz, 4500Hz). In ongoing measurements, we also aim to characterize aging-related auditory changes in adult zebrafish using a behavioral paradigm.

P3-147 ZENG, Y*; NIEDERS, K; PETRICHKO, S; FUDGE, D; Chapman University; *yzeng@chapman.edu*
Epidermal Threads in Pacific Hagfish (Eptatretus stoutii)
The proteinaceous slime threads in hagfish slime feature one of the highest aspect ratios among biological fibers in nature and are essential to the mechanical property of the slime, which functions as a defense against gill- breathing predators. Prior to extracellular export, these slime threads are generated within the cytoplasm of gland thread cells and coiled as highly organized skeins. Both the developmental process and evolutionary origin of the slime threads remain unclear, but they are likely homologous to the epidermal threads generated by epidermal thread cells that are found near the basal region of epidermis. Here, we studied the morphology of epidermal threads in Pacific hagfish (*Eptatretus stoutii*) using confocal laser scanning microscopy and three-dimensional geometry reconstruction. Distributed along the inner periphery of the cell membrane, the epidermal threads are characterized by a loosely packed helical geometry and thus exhibit lower aspect ratio than gland threads. Examining the ontogenetic variation of the chiral helix of gland threads, we further show two levels of structural organization. These results offer the first detailed study on epidermal thread morphology in hagfishes and provide insights into the origins of threads produced in the slime glands.

56-2 ZHANG, Y*; BARNES, SJ; KENKEL, CD; University of Southern California, Los Angeles, CA; *yingqizh@usc.edu*
Familial effects on the thermal tolerance of the brooding coral Porites astreoides during early life stages
The capacity to adapt and/or acclimatize to local environmental conditions has been demonstrated in a wide array of marine organisms to date. Understanding how these adaptive and acclimatory mechanisms affect species survival and fitness at different life stages is especially relevant in the context of climate change, as certain life stages may be more vulnerable to environmental disturbances than others. Reef-building corals exhibit the classic marine life-history dichotomy of sessile adult populations linked by a dispersive planktonic larval stage. We found that the majority of the variation in symbiont density, chlorophyll a and protein content, and survival under acute thermal stress in *Porites astreoides* larvae was driven by larval family rather than day of release or reef origin. To investigate whether this family-level variation persists into recruit and adult life stages, we collected adult *P. astreoides* from two reef zones in the lower Florida Keys in April 2019 and obtained both larvae as well as subsequent juvenile recruits from 5 colonies per site. After being exposed to a 32 °C sublethal temperature treatment, *P. astreoides* adults, larvae, and recruits were sampled to quantify symbiont density, chlorophyll a content, and total carbohydrate content. Additionally, photographs were taken to assess the growth rate of recruits and bleaching status of both recruits and adults throughout the heat stress experiment. This study expands on our understanding of familial effects on thermal performance by linking traits across multiple life stages, which has significant implications for population dynamics and overall community structure in a rapidly changing ocean.

106-7 ZHANG, Y*; WONG, HS; University of Memphis, Buck Institute for Research on Aging ; *yzhang24@memphis.edu*
Are mitochondria the major contributor of reactive oxygen species production? No.
Oxidative stress has been proposed as a mediator underlying different life-history trade-offs. Evolutionary physiologists often assume mitochondria as the center of release and regulation of reactive oxygen species (ROS) levels. Unfortunately, evidences for such an assumption were limited since ROS production levels from different cellular compartments in intact cells were difficult to quantify. Previous studies relied heavily on intracellular fluorescent probes, but such probes are only useful for qualitative rather than quantification of ROS. In the present study, we employed a newly developed method to accurately quantify ROS production from different cellular compartments. We surveyed a large variety of cell types including primary cells from different tissues of various species. Moreover, we also measured changes in ROS profile during tunicamycin induced ER stress as an example for a stress model. Overall, the significance of mitochondria ROS production varies between cell types, with their contribution to total cellular ROS production being less than 50% in majority, but H9c2 cardiomyocytes, of cell types. On the other hand, other cellular compartments such as NADPH oxidases contributed a major portion of ROS production in some cell types under unstressed conditions. These data show mitochondria are not the major site of ROS production in all cell types. As a result, when studying life-history trade-offs, we must be cautious and should not always assume ROS production comes from mitochondria.

