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28.2 ABBOTT, E.M.*; SAWICKI, G; AZIZI, E; Univ. of California, Irvine, North Carolina State Univ. and Univ.of North Carolina, Chapel Hill; *abbotte@uci.edu*

Modeling the effective utilization of tendons during eccentric contractions

Series elastic elements, such as tendons and aponeuroses, greatly contribute to stable and efficient movement. Specifically, muscles and tendons interact to buffer the rate of energy input to the muscle and limit the rate of stretch applied to the fascicle during active lengthening. These interactions may mitigate muscle damage that occurs during active lengthening. Previous studies on active lengthening of muscle−tendon units (MTUs) have identified that the effective use of tendons relies on the timing of activation and the contractile kinetics. However, experimental work is limited in the scope of parameters that can be explored. Therefore, models of muscle−tendon units may 1) allow for examination of a broader range of parameters, 2) limit the use of experimental animals and 3) be readily adopted into larger scale musculoskeletal models. We used a model consisting of a Hill−type contractile element (CE) and a series elastic element (SEE) to explore the role of muscle tendon interactions during energy dissipating tasks. In this model, we incorporated realistic mechanical and contractile properties from bullfrog plantaris MTU. Our results suggest that contractile kinetics affect active lengthening such that slower rates of force development can limit the loading of elastic elements and faster relaxation rates can apply a faster stretch to muscle fascicles during tendon recoil. Regarding timing of activation, early activation allows lengthening to begin at shorter muscle lengths. The results of the simulations are consistent with our experimental results and therefore provide a useful framework for predicting how changes in motor control strategies, fiber type composition, or mechanical properties of tendons affect the integrated performance of the muscle−tendon unit during energy dissipating tasks.

P1.54 ABDEL−RAHEEM, S.T.*; ALLEN, J.D.; College of William and Mary; *stabdelraheem@email.wm.edu*

Developmental responses to temperature and salinity fluctuations in echinoid echinoderms

Animals that reside, reproduce, and develop in nearshore habitats are often exposed to strong fluctuations in abiotic conditions, including temperature and salinity. We studied the developmental responses of five echinoid echinoderms (sea urchins and sand dollars) to increased temperature and reduced salinity. We aimed to document two recently described phenomena: delay of hatching (DOH) and polyembryony. First, we found that DOH is a widespread response to reduced salinity. Hatching was delayed by 79% in *Echinarachnius parma*, 26% in *Strongylocentrotus droebachiensis*, 22% in *Lytechinus variegatus*, and 17% in *Dendraster excentricus*. Only embryos of *Arbacia punctulata* failed to delay hatching in response to reduced salinity. Second, we observed polyembryony in both of the irregular echinoids studied (*E. parma* and *D. excentricus*). In *D. excentricus*, we tested the competency of twinned and normal embryos to reach metamorphosis. We found that twin embryos generated from a single egg are both capable of reaching metamorphosis. To investigate the mechanisms underlying polyembryony, we tested whether reduced Calcium levels in low salinity seawater reduce cell−cell adhesion and allow cells to separate and develop as multiple embryos within a fertilization envelope. We also tested whether osmotic stress caused swelling of the fertilization envelope, allowing embryos more room to produce multiples, or delay hatching into a later, larger stage. However, neither reduced Calcium levels nor osmotic stress alone appears sufficient to induce polyembryony. We currently hypothesize that the swelling of the hyaline layer within the fertilization envelope may facilitate polyembryony.

69.5 ABEHSERA, S.*; GLAZER, L.; TYNIAKOV, J.; PLASHKE , I.; CASPI , V.; KHALAILA , I.; AFLALO , E. D.; SAGI, A.; Ben−Gurion University of the Negev; *abehsera@post.bgu.ac.il*

Binary patterning of chitin metabolism pathways in a crayfish: a tool for multi gene studies of the molt cycle in arthropods

Crustaceans and insects share the mechanism of a molt cycle in which their chitinous exoskeleton is periodically shed to enable growth and metamorphosis. This cycle is a major event in skeletal assembly comprising physiological changes and typical endocrine control and behavior. Numerous molt related genes are involved in these events, therefore studying these genes is of importance when investigating crustaceans and insects. Using NGS technology we constructed a molt related transcriptom library and developed a novel multi gene expression approach, binary patterning. Our approach is of particular interest for molt cycle studies since it is a simplifying tool that gives an integrative temporal picture for such a complex process. The binary patterning was used to study the transcriptomic picture during molt cycle of the crayfish *Cherax quadricarinatus* in two exoskeletal forming epithelia, the gastrolith and the mandible cuticle. An enrichment test revealed that chitin metabolism related genes are differentially expressed in each of the studied tissues. The functions of the chitin related transcripts were assigned to pathways mapped by a generalized pancrustacean−based KEGG. The activity of the forming epithelia of the gastrolith was detected mostly during premolt while in the mandible cuticle it was active throughout the entire molt cycle. Our results give a highly integrative view of chitin metabolism in exoskeletal tissues of a crustacean. Such binary patterning approach could be applicable for investigating molt cycle in other organisms of the pancrustacean group and might shed light on temporal and spatial aspects of such a complex biological mechanism in a simplifying manner.

P2.122 ABOLINS−ABOLS, M*; KETTERSON, E/D; Indiana University; *mabolins@indiana.edu*

Physiological correlates of plasticity in territorial aggression

Behavioral plasticity, which is an important component of life−history trade−offs, is measured by comparing individual behavior across contexts to produce a reaction norm. Plasticity in aggression in the presence or absence of a predator can be critical to the trade−off between survival and reproduction. To date, only a handful of studies have measured aggression in the face of predation risk or addressed the mechanisms that might mediate this critical trade−off. We have previously shown in captive Dark−eyed Juncos (a songbird) that presence of a predator significantly increases plasma levels of corticosterone (CORT). Here we measured plasticity in territorial behavior by comparing behavior of wild male juncos during simulated territorial intrusions (STIs) that were or were not preceded by exposure to a predator. We asked whether CORT or other physiological measures (breathing rate) predicted plasticity in aggression. Birds in the study received two treatments in a random order. In one treatment we simulated the presence of a predator on a male's territory by displaying a hawk mount and playing heterospecific alarm calls for 5 minutes. After the predator was removed, we simulated a territorial intrusion by playing back conspecific male songs and measured aggressive behavior. In the control treatment, we presented a non−threatening object and played heterospecific songs, followed by an STI. Preliminary trials comparing birds across treatments revealed lower levels of territorial behavior after seeing the hawk mount and hearing alarm calls. However, individuals differed considerably in their plasticity and mean behavior. We will report how the slope and elevation of individual reaction norms in aggressive behavior relate to CORT and other physiological measures.

P2.55 ADAMS, A. M.*; TURNER, J. S.; BERLINER, P.; PINSHOW, B.; Ben−Gurion University of the Negev, State University of New York College of Environmental Science and Forestry; *amandaad@post.bgu.ac.il*

The burrows of distantly related scorpions are very similar in architecture

Many animals spend much of their time underground in burrows that serve as refuges from predators and adverse environmental conditions. The intimate association between animal and burrow leads to the question how has burrow architecture been shaped by natural selection on the builder? We used the burrows of scorpions to test the idea that burrow structure is an extension of the organism's physiology, regulating the temperature and moisture levels of its surroundings. Specifically, we predicted that scorpion burrows are built to minimize convective ventilation of the burrow air space. This may maintain high relative humidity in the burrow, thereby reducing the scorpion's evaporative water loss. We made aluminum casts of natural burrows of two species, one from Israel, *Scorpio maurus palmatus* (N = 20), and one from Namibia, *Opistophthalmus setifrons* (N = 4). We quantified burrow shapes and dimensions with 3D scans of the casts. *Opistophthalmus setifrons* had more tortuous (p = 0.001) burrows, but burrow depths were not significantly different between species. All burrows had in common a horizontal platform just below the surface, apparently for the scorpion to warm before emerging to hunt after dark. All burrows descend with at least two bends, to a depth where there is little diurnal temperature fluctuation, and terminate in a humid chamber. Our findings demonstrate how an ectothermic arthropod may modify its environment to serve its behavioral and physiological needs.

15.4 ADAMS, DK*; KNOX, SM; Rutgers, the State Univ. of New Jersey, Univ. of California, San Francisco; *dadams@marine.rutgers.edu*

Neural control of developmental programs as a mechanism for plasticity and evolution

Increasing evidence from multiple systems suggests that the role of the nervous system extends beyond the function, maintenance and behavior of adult metazoans to include contributions to multiple aspects of development. The peripheral nervous system has been shown to regulate morphogenesis, patterning and stem cell maintenance and differentiation. With essential roles in orchestrating development, nerves and neural signals can become a conduit for environmental signals to influence development in a coordinated manner, across multiple tissue types and even throughout the whole organism. Furthermore, temporal or spatial changes in neural development could alter morphological and functional phenotypes and thus contribute to the evolution of species. Here, we synthesize the developmental, cellular and molecular mechanisms by which neural signals alter development to gain insight into organismal plasticity and evolution.

5.5 ADJERID, K*; PENDAR, H; HARRISON, J.F.; SOCHA, J.J.; Virginia Tech, Arizona State University; *adjerid@vt.edu*

Functional compartmentalization in the hemocoel of the American locust

The hemocoel of insects is often considered as an open compartment in which hemolymph is free to flow, particularly in insects lacking a petiole (narrowed waist). However, recent work using synchrotron x−ray imaging has shown indirect evidence of compartmentalization in the American locust (*Schistocerca americana*). Here, we tested the hypothesis of compartmentalization by simultaneously measuring hemolymph pressures in the thorax and abdomen using two fiber−optic pressure sensors recording at 100 Hz (n = 11 locusts). Pressures were recorded continuously for two hours per trial. Comparing the signals from the two body segments, we observed 80% or greater correlation of patterns and magnitudes in 17.5 ±4.9% of the trial duration. However, for the majority of the trial duration (>82%), there was far less correlation between the two pressure signals (45.5±4.8%). We also recorded baseline pressures as the insects were re−oriented from horizontal to head−up or head−down positions in order to test potential effects of gravity on hemolymph pressure. We observed an average of 0.119 kPa and 0.122 kPa difference from expected values for change in hydrostatic pressures in the thorax and abdomen, respectively. These large variations in pressure patterns between abdomen and thorax suggest a functional compartmentalization within the locust that affects the flow of hemolymph between segments. Functional compartmentalization may result from movements of the gut wall or changes in the orientation of internal anatomical features; alternatively, the gut may expand or contract to allow or impede flow. These observations suggest that hemolymph circulation in locusts is more complex than previously understood. Supported by NSF 0938047.

S9.8 ADLER, F. R.; University of Utah; *adler@math.utah.edu*

Using simple models to motivate mathematics and understand cancer: Making the classroom into a workshop for collective model development

Almost everyone has experience with cancer in their family or friends, and this can provide students with motivation sufficient to overcome their fear of mathematical models to investigate further. In the active classroom, students first learn about the biology of some particular cancer, and then work together to translate that understanding into a mathematical model. This process always demands answers to new and unexpected questions that the class can investigate as a whole, and delivers a powerful message about the power of model−building as tool for clear thinking. The hard work that goes into building their own model works like nothing else to make students want to learn whatever mathematical and computational techniques they need to see what their model predicts. We will attempt to work through this whole process, although rather quickly, starting by breaking into groups to discuss and then combine our knowledge of some particular cancer, working as a large group to construct a model, identifying some unknowns, hitting the smartphones to pin them down, and thinking about how we would modify the model and use it to open up new avenues. We'll conclude with a discussion of the most effective ways to use model−building in the classroom, and of the challenges of working with classes that mix very different levels of mathematical and biological background.

93.6 ADLIMOGHADDAM, A.*; O'DONNELL, M.J.; WEIHRAUCH, D.; University of Manitoba, Mcmaster University; *umadlimo@umanitoba.ca*

The potential involvement of Rh proteins in the ammonia excretory system in Caenorhabditis elegans

Ammonia is the major product of cellular amino acid metabolism in animals. Due to the toxicity of ammonia, an efficient ammonia detoxification or excretion system is crucial to maintain hemolymph ammonia levels within a tolerable range, and to insure normal cellular function. Rh proteins, candidate genes involved in ammonia excretion strategies (AES), are highly conserved through evolution, but their physiological significance and functional essentiality in metazoans is poorly understood. C. elegans was subjected to various environmental stresses to investigate whether and to what extent Rh proteins are involved in AES. Also, gene expression analysis revealed that both Rh proteins respond to HEA, suggesting that there are likely involved in ammonia regulation. Our results about C. elegans following exposure to various pH regimes suggest that ammonia excretion is sensitive to environmental pH, with enhanced excretion rates in low pH environments. This suggested that the ammonia excretion mechanism involves ammonia trapping with an apical pathway likely via Rh proteins. Also, our tissue localization studies revealed a strong presents of Rh−r2 in the hypodermis. We used SIET to re−evaluate whether the Rh−r2 protein is critical for H+ secretion and it was shown that H+flux rates across the hypodermis are hampered in ΔRhr−2 strain compared to wild type (N2) animals. Enhanced ammonia excretion rates in N2 animals exposed to a low pH environment completely vanished in ΔRh−r2, which indicates a role of Rh−r2 in AES. Our yeast complementation assay results strongly suggested that the Rh−r1 of C. elegans is indeed capable at mediating the transport of ammonia when expressed in yeast. Taken together, our data provide the first evidence that indicates the essentiality of the Rh proteins in ammonia homeostasis in a nematode.

S9.12 ADOLPH, SC; Harvey Mudd College, Claremont; *adolph@hmc.edu*

Transforming classical models and original research into active learning activities in quantitative biology

I use in−class active learning exercises for numerous topics in ecology, introductory biology, mathematical biology and statistics courses for undergraduates. These exercises range in length from full class sessions to mini−exercises embedded within a lecture. The subjects of these activities include classical quantitative topics as well as specialized topics derived from my past collaborative research. I will describe several examples of these exercises, including: 1. An in−class exercise on the classical Lotka−Volterra competition model; 2. An exercise based on a mathematical model of phenotypic plasticity (Padilla and Adolph 1996); 3. An open−ended exercise analyzing sequences of basketball free−throw data. Students are engaged and alert while working on these activities, can choose their own pace, often work together, and can get help from teachers who circulate around the room. The in−class exercises usually lead to homework problems, often involving computer work. I will share some ideas for choosing suitable topics, for converting these topics into active learning exercises, and for adjusting the level for students with different quantitative backgrounds.

P1.132 AFSHRIANI, Z.; KHODABANDEH, S.*; ZAREI, B.; Tarbiat Modares University; *surp78@gmail.com*

Study of Endo−symbiotic Micro−algae density and distribution in the Sea anemone Stichodactyla haddoni, tissues by histology method

Zooxanthellae or endo−symbiotic dino−flagellates are unicellular micro−algae that are found at high population densities into the corals. Their density consideration is important for host autotrophic nutritionally, because they are photosynthesis and transfer much of the fixed carbon to the host animals. In the sea anemones for studding of their density, homogeneities and isolation methods were used normally. It is reported that, in this method the percent of zooxanthellae degradation is high, thus in the present study the histological method was examined. First, 6 randomly selected sea carpet, *S. hadoni* were collected from the inter−tidal areas of the eastern part of the Hormuz Island (from Persian Gulf), and pieces (1cm"^{3}")from different parts of oral disc of six sample were separated by a cutter and fixed in Bouin's solution. After paraffin embedding, the samples sectioned in 5 μm thickness and stained with Hematoxilin and Eosin (H&E). The slides then studied under a Nikon light Microscope. Result showed that a good density of the zooxanthellae exist in gastrodermal sections of tentacle (1,289,200 cell/μm "^{2}") and also into the mesentare gastrodermal cells (528,000 cell/μm"^{2}"). This density in the tentacles sections was much more than the mesanter sections and also, zooxanthellae showed more density in the basal parts of mesentare gastroderms (640,960 cell/μm"^{2}") than belong and far than them (415,975 cell/μm"^{2}). Intracellular zooxanthellae main diameters also were 9.4 μm. We concluded that, by using of histology method we can determine the endo−symbiotic microalgae, division, size, distribution and density which can be a useful method for future studies as environmental factors effects on these animals.

77.7 AGUILAR, J J*; KARSAI, A; GOLDMAN, D I; Georgia Tech; *jjaguilar1@gmail.com*

Pressure, drag and virtual mass influence hops on granular media

Impulsive movements in deformable media are generated during locomotion on water or sand. When basilisk lizards run on water, reaction forces arise resulting from combinations of hydrostatic pressure, drag forces with quadratic velocity dependence and virtual mass forces associated with accelerating fluid. We are interested in understanding how and if such forces contribute to impulsive interactions of limbs with granular media (GM), which can act like fluids and solids. To gain insight into these interactions, we study the jump height of a one−dimensional locomotor, a self−actuated spring mass robot with a ~7 cm flat circular foot in a deep bed of 1 mm poppy seeds, varying the compaction of the GM. We also vary parameters associated with the self−deformation of the robot, including a 1−cycle sine wave "single jump" starting with a low center of mass and a counter−movement induced "stutter jump" consisting of a preliminary hop. While both jumps perform well on compact GM (and on hard ground), they perform poorly in loose GM, reaching only ~40% and ~50% of the compact GM jump height. Introducing a delay time between the pull−up phase and the push−off phase of the stutter jump (which we call a "delayed stutter jump") results in improved jump heights at low compaction, achieving ~80% of the compact GM height. A simulation of the robot in conjunction with particle image velocimetry monitoring of sidewall grain flow reveals that, like in fluids, a combination of hydrostatic−like pressure, quadratic drag and a granular virtual mass are required to reproduce experimental results. Virtual mass effects are important in loose GM, especially for the stutter jump.