P3-92 ZHANG, P*; XU, S; HEATH-HECKMAN, E; JACOBS, D; University of California, Los Angeles; *pzhang312@ucla.edu*
Historical DNA Methylation Using Computational Methods
DNA methylation leaves behind 'footprints' in genomes which allows us to infer historical DNA methylation levels and patterns using genomic or transcriptomic data. Empirical measurements of invertebrate DNA methylation has shown a distinct signature compared to vertebrate methylation. Here we use computational methods investigating the said 'footprints' as well as methylation-related genes to sample broadly across invertebrate taxa. Our results show that the bimodal distribution of gene body DNA methylation is likely to be the ancestral state in Metazoa, and DNA methylation is absent in a number of invertebrates.

107-3 ZHAO, X*; MILLION, W; KENKEL, C; University of Southern California, Department of Biological Sciences, Los Angeles, CA; *xuelinzh@usc.edu*
Gene expression noise its role in coral responses to environmental variation
Analysis of differentially expressed genes under different stressors or development stages is a common method for investigating physiological response mechanisms of organisms and their tissues. But notably, gene expression in individual cells is often noisy and dynamic and the expression patterns of genetically identical cells under the same environment can be widely different. This gene expression noise has been shown to significantly impact the fitness of unicellular organisms. However, the influence of noise on the relationship between genotype and phenotype in multicellular organisms remains unclear. Reef-building corals are a promising system in which to evaluate the ecological and evolutionary significance of gene expression noise as asexual clonal reproduction is a common life-history strategy. We analysed gene expression variability between replicate clonal fragments (~ramets) of ten Acropora cervicornis genotypes growing in a common garden nursery. Hundreds of genes exhibiting high inter-ramet variability, or noise, were identified. Different genotypes varied in the top ontology enrichments identified among noisy genes, but genes related to structural organization were enriched in all genotypes. Almost half of genotypes also exhibited enrichment of genes related to toxin activity and energy metabolism in noisy genes. Patterns of expression noise will be correlated with both global expression and other physiological trait responses of ramets following one year of transplantation to novel reef environments in the Lower Florida Keys to quantify the role of expression noise in acclimatization to environmental variation.

76-2 ZHONG, B*; SCHIEBEL, P; OZKAN-AYDIN, Y; BROWN, M; CARRUTHERS, A; RIESER, J; SPONBERG, S; GOLDMAN, D; Goergia Tech; *baxichong8@gmail.com*
Coordination of body undulation and leg wave during centipede locomotion, in a geometric perspective
Epimorphic centipedes running at high speed display a characteristic body undulation. Elucidating the interplay between body and limb waves and the resulting running performance is difficult because of the many degrees of freedom in the flexible body and numerous limbs. We characterized the body undulation and the limb stepping wave using amplitude and wavenumber, and captured the coordination by the relative phasing between the two waves. We used geometric mechanics (e.g. Hatton et al., PRL, 2013), in which inertial effects were assumed negligible, to model and predict the locomotion performance of a centipede with 19 leg pairs and body joints. Our theory predicted that the body-lengths traveled per cycle (BLC) was maximized when the body undulation (with 1.6 waves, maximum body curvature = 0.42 BL^(-1)) had a phase 2.51 rad ahead of the leg wave (with 2 waves, maximum leg joint angle 0.65 rad). At this phase offset, the theoretical prediction of centipede speed was 0.40 BLC, compared to 0.25 BLC with no body undulation and 0.10 BLC with worst body undulation. Using high-speed video, we captured the motion of five trials of centipede (*Scolopendra polymorpha* , 19 leg pairs) running on a treadmill and tracked the position of each leg and body. The centipedes ran at 0.41±0.05 BLC with a leg-body phase offset of 2.51±0.71 rad, in good agreement with our best-performing theoretical prediction. The good agreement indicated that our geometric approach can capture the kinematics of centipede locomotion without including inertial effects. Further, our results revealed that body undulations enhanced running performance, but only if the body and limbs were properly coordinated.