21.5 AIELLO, B.R.*; WESTNEAT, M.W.; HALE, M.H.; Univ. of Chicago; *braiello@uchicago.edu*

Pectoral fin proprioception is tuned to fin mechanics

Proprioception, the sense of movement and position of one's body elements in space, is critical to the motor performance of many animals. Proprioception has been documented in the pectoral fins of fishes; however, pectoral fin morphology, mechanics, and kinematics vary markedly among species and it is unknown whether afferent physiology is adapted to a fin's biomechanics. In the morphologically diverse clade of wrasses (Labridae), some species use their broad flexible fins for drag−based propulsion, while others employ stiffer fins for lift−based propulsion. Here we compare the proprioceptive afferent response to fin ray bending in a pair of closely related wrasse, the flexible finned *Halichoeres bivittatus* and the stiff finned *Gomphosus varius* in order to determine if fin ray afferent physiology can be tuned to fin biomechanics. In both species, phasic afferent activity was observed in response to sinusoidal stimuli between 3 and 6Hz, which corresponds to the range of fin beat frequencies observed in these species. In response to step−and−hold stimuli, a burst of spikes occurred both when the fin was raised from and when it was returned to its resting position. The duration and number of spikes of these bursts increased with increasing bending amplitude. Comparing between species we found that it required a four times larger bending amplitude to elicit afferent activity in *H. bivittatus* than in *G. varius*. The spike rate over the hold period (3.5s) also increased with increasing bending amplitude, but again, a larger bending amplitude was required to elicit sustained activity during the hold period in *H. bivittatus*. The results of this study suggest that sensory physiology can be tuned to the fin mechanics through adapting sensitivity of the proprioceptive system.

P3.144 AIELLO, B.R.*; HARDY, A.R.; CHERIAN, C.; HALE, M.E.; WESTNEAT, M.W.; Univ. of Chicago; *braiello@uchicago.edu*

Tuning mechanical properties for locomotion: flexural stiffness of pectoral fin rays in lift−based and drag−based labriform swimmers

The mechanical properties of tissues in appendages play a key role in vertebrate locomotion. For fishes, fin ray stiffness has been proposed to be associated with locomotor behavior. Here we explore this idea in the wrasses (Labridae), a clade that employs pectoral fin−based propulsion with kinematics ranging from drag−based rowing to lift−based flapping. We predicted that wrasses employing a flapping swimming behavior have stiffer fins than those employing a rowing behavior. To describe the flexural stiffness of the pectoral fins more broadly and to test this hypothesis, we quantified intrinsic pectoral fin ray flexural stiffness in similar sized fins of two closely related species, the flapping *Gomphosus varius* and the rowing *Halichoeres bivittatus*. The proximal portions of *G. varius*'s fin rays were significantly stiffer than those of *H. bivittatus*. However, there is not a simple dichotomy in fin stiffness between these two species. We found a consistent spatial arrangement of fin stiffness between the two species. The flexural stiffness of each species' pectoral fin decreases along each ray's proximodistal axis as well as across the fin's chord from the leading to trailing edge. The flexural stiffness along the length of a given fin ray rapidly declined in *G. varius* but only gradually declined in *H. bivittatus*. The distal thirds of the fin rays did not differ significantly in flexural stiffness between these species. We develop a stiffness field profile across the fin surface that will allow us to explore how the flexible fin rays of *H. bivittatus* and the proximally stiffer fin rays of *G. varius* might impact fin deformation and proprioceptive feedback during swimming.

65.7 AKANYETI, O*; THORNYCROFT, P.J.M ; PETERSON, A.N.; LAUDER, G.V.; LIAO, J.C.; University of Florida, Harvard University; *otar@whitney.ufl.edu*

Swimming performance of flexible 3−D printed fish

Fishes swim through the water by passing undulatory waves down their body. To better understand the mechanics of fish locomotion, we fabricated a passive, compliant model from 3−D scans of a rainbow trout (*Onchorynchus mykiss*, 18 cm body length) that could generate thrust−producing undulatory movements when actuated. We used a mechanical controller capable of simultaneously actuating translation (lateral heave) and rotation (yaw) of the model independently from a single actuation point located near the head. We monitored the swimming kinematics of the model with high speed video while simultaneously recording the locomotor forces and torques on the mounting rod with a six−axis force transducer. A sine wave was used to drive both heave and yaw at 2.5Hz. We measured the thrust production and propulsion efficiency of the model while systematically changing the phase angle between heave and yaw at a single flow speed (0.5 body lengths per second). The model exhibited a variety of bending movements depending on the phase angle: no bending at 0°, a travelling undulatory wave at 90° − 180° and a standing wave at 270°. Minimum and maximum thrust values were generated at phase angles of 0° and 180°, respectively. Thrust production was positively correlated with the tail beat amplitude. The model was most efficient at phase angles between 120° and 180°, which, unlike previous studies with hydrofoils, generated thrust throughout the entire tail beat cycle. Our results highlight the remarkable importance of phase angle as an actuation parameter in establishing efficient undulatory locomotion.

9.4 AKCAY, C*; LENDVAI, AZ; DOMALIK, AD; ST JOHN, P; STANBACK, MT; HAUSSMANN, MF; MOORE, IT; BONIER, F; Virginia Tech, Queens Univ., Queens Univ., Davidson College, Bucknell Univ.; *caglar@vt.edu*

Dads save the day: strategic adjustment of parental care in response to nestling begging calls.

Although there is extensive evidence that individuals can strategically adjust their investment into various activities such as parental care and self−maintenance, the cues that they use in making these strategic decisions are not well understood. Here we report an experiment with tree swallows, *Tachycineta bicolor*, asking whether parents adjust their feeding rates in response to increased demand from nestlings. We studied tree swallows at two locations: at Queens University Biological Station (QUBS), Canada and near Davidson, NC. These two populations differ in the current brood value with the QUBS population having higher current brood values because of lower return rates and the shortness of the breeding season for northern populations vs. southern populations. We used an automated RFID system that played back extra nestling begging calls every time the female but not the male entered the box. We asked 1) whether the females would adjust their feeding rate in response to increased demand 2) whether the males would respond to any changes in female behavior and 3) whether there would be population differences in female and male responses. We found that females in neither population showed significant differences in feeding rates with respect to playback. Similarly, males in NC population did not show any change in feeding rates in response to playback their mates were getting. Surprisingly however, males in QUBS showed a significant increase in feeding rates when their mates were getting playbacks than when they were not. We discuss these results in the context of how mates adjust their parental behavior based on cues from nestlings and from each other.

P3.14 ALBECKER, M.A.*; MCCOY, M.W.; East Carolina University; *albeckerm09@students.ecu.edu*

Salty frogs: Saltwater tolerance in coastal anurans

As sea levels rise from global climate change, animals inhabiting coastal wetlands will be increasingly exposed to elevated and more variable salinities. While it is presumed that anurans are poor osmoregulators and therefore will be extirpated from salt−intruded wetlands, mounting evidence suggests that some species are not only capable of tolerating elevated salinities but actually thrive in wetlands with chronic saltwater exposure. Indeed, we have found that coastal amphibian populations with a history of exposure to increased salinities persist in abundance in high salinity habitats. Interestingly, few studies have investigated how these species cope with salt stress and little is known about how amphibians maintain water balance in hypertonic environments. We are investigating how the localization, regulation, and abundance of ion pumps (i.e., NKA/NKCC) and water channel surface proteins (i.e., aquaporins) in different tissues vary in response to elevated salinities, species identity, and population location (salt protected inland populations vs. salt exposed coastal populations). Specifically, in this study we quantify changes in mass, blood osmolality and expression and localization of key osmoregulatory proteins in a putatively salt−tolerant species (*Hyla cinerea*) and a putatively intolerant species (*Hyla chrysoscelis*) after exposure to a salinity gradient. We found differences among species in both change in mass and in blood osmolality. *H. chrysoscelis* lost mass at a faster rate with increasing salinity above isotonic and had a concomitant faster increase in blood osmolality than *H. cinerea*. Finally, we show differences in the abundance and localization of key osmoregulatory proteins (e.g. aquaporins).

P3.148 ALBERT−DAVIE, F.A.*; RAY, R.P; BOMPHREY , R.J.; Royal Veterinary College, Univ. of London, UK, CRUK London Research Institute, Lincoln's Inn Fields Laboratories, UK; *falbertdavie3@rvc.ac.uk*

Genetic manipulation of Drosophila wing morphology and its effect on flight performance

Insects are renowned for their extraordinary agility in flight. They are also extremely diverse in the crucial wing morphology that enables their flight. Our objective is to understand the link between wing shape and flight performance in insects. To avoid the disadvantages of invasively changing wing shape by clipping or sampling across a very large number of species, we have turned to a genetic approach. Whole organism gene knockouts are problematic in this context because the association between flight performance and wing shape change is confounded by unknown pleiotropic effects. In this study, we used RNA interference (RNAi) to modify wing shape within a single species, *Drosophila melanogaster*. RNAi knocks down expression of single genes in the developing wing blade only, leaving the rest of the fly unaffected. Restriction of the RNAi to the wing blade is achieved by coupling the bipartite Gal4/UAS yeast system with RNAi constructs. We present results from unorthodox wing shapes, sizes and vein arrangements. Flight performance is measured using high−speed cameras, photogrammetry and flight trajectory analysis.

106.3 ALBERTSON, R.C.*; NAVON, D.; PARSONS, K.J.; University of Massachusetts, Glasgow University; *rcraigalbertson@gmail.com*

The genetic basis of developmental plasticity in cichlid fishes

Phenotypic plasticity is the capacity of an organism's phenotype to vary depending on the conditions under which it develops. The ability of an individual to change its phenotype in response to environmental cues may increase its fitness in novel and/or fluctuating environments, which suggests that developmental plasticity may be adaptive and therefore subject to selection itself. While sufficient levels of genetic variation have been documented for plasticity to respond to selection, a strict genetic basis for this trait has remained elusive. Here we explore this question in cichlid fishes. We first document that cichlids reared under distinct kinematic conditions, whereby fish are made to feed with either a biting or sucking mode, vary in a way that mimics natural eco−morphological variation between species. Next, we show that different lineages vary in their ability to mount a plastic response when reared under unique trophic conditions. Finally, we document an explicit genetic basis for developmental plasticity by mapping jaw, skull and body shape under distinct trophic environments. These data advance our understanding of how the genotype−phenotype map is shaped by the environment, and provide insights into the "flexible stem" theory of adaptive radiation.

P1.150 ALEXANDER, A.E.*; BUDDEMEYER, K.M.; SECOR, S.M.; University of Alabama; *aealexander2@crimson.ua.edu*

Testing the cooking hypothesis in human evolution

The cooking of food is hypothesized to have played a significant role in human evolution by providing an increase in net energy gain from each meal. Cooking softens food thereby reducing the time and energy devoted to chewing and digestion. Hence, more food can be consumed at a lower cost, and more energy can thus be allocated to growth and reproduction. We tested this hypothesis by comparing the efforts of chewing and the energy expended on the digestion of raw versus cooked sweet potato and carrot for juvenile and adult bearded dragons (*Pogona vitticeps*). For juvenile and adult lizards, pieces of raw sweet potato and carrot required 2.4 and 3.5 times more chews, respectively, than cooked pieces. We used closed−system respirometry to compare peak postprandial metabolic responses and to quantify specific dynamic action (SDA) of raw and cooked meals equaling 5% of lizard body mass. Juveniles responded with a 25% greater metabolic peak digesting the raw meals, whereas adults experienced a 12% greater metabolic peak. The SDA generated from the cooked meals were significantly less than those from the raw meals. On average, lizards expended 35% less energy digesting and assimilating the cooked sweet potato and carrot meals compared to the raw meals. These results demonstrate the energetic benefits of consuming cooked versus raw foods and support the hypothesis that the advent of cooking had a significant impact in human evolution.

98.3 ALFARO , G.*; ROCHA, C.; ROCHA, L.; MOOI, R.; HALLAS, J.; Sonoma State University , California Academy of Sciences; *gabriela20289@gmail.com*

DNA analysis and morphological comparison of the damselfish genus Chromis (Labroidei: Pomacentridae) from deep coral reefs in the Philippines suggest new species

The lack of knowledge concerning biodiversity of the oceanic mesophotic zone (also known as the "Twilight Zone") is caused by the previous absence of deeper diving techniques that now allow exploration below depths, at which conventional SCUBA diving is safe. As technology improves and diving techniques are perfected, new frontiers await to be explored. The California Academy of Sciences led an expedition to the Philippines during 2013 and 2014 to explore the seldom−studied mesophotic zone (60−120m depth). Several species of Chromis were observed and collected at about 100 m deep. The aim of this study was to investigate possible cryptic diversity in deep reef species of Chromis. To test this hypothesis, morphological characters were scored and the mitochondrial fragment cytochrome c oxidase I (COI) was sequenced to estimate relationships among Chromis. Bayesian inference analysis of COI strongly supports the existence of at least one new species of Chromis from the mesophotic zone, allowing us to describe a new species of damselfish from this poorly explored region. Further collection and analyses of deep reef specimens will be needed to create a more comprehensive phylogenetic tree for fishes from the mesophotic zone.

32.5 ALLAM, B*; PALES ESPINOSA, E; Stony Brook University; *bassem.allam@stonybrook.edu*

The multiple, central, roles of mucosal secretions in marine bivalves

Mucosal tissues represent the major interface for exchange between animals and their environment and mucus itself is one of the most important lines of defense against microbes. Mucus is produced from virtually all molluscan epithelia and plays a role in several biological functions such as locomotion and navigation, freeze protection, attachment and defense against predators. In filter−feeding bivalves, copious amounts of mucus are produced by pallial organs (gills, mantle, palps) to help process waterborne microbes. This presentation will summarize our findings on the role of pallial mucus in interactions with waterborne microbes in the framework of predator−prey and host−pathogen associations. Our results showed the presence in pallial mucus of lectins that bind glycans associated with the cell surface of microalgae allowing selective processing and mediating the sorting of food particles in suspension−feeding oysters and mussels. In parallel, we demonstrated that mucus factors can serve as triggers for the activation of adapted microbes to initiate host colonization and invasion. For example, significant regulation of the proliferation and virulence was recorded in the alveolate parasite *Perkinsus marinus* following exposure to oyster mucus. While the pallial mucus of the susceptible oysters (*Crassostrea virginica*) enhanced the growth and the virulence of the parasite, mucus from resistant oysters (*C. gigas*) was strongly inhibitory suggesting that *P. marinus* host specificity may begin in the mucus. Evidence also suggests a dynamic regulation of mucus factors in response to intrinsic and extrinsic triggers. This context raises fascinating questions around host−microbe crosstalk and feedback controls of these interactions and calls for appealing inquisitive research in the years to come.

1.4 ALLEN, P.E.*; MILLER, C.W.; Univ. of Florida, Gainesville; *pabloallen@ufl.edu*

Adaptive plasticity of mouthparts and its potential consequences for sexually selected traits

Adaptive phenotypic plasticity can evolve when populations experience variable environments. For organisms that feed on a variety of foods, plasticity in the shape and size of mouthparts may allow greater intake and efficiency in eating. In this study we examined mouthpart plasticity in the leaf−footed cactus bug, *Narnia femorata*. This insect uses its long mouthparts to reach seeds within the cactus fruit. Some species of cacti have seeds buried deep within large fruits, while other cacti have shallow seeds. We first tested the effect of the insect's current host plant species versus a novel species with deep seeds on mouthpart length. We found that insects fed the novel cactus species grew longer mouthparts, as predicted. To address possible mechanisms of mouthpart plasticity, we also tested the effect of unripe cactus fruit (without seeds) on mouthpart length. Interestingly, insects that developed on unripe fruit also developed longer mouthparts. This pattern suggests that mouthparts respond to the absence of seeds with an increase in length. We next examined possible consequences of mouthpart plasticity for body size and sexual dimorphism. We found that the insects that grew longer mouthparts and were presumably able to reach seeds in the novel host fruits achieved larger sizes. The result was an increased size disparity between the sexes, as the relatively smaller males with shorter mouthparts were unable to reach the seeds. Additionally, this further reduced male expression of sexually selected traits. When fruit was unripe and seeds were not present, insects with longer mouthparts did not enjoy additional benefits. The evidence suggests that beak length has adaptive plasticity in this species, yet this plasticity has limits and where these limits lie can have consequences for sexual selection.

82.5 ALLIGOOD, KS*; CURREY, M; LESCAK, E; BASSHAM, S; CATCHEN, J; KIMMEL, C; CRESKO, W; University Of Oregon, University of Alaska, Anchorage; *kristin.alligood@gmail.com*

Identifying the genetic basis of craniofacial variation using threespine stickleback

Tremendous change in head shape morphology has accompanied the repeated and independent invasion of oceanic threespine stickleback into freshwater habitats. Evolution of the opercle (OP) bone shape is particularly important to adaptation to different habitats because of the profound effects on feeding mechanics. Much has been learned about the development of the OP in zebrafish, but little is known about what the genes are that underlie OP shape change or how variation in those genes alter developmental processes to give rise to OP shape changes in stickleback evolution. We use two populations of stickleback, with variable OP morphologies, that are separated by age and geography to identify if the genomic regions underlying parallel OP shape evolution is characterized by parallel genomic evolution and to identify the genes associated with OP shape change through genome wide association (GWA). Furthermore, we use lab populations of Alaskan oceanic and freshwater stickleback with fixed OP shapes to identify differences in bone outgrowth, cellular behavior, and gene expression through development that may contribute to OP shape change.