120-3 ZHU, JJ*; WAINWRIGHT, DK; LAUDER, GV; BART-SMITH, H; University of Virginia, Charlottesville, VA, Harvard University, Cambridge, MA; *jz8n@virginia.edu*
Tuna robotics: design and control of an autonomous underwater vehicle inspired by tuna
Design of bio-inspired autonomous underwater vehicles (AUVs) is of scientific and technological importance. Most current autonomous "fish-like" robots usually suffer from slow speed, energy inefficiency, low maneuverability, and high cost. Our previous thunniform robotic platform has successfully addressed these challenges by implementing a high efficient propulsion system. In this study, we further developed the Tunabot into an autonomous version of the platform. The autonomous Tunabot is powered by a 42 Wh battery pack and controlled with an ARM Cortex M3 microcontroller. It measures 387.4 mm long, 129.8 mm high, and 205.3 mm wide. The design of the Tunabot adopted a modular approach for the purpose of easy maintenance and upgrade. Each module has a unique function and can be altered independently, which significantly reduces the design iteration cycle time and overall cost. Current work is focusing on pitch and yaw control of the Tunabot. A multi-sensor fusion and trajectory control algorithm was developed and applied to the system. The effect on pitch control was investigated with different size of the pectorals fins based on previous biological data. Yaw was controlled by asymmetric tail flapping. Finally, the kinematics of the autonomous Tunabot are compared to data obtained from live tuna and from the laboratory test-platform version of the Tunabot.

62-2 ZHU, R*; MATTHEWS, DG; WANG, J; LAUDER, GV; DONG, H; BART-SMITH, H; University of Virginia, Harvard University; *rz6eg@virginia.edu*
Effects of Peduncle Stiffness on Propulsive Performance of Tuna-shaped Panel
Peduncle joint is an essential part of tuna swimming. Here we propose a simplified panel model to study the effects of peduncle joint stiffness on swimming performance. We use composite 3d-printed structure to vary the stiffness around the peduncle region and measure the thrust and power consumption at a wide range of swimming kinematics with different frequency and heave amplitude. Flow structure around the panel in high-performance cases is also visualized using Particle Image Velocimetry and Computational Fluid Dynamics.

P3-36 ZIAUDDIN, LS; SARATHY, J; HALL, IC*; HALL, Ian; Benedictine University; *ihall@ben.edu*
Prolactin influences osmoregulation in adult African clawed frogs, Xenopus laevis.
Amphibians are able to osmoregulate through their skin, and hormones can modulate these processes. In anuran amphibians, prolactin typically increases ion movement across the skin. However, the specific ions and mechanisms vary by species. We hypothesize that part of this variation can be explained by differences in life history traits, specifically the amount of time the adults of different species spend submerged in water. Unlike most anuran amphibians, African clawed frogs, *Xenopus laevis*, are fully aquatic even during the adult stage of their lifecycle. Thus, we investigated the effects of prolactin on ion transport in *X. laevis* by measuring short circuit current across isolated skin samples. Prolactin increased short circuit current in a dose-dependent fashion. Prolactin increases apical to basolateral sodium transport across the skin. The effect on key transporters, such as the epithelial sodium channel (ENaC) and the Na^+ /K^+ pump, were investigated using nystatin permeabilization and protein inhibitors (ex. amiloride and ouabain). Further, the transient nature of the prolactin-induced current suggested a role for intracellular calcium. To delineate the role of intracellular vs. extracellular calcium, experiments were conducted in calcium-free buffer and chelating intracellular calcium using BAPTA. Future experiments will measure intracellular calcium concentration in response to prolactin using spectrofluorometry and the calcium sensitive fluorescent probe FURA-2AM.