P2.18 ALONSO, C.*; BERGMANN, P.J.; Clark University; *calonso@clarku.edu*

Standardizing phylogenetically independent contrasts using estimates of phylogenetic signal

Comparative methods allow biologists to address questions pertaining to macroevolutionary processes, making their use in biology commonplace. However, to infer the mechanisms responsible for the diversity of life, a holistic consideration of the relationships between organisms is necessary. Phylogenetic comparative methods take phylogeny to be of fundamental importance in the analysis of multispecies data. The classic method of Phylogenetically Independent Contrasts (PICs) continues to be widely used to meet the statistical assumption of independence of observations. The method assumes that traits evolve by Brownian Motion (BM), so that non−independence in species' traits is proportional to the length of time species share a common ancestor and independence corresponds to unshared lineages. When the dependence between traits due to shared ancestry (phylogenetic signal) is different than expected under BM, PICs may still be applied if branch lengths can be transformed to serve as measures of covariance. We hypothesized that transforming branch lengths by estimates of phylogenetic signal would be an effective way of standardizing PICs when trait evolution deviates from BM. We simulated traits evolving by different models along random pure birth trees of varying sizes and estimated two parameters of phylogenetic signal: Pagel's lambda, and the Ornstein−Uhlenbeck strength−of−stabilizing−selection parameter, alpha. We then transformed branch lengths by these signal estimates to compute PICs. Our results indicate that estimating lambda, more so than alpha, is an effective approach to PICs standardization, as branch lengths transformed by this parameter adequately standardized PICs in about 95% of all simulated cases. Likewise, this approach was successful in standardizing PICs for various empirical datasets.

21.2 AMADOR, GJ*; MAO, W; DEMERCURIO, P; MONTERO, C; CLEWIS, J; ALEXEEV, A; HU, DL; Georgia Institute of Technology; *gamador3@gatech.edu*

Eyelashes divert airflow to protect the eye

Eyelashes are ubiquitous features of the eyes of mammals and have been speculated to act as 'dust catchers' to protect the moist and sensitive cornea. In this study, we discover the aerodynamic mechanism whereby eyelashes minimize air flow across the ocular surface without obstructing vision. Measurements of 22 phylogenetically diverse species of mammals, from hedgehogs to giraffes, indicate eyelash length is tuned to a length of approximately one−third the eye width. Wind tunnel experiments using eyelash−inspired synthetic meshes show eyelashes of the appropriate length reduce both evaporation rates and particle deposition by 50 percent. Numerical simulations and viscous flow theory reveal two competing aerodynamic resistances for incoming flow: airflow through the lashes is resisted by viscous drag, or alternatively, airflow turns to flow around the lashes and is resisted by the pressure of the incoming flow. Our modeling shows that at the observed optimal eyelash length, these two resistances are equal and at a local maximum, suggesting a minimal flow rate at the eye surface. The ability for eyelashes to protect the eye can motivate bio−inspired solutions for passive and scalable dust control of optical sensors.

53.3 AMARPURI, G*; DIAZ, C; BLACKLEDGE, T; DHINOJWALA, A; Univ. of Akron, Ohio; *ga25@zips.uakron.edu*

Direct measurement of the glue viscosity explains the humidity responsive adhesion of spider glue

Modern orb−web spiders use micron sized glue droplets to capture and retain prey. The orb−web spider glue is a unique biological adhesive that gets stickier upto an optimal humidity that varies among species. A combination of bulk glue viscosity and surface bonding contribute to the glue adhesion. However, the mechanism of humidity response of adhesion is poorly understood. Here, we use high−speed imaging and adhesion tests to probe glue adhesion at different humidity's. For the first time glue viscosity was directly measured from the spreading of the glue droplet during immobilization. Peeling of the glue droplets at different humidity's show a transition from adhesive failure, at low humidity, to cohesive failure, at high humidity. The adhesion results support the microscopic observations. Hence, significant changes in glue viscosity explains the humidity response of the spider glue adhesion and can help in designing better synthetic adhesives for the high humidity environment.

P2.140 AMATO, CM*; MCCOY, KM; East Carolina University; *amatoc13@students.ecu.edu*

Beyond Binary: Standardizing Hypospadias Severity Scoring in the Mouse

Hypospadias has increased 400% in the past 40 years, making it the second most common birth defect in the USA. Hypospadias occurs when altered androgen signaling disrupts penile development and results in mis−localization of the urethra ventrally along the shaft of the penis. Variation in severity of hypospadias is likely caused by a number of molecular mechanisms, which have not been adequately evaluated. In fact, evaluating hypospadias as a binary trait (presence or absence) could increase noise in the data and reduce our ability to investigate the developmental genetics driving variation in hypospadias severity. We developed a standardized visual scoring system for the mouse model to evaluate hypospadias severity with hopes to better compare results across studies, chemicals, and doses. Pregnant CD1 mice (n=3) were gavaged with corn oil control, 100, 125 or 150 mg/kg of vinclozolin during the genitalia masculinization window (embryonic days (E) 13.5−16.5). Genitalia of E18.5 pups were fixed, photographed, encrypted, and randomly assorted. Three researchers, blind to treatment, scored hypospadias presence (proportion of pups with hypospadias) and severity (scale of 1−3 indicating whether the urethral meatus opens in the distal third (1), mid−shaft (2), or proximal third of the penis (3)). Other penile abnormalities were also recorded. Each researcher scored twice so inter− and intra− score validity could be determined and incorporated into the scoring system. Histological evaluation of penile length and urethral opening was used to validate our scoring system. Indeed, our visual scoring system was representative of the histological data. A standardized scoring system will improve our ability to compare variation in hypospadias severity across studies, within and among laboratories.

39.3 AMBARDAR, M.*; SABOL, A.C.; REYNOLDS, E.E.; GRINDSTAFF, J.L.; Oklahoma State University, The Ohio State University; *medhavi@okstate.edu*

Effects of brood size manipulation on parental care and nestling corticosterone levels in eastern bluebirds (Sialia sialis)

Birds with biparental care can maximize their fitness by producing many offspring, but producing too many offspring in a single reproductive event can be costly. Parents with large broods may feed nestlings more frequently to provide sufficient resource, but nestlings in large broods still commonly experience more competition with siblings for parental resources than nestlings raised in smaller broods. Nestlings in larger broods may experience higher levels of food stress and develop more slowly than nestlings in smaller broods. Several studies have increased or reduced brood sizes to examine effects on parents. Relatively fewer studies have considered effects on offspring and the results have been inconsistent. We conducted a brood size manipulation using eastern bluebirds (*Sialia sialis*) in Payne County, Oklahoma, USA. When nestlings were 2 days old, we moved 1−3 nestlings between nests with the same hatch date to create reduced and enlarged broods. Some broods were unmanipulated. To quantify parental care, we analyzed nest attendance and number of nest visits from video recordings of the adults. We weighed nestlings on days 2, 5, 11, and 15 post−hatching to measure growth rates. On day 15, we also took a blood sample to measure corticosterone (CORT) concentrations as an indicator of stress exposure. Neither nestling CORT nor body mass differed across any of the brood size groups. Adult bluebirds raising enlarged broods may have been able to compensate by increasing feeding and nest attendance. In resource abundant years, increased parental care may be less costly than in years when resources are scarce.

P1.116 AMORIN, NA*; BENTLEY, GE; CALISI, RM; Univ. of California, Berkeley, Barnard, Columbia University; *amorin@berkeley.edu*

GnRH−I and GnIH cell soma size and peptide concentration change with season, nest box status, and circulating testosterone in European starlings

Hypothalamic neurohormones involved in vertebrate reproduction, gonadotropin releasing hormone (GnRH−I) and gonadotropin−inhibitory hormone (GnIH), can vary in peptide cell abundance in accordance with reproductive stage, and concerning GnIH, nest box status in European starlings. Using cell abundance as a proxy for neurohormone activity is informative, but incorporating other information gathered from visualizing these cells may yield a heightened understanding of hormonal dynamics associated with environmental change. We hypothesized that, along with previously reported cell abundance, soma sizes and a proxy for peptide concentrations of cells immunoreactive for GnRH−I and GnIH increased during the beginning and middle of their breeding season as compared to the non−breeding season. We report that the direction of increase follows the same seasonal patterns of previously reported GnRH−I and GnIH cell abundance. Additionally, we hypothesized that, like cell abundance, only GnIH (and not GnRH−I) soma size and peptide concentration would respond to a change in nest box status. However, we found only GnIH peptide concentration and not soma size followed this pattern, and only during the mid−breeding season. Finally, we examined the relationship of the gonadal sex steroid testosterone with GnRH−I and GnIH soma size and peptide concentration. In males, but not females, testosterone was positively correlated with GnRH−I and GnIH factors. In sum, GnRH−I and GnIH soma size and peptide concentration change in accordance with breeding period and, in males, with testosterone, and GnIH peptide concentration changes with nest box status. These details have the potential to offer a more in−depth snapshot of how GnRH−I and GnIH may be functioning.

80.6 ANDERSON, C.V.*; TOLLEY, K.A.; Brown University, Providence, South African National Biodiversity Institute, Cape Town; *Christopher_V_Anderson@brown.edu*

Scaling of ballistic tongue projection performance in chameleons

Body size and dimensions of organisms are known to have a profound impact on functional properties associated with animal movement. Predictions about how whole organism performance varies with body size can be derived from the scaling of morphological proportions. While the anatomy of many ectotherms scale with geometric similarity, a variety of selective pressures may act on an organism to produce allometric scaling patterns, which will alter predictions of whole organism performance. The feeding apparatus in chameleons, for instance, is known to scale with negative allometry with respect to snout−vent length, affording small chameleons with a proportionately larger feeding apparatus by weight than larger chameleons, both within and among species. To understand how this allometry affects whole organism performance, we examined the interspecific scaling patterns of tongue projection performance in chameleons. We analyzed over 275 feedings collected from 55 individuals representing 20 species in nine genera and a five−fold range in body length using phylogenetically corrected methods. We found that tongue projection length scaled with negative allometry with respect to both snout−vent length and jaw length, and that the peak acceleration of tongue projection and the peak mass−specific power required to power tongue projection both declined with increasing body size. This data shows that among species, smaller chameleons are able to project their tongue proportionately further than larger species, and are able to do so with higher accelerations and higher power output. These scaling relationships thus serve to increase the functional range and performance of the feeding apparatus of small chameleon species, which may be beneficial for animals with higher mass−specific metabolic rates than their larger relatives.

7.1 ANDERSON, PSL*; PATEK, SN; Duke University; *philip.anderson@duke.edu*

Mechanical redundancy, mechanical sensitivity and constraint in the evolution of the mantis shrimp raptorial appendage

Mechanical redundancy allows mechanical systems to vary overall morphology while retaining similar outputs, as exemplified by the 4−bar linkage system in fishes. However, even in mechanically redundant systems, mechanical output may be particularly sensitive to variation in individual components. We define mechanical sensitivity as the process by which small changes in some components may have larger effects on output than similar changes in other components. Here we test whether mantis shrimp (Stomatopoda) 4−bar linkages are mechanically redundant while also exhibiting mechanical sensitivity to variation in the component links. While the overall linkage system showed a classic pattern of mechanical redundancy, it also presented distinct mechanical sensitivity to a single component of the system (carpus link), which was tightly correlated with output (kinematic transmission; KT). Analyses of trait evolution indicated that the mechanically sensitive component (carpus link) evolved in tandem with KT, while insensitive components (other links) evolved independently. Our results illustrate the connections between mechanical redundancy, mechanical sensitivity and constraint: mechanically insensitive components vary freely, creating mechanical redundancy in the whole system, while mechanically sensitive components act as structural constraints that play a significant role in the function and evolutionary variability of the system.

63.1 ANDERSON, R.A.; Western Washington University; *Roger.Anderson@wwu.edu*

Consequences of climate variation across several trophic levels of ectotherms in a desert lizard community

The among−year variation in means and extremes of rainfall and precipitation of deserts ecosystems are expected to cause predictable, among−year responses in production through several trophic levels of desert ectotherms. How ectotherm consumers compare in the variation of production responses is not readily apparent, however, because species of ectotherms vary considerably in a) modes of food acquisition, b) prey types, c) activity patterns, d) predation threat, e) daily patterns of body temperature, and e) life−history traits. Thus, given annual variation in climate and prey availability in the northern Great Basin desert, a bewildering plethora of alternative and contrasting assumptions and associated predictions can be made for the outcomes of production in trophically contrasting lizard species. A first approach to this multivariate conundrum was a decade−long observational−descriptive−comparative study of lizards from three genera: 1) the western whiptail lizard, *Aspidoscelis tigris*, which eats many caterpillars in late spring and other prey such as termites in summer, 2) the desert horned lizard, *Phrynosoma platyrhinos*, primarily a specialist on ants and 3) the long−nosed leopard lizard, *Gambelia wislizenii*, which preys mostly on grasshoppers and lizards. The annual patterns of body condition and fecal production as measures of foraging success and the following−year patterns of juvenile recruitment into the populations of these three species were measured, and then these response variables were examined with respect to among−year variation in availability of prey and climate. There were some of the expected correlates of climate with prey and predator productivity, but variation in responses among the three lizard species suggests intrinsic features unique to each species.

P3.127 ANDERSON, CD; Valdosta State University; *coreanderson@valdosta.edu*

Variation in the spatial distribution of Spanish moss (Tillandsia usneoides) in different forest communities: stand level patterns.

Epiphytic plants may exhibit complex spatial patterns within forest communities that reflect multiple factors, including: microclimatic variables, environmental stability, and modes of reproduction. However, developing predictive models of epiphyte distributions requires basic information about the spatial distribution of individuals at multiple sampling extents. In a previous study, based on sampling Spanish moss coverage on all phorophytes within 50 x 50 m quadrats, we found evidence of spatial gradients in Spanish moss coverage in both forest communities sampled [i.e., 1) pine−dominated forest, and 2) a mixed hardwood and pine secondary forest]. However, it was not clear whether the gradients detected represented global trends at the stand level or the edges of localized patches within a stand. To clarify patterns at the stand level, in the present study, we sampled linear transects through each forest community and calculated the average rank coverage of Spanish moss on all phorophytes at 10 m intervals. To assess spatial pattern, we plotted average Spanish moss coverage at each point and used spatial correlogram analysis to assess pattern. While patterns varied among transects and between forest communities, results showed clear evidence of stand level gradients in Spanish moss coverage, usually emanating from the edges of the forest stand. Results also revealed localized patchiness superimposed on stand level gradients, indicating different spatial patterns at different spatial scales. Our results suggest that studies seeking to delineate predictors of Spanish moss abundance should use statistical models that can resolve multiple scales of spatial structure, and that edge effects between forest communities might be predictive of stand level spatial gradients.

13.3 ANDERSON, E.J.*; GARBORG, C.S.; THORNYCROFT, P.; LAUDER, G.V.; Grove City College, Grove City; Woods Hole Oceanographic Institution, Woods Hole, Grove City College, Grove City, Harvard University, Cambridge, Harvard University, Cambridge; *eanderson@whoi.edu*

Undulatory propulsion in swimming fish: evidence of fluid−body resonance effects on tail beat frequency

Recent work by us and our collaborators has demonstrated that the performance (speed, cost of transport, and thrust) of swimming plastic panels is a function of length and stiffness for any given actuation of the leading edge. More interestingly, we found by experiment and modelling that there are multiple performance maxima and minima as panel length is varied, and that swimming panels exhibit kinematic differences that correlate with performance. The work suggests the existence of resonance in the fluid−body interaction of undulatory swimming. To investigate whether this phenomenon plays a role in the behavior and morphology of fishes *in vivo*, we tracked the trailing edge of the tail of swimming striped bass (n = 3, FL = 37.3 − 48cm) in live digital video as fish swam in a recirculating temperature controlled flume. What distinguishes these data from past studies of tail beat frequency and amplitude is that we took data in very small increments of swimming speed from very slow up to speeds where the fish began to exhibit burst−and−coast behavior, and we processed 5500 − 7400 tail beats per fish to generate a very high−resolution data set. Swimming speed versus body length at fixed tail beat frequencies, and tail beat frequency versus swimming speed show evidence of deviations from gradual increase. This is suggestive of the sort of resonance seen in the swimming performance of plastic panels. If swimming performance in fish is characterized by significant peaks and troughs that are a function of body stiffness and length, then fluid−body resonance could be important in understanding how and why fish control changes in swimming speed, especially through development from fry to adult.

56.3 ANGELINI, DR*; GRUBB JONES, AE; PARKS, MC; Colby College; *dave.angelini@colby.edu*

Insulin signaling in appendage allometry and wing polyphenism in the soapberry bug, Jadera haematoloma

Polyphenic traits develop different final states due to environmental cues. However, it is unclear how developmental processes differ at the level of gene function to achieve distinct morphs. Differences in gene regulation may be particularly important in instances where structures are alternatively patterned, rather than one morph simply lacking the polyphenic structure. The red−shouldered soapberry bug *Jadera haematoloma* exhibits polyphenic wing morphs in both sexes, where individuals may develop to adulthood with complete wings and functional flight muscles or brachypterous wings with undeveloped flight muscles. Therefore, wing morphs present a combination of alternative patterning and growth, especially within the distal membrane region of the wing. While wings exhibit this polyphenism, other appendages are more canalized in their size. We have explored the biology of the polyphenism using studies of growth and functional tests of gene expression through RNA interference. A steep positive scaling coefficient exists for the wing of both morphs, with modest positive scaling for legs and antennae, and isometric growth for the beak. RNAi was used to knock down several genes with roles in wing patterning and organ size regulation during juvenile−to−adult development. Several genes, including *Distal−less* are required for growth and patterning within the distal region of the wing. Knock down of the insulin signaling pathway component encoded by *FoxO* alters the relative size of the body and various appendages. Despite different scaling coefficients, wings and beaks both increased in relative size after *FoxO* RNAi. This effect was restricted to long−wing morphs. These findings suggest that insulin signaling mediates the relative growth of appendages in this species, and that this influence contributes to polyphenic developmental outcomes.