S1-4 ZIEGLER, AF*; HAHN-WOERNLE, L; POWELL, B; LUNDESGAARD, Ø; CAPE, M; SMITH, CR; University of Hawaii at Manoa, Honolulu, HI, University of Hawaii at Manoa, Honolulu, HI and Norwegian Polar Institute, Tromso, Norway, University of Washington, Seattle, WA; *ziegler8@hawaii.edu*

From Glaciers to Benthos: Fjord Ecosystem Processes in a Changing Climate

Glaciomarine fjords of the West Antarctic Peninsula (WAP), e.g., Andvord Bay, form distinct hotspots of benthic biomass/diversity. Important drivers of these patterns may be 1) enhanced fjord primary productivity and export flux, and 2) limited larval dispersal from restricted fjord circulation. We found during our FjordEco Project that inner-middle Andvord Bay experiences limited meltwater/sediment input, high annual primary production, and high export flux, all of which support high benthic respiration and macro-/megafaunal abundance and biomass. Massive phytodetritus deposition mid-fjord in Jan 2016 led to rapid feeding by deposit-feeders yet still produced a substantial sediment food bank to sustain detritivory throughout the winter. To explore the influence of larval dispersal on benthic community structure, we used a high-resolution hydrodynamic/particle-tracking model to simulate larval transport. Larval dispersal between fjords is limited on ecological time and space scales due to weak circulation in most parts of the fjords. Occasionally, katabatic wind events may export near-surface larvae (

109-2 ZIKELI, S*; YAMADA, K; YAP, K; ZHANG, Y; KIARIS, H; HOOD, W; Auburn University, University of South Carolina; *slz0001@auburn.edu*

Shy and Stressed? Correlations Between Corticosterone Level, Unfolded Protein Response, and Animal Personality

Variation in animal personalities has been linked to experience and response to stressors. The stress response has been traditionally evaluated by quantifying glucocorticoids yet, individual variation exists in how animals, and presumably cells, respond to a similar signal. One intracellular process that likely underlies variation in the response to stress is the unfolded protein response (UPR). The variation in UPR has been shown to correlate with the several variables relevant to human health, but our understanding of the ecological relevance of variation in UPR is poor. To evaluate the relationship between the UPR and animal personality, we use deer mice (Peromyscus maniculatus) as a model, as they have been shown to display considerable individual variation in UPR. Prior to the onset of this study, responsiveness in cultured fibroblasts to tunicamycin, a compound stimulating protein unfolding, was quantified for each mouse by evaluating the relative expression of different molecular chaperones. The mice were then released into semi-natural enclosures where behavior was quantified. The behavioral tests included a novel object test, handling test, and predator cue test. Fecal samples were collected from individuals monthly to evaluate corticosterone.. We predict that animals with bolder personalities, and more ‘extreme' behavioral responses, will show greater capacity to perform under stress, i.e. display a relatively high UPR phenotype. These bolder animals may also have lower baseline corticosterone. Together, these data could help to illuminate the necessity of acknowledging individual variation at the cellular level and may identify the UPR as a modifier of the stress response at the organismic level.