P2.184 ANWAR, SB; DARAKANANDA, K; GAING, AN; VRONAY RUGGLES, XT; WRIGHT, DN; ELLERBY, DJ*; Wellesley College; *dellerby@wellesley.edu*

Adhesion mechanics of the medicinal leech (Hirudo verbana)

Leeches use circular attachment organs to anchor themselves to substrates and prey. Several adhesive mechanisms, including suction and wet adhesion, could contribute to the total attachment force. A force plate incorporating a pressure transducer was used to simultaneously measure attachment force and pressure under the posterior attachment organs of medicinal leeches (*Hirudo verbana*). The maximum measured attachment force was 0.21 N, approximately 20 times the leech body weight. Pressures up to 27 kPa below ambient were generated during attachment. On a perforated substrate where a pressure differential could not be formed, the attachment force was 0.0085 ± 0.003 N (mean ± SD), 4.0 % of the maximum during suction. This indicates that suction is the primary mechanism for temporary attachment to a substrate during feeding or locomotion. Leeches also anchor to substrates in the longer term, potentially for days or weeks. Long term attachments are accompanied by the secretion of thick mucus at the attachment point. In the presence of a methyl cellulose solution with a viscosity approximating that of mucus, a mean attachment force of 0.055 ± 0.012 N (mean ± SD), or 26 % of the suction maximum, was generated in the absence of suction. Mucus secretion therefore allows for long term anchorage without the need to generate suction pressures with energetically costly muscle contractions.

31.7 APANOVITCH, E.K.*; RIDDELL, E.A.; SEARS, M.W.; Clemson Univeristy, Clemson University; *eapanov@g.clemson.edu*

Rising Stress: Investigating Plethodon metcalfi stressors across range limits using elevation and latitude as climate change proxies

Stress responses allow organisms to cope with environmental changes by allocating resources toward processes that enhance survival. Over short timescales, stress may increases survivorship in adverse conditions, but stress becomes detrimental over longer periods. At species range limits, where physical barriers are not limiting, individuals may be constrained by their physiology. Here, individuals are more likely to encounter physiologically demanding conditions that will worsen if the climate warms. Suitable habitat for Plethodontid salamanders in the southern Appalachians is predicted to decrease by up to 40% as early as 2020. Given these salamanders' reliance on cool and moist habitats, our understanding of their responses to such change will depend on: (1) how physiological stresses vary with the natural hydrothermal gradients of elevation and latitude, (2) whether current stress levels help to predict future species range limits. We assessed stress using leukocyte ratios (neutrophils:lymphocytes) from field−fresh southern grey−cheeked salamanders (*Plethodon metcalfi*) to compare relative background stress levels between collection sites. Individuals were sampled across the known species limits from as wide a range of elevation as possible to encompass environmental variation. Stress levels are expected to increase with decreased elevation and latitude. Therefore, as the climate warms, individuals at low and southern sites will face greater physiological demands and likelihood of local extinction. Future work will test *a prior* background stress predictions based on environmental and locality data, and tease apart the timescale at which stressors act to examine factors that may impact range shifts.

P1.134.5 ARAUJO, A.M.*; WARNE, R.W.; DA, C.; Southern Illinois University; *alessandra@siu.edu*

Temperature Effects on TDCPP Uptake and Toxicity in Amphibian Larvae

Climate change is expected to differentially affect homeostatic processes of most animals, as well as their physiological capacity to mediate exposure to many interacting natural and anthropogenic stressors. Temperature shifts combined with increasing levels of contamination, for instance, might result in increased toxicity of certain contaminants, as organisms must allocate finite resources towards temperature regulation, cellular repair, and detoxification. Amphibians might be particularly sensitive to these interactions because their permeable skin offers little resistance to contaminant uptake. In addition, since most physiological changes during amphibian metamorphosis are mediated by hormonal regulation, temperature facilitated bioaccumulation of endocrine disrupting contaminants might result in altered larval development. One such endocrine disrupting contaminant is the flame retardant TDCPP (Tris (1,3−dichloro−2−propyl)phosphate). Limited information is available on the thresholds and mechanisms of toxicity of TDCPP under different environmental conditions. In order to address this issue, we chronically exposed Xenopus laevis larvae to environmentally relevant concentrations of TDCPP and monitored survival and developmental rates at different temperatures until metamorphosis. We investigated the effects of warmer temperatures on elimination of TDCPP metabolites from larval and juvenile tissues and measured expression of genes central to cellular integrity and metabolism in exposed individuals post−metamorphosis. We hypothesized warmer temperatures would increase ventilation and feeding rates in larvae, which in turn would result in higher exposure to TDCPP and more pronounced energetic tradeoffs between xenometabolism, growth, and inflammatory processes.

P2.149 ARMSTRONG, E.J.*; PAGE, T.M.; MILLER, N.; PAPINEAU, E.N.; CALOSI, P.; STILLMAN, J.H.; Univ. of California, Berkeley, San Francisco State Univ., Plymouth Univ., Univ. of California, Berkeley ; San Francisco State Univ.; *armstrong@berkeley.edu*

Exposure to Lowered pH and Acute Thermal Stress Increases Mortality in Embryonic Porcelain Crabs.

Increased atmospheric pCO_2 is expected to lead to decreased oceanic pH and increased frequency and severity of extreme heat events, both of which are likely to be deleterious for intertidal ectotherms. However, responses to these forcing agents can vary greatly even within a single species, and sensitive early life history stages may pose an ecological weak link in population persistence. We investigated the effects of reduced pH and acute thermal stress on growth and survival of embryos of the porcelain crab *Porcellana platycheles*. Early stage embryos were removed from field−collected females (n = 6; 96 embryos/female) and reared until hatching (~27 days) under one of two pH treatment conditions (pH=8.0, pH=7.6). Embryos were exposed to one of four temperature regimes: (1) constant ambient 20 °C, or 1 h exposure to 31 °C on (2) Day 1, (3) at start of heart beat, or (4) both Day 1 and start of heart beat. Photos of embryos were taken every other day for the duration of the experiment. Embryo lengths and volumes were estimated from photos using the program ImageJ and growth rates were calculated as change in length/time. Embryo mortality was ~1.5 times higher with heat shock in early development (Day 1) under low pH when compared to controls, suggesting that *P. platycheles* embryos are likely to be strongly negatively impacted by acute heating events predicted under future climate scenarios. This project was funded by NSF grant MCB−1041225 to JHS, and PU funding to PC.

P2.79 ARMSTRONG, LM*; TRACY, CR; California State University, Fullerton; *lmarmstrong@csu.fullerton.edu*

Thermoregulatory behaviors in the insular giant chuckwalla Sauromalus varius

The insular giant chuckwalla (*Sauromalus varius*) provides a novel opportunity to study thermoregulatory behaviors not yet researched in this larger−sized reptile. This descriptive study aims to determine the preferred temperature range of *S. varius* in an enclosed thermal gradient, and compare that temperature range with their selected temperature in a semi−natural outdoor enclosure. iButton thermal dataloggers were attached to six giant chuckwallas using a gaffer tape vest technique. The lizards were then individually placed within the thermal gradient and observed for twelve hours. Temperatures in the outdoor enclosure were measured using iButtons placed inside seven copper models. iButtons were also attached to the giant chuckwallas and the copper models were placed at the areas perceived to have the hottest and coldest temperatures throughout the day. The average temperature selected by *S. varius* in the thermal gradient was 35.3 °C ± 2.60. Selected temperatures by individuals ranged from 31.5 °C to 39.3 °C. Preliminary data from mid−summer show that they only reach their preferred temperature for an average of 1.4 hours per day. The outdoor copper models show that they have the capability to reach their preferred temperature for about 8.5 hours per day. This suggests that thermoregulation to their preferred temperature is not the highest priority at this time of year. The identification of a species' preferred temperature is crucial for understanding thermoregulatory patterns in the field. Examining how this endemic island species copes with rising temperatures in a rapidly−changing world can provide useful information toward conservation efforts and husbandry practices.

18.1 ASHLEY, NT*; HASSELQUIST, D; WINGFIELD, JC; Western Kentucky Univ., Bowling Green, Lund University, Lund, Sweden, Univ. of California, Davis; *noah.ashley@wku.edu*

Testosterone and Immunosuppression in an Arctic−Breeding Songbird

More than 20 years have elapsed since Folstad and Karter introduced the Immunocompetence Handicap Hypothesis (ICHH), which proposes that honesty of androgen−dependent traits is enforced by the obligatory suppressive effects of testosterone (T) upon immune function. The ICHH has been tested mostly in temperate−breeding bird species, and support for the ICHH is mixed. Arctic−breeding birds provide a unique opportunity to investigate the ICHH because some species exhibit behavioural insensitivity to T at different stages of breeding. For example, T implants increase song, but not aggression in Lapland longspurs (*Calcarius lapponicus*) when females are incubating. We hypothesized that immunosuppression from T would also be blunted during this time, and therefore, not obligatory. Male longspurs were captured in Barrow, Alaska (71° N), placed in captivity, and implanted under the skin with silastic implants (20 mm) filled with testosterone or empty (control). T implants reduced cell−mediated immune responses to phytohemagglutinin (PHA), but not primary humoral responses to keyhole limpet hemocyanin (KLH), compared with controls. Baseline glucocorticoids were also elevated in T−implanted birds relative to controls, which suggests that stress hormones could be mediating immunosuppression. To support a role for indirect mediation by stress hormones, another group of males received corticosterone implants (12 mm) or control (empty) and then cell−mediated immunity was assessed. Corticosterone suppressed cell−mediated responses to PHA compared with controls. Despite exhibiting behavioral insensitivity to T, Lapland longspurs display T−induced immunosuppression similar to previous findings in temperate−breeding birds.