P3-241 ZINN, D*; CONNOR, C; WATSON, CM; Midwestern State University; *drzinn1999@gmail.com*

Indications of stress in Anolis oculatus and Anolis cristatellus populations two years after Hurricane Maria

In September of 2017, Hurricane Maria struck the Island of Dominica and caused widespread destruction. Among the animals effected by this major disturbance event are the endemic *Anolis oculatus* and the invasive *Anolis cristatellus*. At that time, our research laboratory had been studying both Anoles on the island for two years. This allows us the opportunistic ability to compare basic health indicators from before and after. We compare a basic body condition index (Snout-to-vent length / mass) of lizards sampled prior to Hurricane Maria to those sampled in the two years since to determine if the aftermath of the storm caused noticeable deleterious effects. Some populations of *Anolis oculatus* were affected more strongly than others. Among those populations most affected, we recorded increased instances of noticeable parasites and generally poor body conditions. Additionally, specimens of both species sampled post-hurricane presented multiple scars and healed wounds that were generally absent from populations sampled pre-hurricane.

P3-183 ZONA, JO*; MACOMBER, GE; MARTIN, AL; MOORE, PA; Saginaw Valley State University, Bowling Green State University; *jozona@svsu.edu*

Effects of Population Structure on Crayfish Behavior

Animals compete for resources by engaging in agonistic interactions. Animals use self and mutual assessment when engaging in these bouts, including but not limited to factors such as: size, sex, resource acquisition and population structure . The size of conspecifics plays an important role in determining the outcomes of interactions. This study examines the structure of a population, in relation to size, and its influence on assessment and the dynamics of aggression within the population. More specifically, this study attempts to empirically address the influence of population structure on aggression by examining the duration and frequency of interactions. Variably sized populations of four crayfish each are provided with four identical shelters and are recorded for 24-hour trials to determine fight duration, frequency, and outcome . Data suggests populations with primarily large animals (4 large, 3 large vs. 1 small) fight longer as compared to populations with an equal or greater number of small animals (2 large vs. 2 small, 1 large vs. 3 small). Additionally, numbers of fights were found to be greater in populations with all large animals. This project is a component of a broader study to provide empirical evidence to better understand the relationship and dynamics between self and mutual assessment in populations, and to develop a better understanding of how population structure affects the intricacies of aggressive behavior in animal contests.

15-6 ZUMAJO-CARDONA, C*; AMBROSE , BA; The New York Botanical Garden; The Graduate Center-CUNY, The New York Botanical Garden; *czumajo@nybg.org*

Evolution of the integument and its implication in seed plant evolution.

Gene duplication plays a decisive role in organismal diversification and the appearance of novel structures. One of these novel structures are the ovules/seeds which have unique morphological characteristics across seed plants. The genetic mechanisms regulating ovule development have been identified in Arabidopsis thaliana. The initiation of the ovule development appears to be mainly controlled by SEEDSTICK, BEL1 and AINTEGUMENTA. The Arabidopsis ovule has two integuments covering the nucellus. The asymmetric growth of the outer integument reorients the ovule resulting in an anatropous orientation. While BEL1 establishes the initiation of the integument development, INNER NO OUTER (INO), KANADI1 and 2 (KAN1/2) act in the proper development of the outer integument and ABERRANT TESTA SHAPE (ATS/KANADI4), is involved in outer integument development and the proper separation of both integuments. UNICORN (UCN), acts in the outer integument, repressing ATS. SHORT INTEGUMENTS1 (SIN1) is involved in cell elongation of both integuments and the sin1 mutant integuments do not cover the nucellus. We made a comprehensive search of these genes involved in the correct morphological development of the integuments to assess large scale duplications in addition, to expression analyses in the gymnosperm Ginkgo biloba. Our results show that each of these genes has undergone a different evolutionary history across seed plants and that the expression patterns are not conserved between Arabidopsis and Ginkgo. Our results suggest that the integument development network is not conserved between angiosperms and gymnosperms. We analyze the possible impact of these results on the morphological evolution of ovules as well as on the evolution of major seed plant lineages.

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The Society for Integrative and Comparative Biology

950 Herndon Parkway, Suite 450

Herndon, Virginia 20170

Phone: 703-790-1745 - 800-955-1236

FAX: 703-790-2672

Email: SICB@BurkInc.com

Web: www.SICB.org