P3.81 ASSIS, VR; DAGG, JN; MICHAELSON, CS.; MENDONCA, MT*; GOMES, FR; Universidade de Sao Paulo, Auburn University; *mendonca@auburn.edu*

Restraint−induced changes in plasma corticosterone levels and immune parameters for invasive cane toads in Florida

Previous studies in a variety of vertebrates indicate that stressed animals exhibit an acute increase in circulating plasma glucocorticoid levels and a consequent immunocompetence modulation. Little is known about physiological reactions to stressors in *Amphibia* and the consequences of elevated glucocorticoids on the animals' immune response. In order to further explore the relationship between glucocorticoids and immunocompetence, we subjected newly captured toads to a restraint challenge with or without movement restriction (maintenance in a small plastic bag vs. maintenance in a bin) for 24h. Our goal was to test if both types of restraint can be considered a stressor, promoting elevated plasma levels of corticosterone (CORT) and reduced immunocompetence in the invasive cane toad species, *Rhinella marina*, from Florida/USA. We predicted animals subjected to restraint with movement restriction would exhibit higher levels of CORT and immunosuppression. We analyzed CORT, neutrophil/lymphocyte ratio (N:L) and bacterial killing ability (BKA). CORT significantly increased 8 fold ($t = -3.69$; $p= 0.01$) in response to restraint without movement restriction, while animals who were movement restricted only exhibited a non−significant 3 fold increase ($p=0.29$). Additionally, restraint with and without movement restriction increased N:L 2 fold, but had no effect on BKA. It may be the significant CORT increase in animals that could move more is related to CORT associated metabolic effects. We also found a significant, positive correlation between BKA and N:L ($r = 0.725$; $p = 0.04$) after restraint without movement restriction, which may be related to increased mobilization of neutrophils into the blood stream.

40.2 ASTLEY, H.C.*; GONG, C.; TRAVERS, M.; SERRANO, M.M.; VELA, P.A.; CHOSET, H.; MENDELSON, J.; HU, D. ; GOLDMAN, D.; Georgia Institute of Technology, Carnegie Melon University, Zoo Atlanta; *henry.astley@physics.gatech.edu*

Modulation of orthogonal body waves enables versatile and rapid maneuverability in sidewinding locomotion.

Sidewinding rattlesnakes (*Crotalus cerastes*) are exceptionally maneuverable, even on sand. Straight line sidewinding locomotion of the snakes and sidewinding snake robots can be described by an appropriate phasing of horizontal and vertical body waves. We hypothesized that the high maneuverability of these animals emerged from independent control of the two waves and that the robots' maneuverability could be enhanced by mimicking the methods used by the snakes. To test this hypothesis we collected motion capture data of the snakes, and observed two distinct turning methods: "differential turning" and "reversal turning". In differential turning we observed one end of the snake to move further forward per cycle than the other, leading us to posit that the snakes were imposing an amplitude gradient in the horizontal wave as it propagated posteriorly. In reversal turning, the snake rapidly exchanged lifted and grounded body segments, resulting in a large change of direction without significant body rotation. We hypothesized that the snakes shifted the phase of the vertical wave relative to the horizontal wave by pi. We tested these mechanisms in the robot and generated differential and reversal turning on sand as well as hard ground. Further explorations of two−wave mixing parameters revealed a third turning mode, "frequency turning", not observed in biological snakes. These results show how the relative modulation of two component body waves can result in the emergence of complex behaviors, and that high degree of freedom biological and robotic systems can be controlled and maneuvered using this simple control template.

P1.90 AUSTIN, M*; HUMFELD, S.A.; University of Missouri; *humfelds@missouri.edu*

Breeding phenology of female gray treefrogs: effects of male calling and environmental variables

Many anuran amphibians (frogs and toads) breed in or near a body of water, where males produce acoustic signals in aggregations called choruses. The cues that influence when females travel from the terrestrial habitat and arrive at the breeding location are, however, still not fully understood. Females select mates based on the acoustic properties of male calls, so female attendance at a chorus is generally thought to be either a direct response to chorusing males or to favorable environmental conditions which correlate with male chorusing. This study aimed to better understand the cues determining female arrival in a population of the gray treefrog (*Hyla versicolor*). To accomplish this, we conducted nighttime censuses that estimated the number of breeding females over the course of the 2013−2014 breeding seasons (April−July). We then correlated female attendance with environmental variables (precipitation, wind speed, barometric pressure, temperature, relative humidity, ambient light) measured at a nearby AmeriFlux tower and the average intensity of the male chorus (dB SPL). We present multivariate statistical analyses designed to determine whether female arrival is more highly correlated with male calling behavior than with particular environmental variables. We predict that rainfall and humidity will be important determinants of breeding behavior for both sexes, as well as test hypotheses about the importance of variables that increase the risk of female movement (ex: ambient light levels). The results of this study are important for understanding how the interaction between climate and chorus activity affect reproductive behaviors in H. versicolor, and allow for comparisons with other temperate species.

P1.164 AVILES−RODRIGUEZ, K*; KOLBE, J; Univ. of Rhode Island, Kingston ; *kev.aviles.rodz@gmail.com*

Does urban environment impact Anolis cristatellus antipredator behavior?

As the human population increases, urban areas are expanding, which often brings humans in close proximity to wildlife. Disturbance by humans can lead to changes in animal behavior and ecological interactions. Urban areas also provide access to novel substrates (e.g., cement walls and metal posts), which may influence the behavior and performance of organisms. We studied whether urban habitats and the novel, artificial substrates found in cities influenced the escape behavior of the lizard *Anolis cristatellus*. We tested whether lizards in urban environments show reduced flight initiation distance (i.e. distance between the observer and the lizard when the lizard begins escape) and whether flight distance differs between urban and natural habitats. We found that flight initiation distance was significantly shorter in urban environment as compared to natural habitats. We also found differences in flight initiation between urban anoles that were perched on trees and those perched on artificial substrates. Anoles on urban trees initiated escape at shorter distances than those on metal posts and cement walls. Flight distance was not significantly different between habitats. Our results suggest that urban lizards have adjusted their escape response, reducing the distance at which they react to the persistent presence of humans near their perches. Both the urban environment itself and artificial substrates found in cities affect escape behavior of anoles.

P2.12 AYOUB, N. A.*; GARB, J. E.; HAYASHI, C. Y.; CLARKE, T. H.; Washington and Lee University, University of Massachusetts, Lowell, University of California, Riverside; *ayoubn@wlu.edu*

Transriptomics identifies the gene repertoires underlying functional differentiation of spider silk glands

Spiders (Araneae) are exceptional among silk producing arthropods for the diversity of silk types and functions found within and among species. Functionally and mechanically distinct silk fibers are composed primarily of unique proteins synthesized in specialized abdominal glands. Araneoid spiders (a mega−diverse clade that include orb−web, sheet−web, and cobweb weavers) possess up to seven gland types, each producing silk fibers or glues with distinctive mechanical properties that correspond to a particular function. Almost all molecular studies of spider silks have focused on members of the gene family that encode the fibers' primary structural proteins − spidroins. Each of the spidroin paralogs characterized thus far appears to have gland−specific expression. Recently, high throughput sequencing of genes expressed in the silk glands of the Western black widow identified ~650 transcripts that were significantly more abundant in silk glands than other tissues, suggesting a far more complex silk protein system than previously recognized. Here we describe gene expression patterns of all seven of the functionally differentiated silk gland types in three species of cobweb weaving spiders including the Western black widow. GO term analysis of differentially expressed transcripts identified similar functions enriched in each of the differentiated gland types in all three species, including oxidation−reduction, extracellular exportation, and lipases. Intriguingly, the identity of these transcripts in each of the individual gland types is unique − e.g. different paralogs are expressed in each of the gland types within a single species. Thus, silk glands types share basic functions, but have diverged in paralog expression, mirroring the pattern found for spidroin expression.

3.2 BABBITT, C.C.*; PFEFFERLE, L.W.; CRAWFORD, G. E.; WRAY, G. A.; University of Massachusetts, Amherst, Duke University; *cbabbitt@bio.umass.edu*

Evolution of gene expression network underlying a disease state

We used a comparative approach to understanding differential disease susceptibilities between closely related species. Humans and chimpanzees are separated by approximately 4−6 million years of evolution, but have very different phenotypic traits, including the susceptibilities to a number of diseases. We tested one of these disease phenotypes, epithelial cancer progression, in cell culture. Previously, we found that many of the genes involved in this pathway show signals of positive selection in putative *cis*−regulatory regions. Presumably these changes are advantageous at other life−history timepoints. Other studies have shown that when human fibroblasts are starved and then exposed to serum, they undergo a transcriptional response that involves categories of genes that are highly correlated with gene expression signatures found in human epithelial cancers. We have now performed this same experiment on human and chimpanzee cell lines, using RNA−Seq and DNase−Seq (a measure of open chromatin) to understand how these species react differently to this important physiological response. Our results suggest that there are a few important gene expression pathways that have changed over evolutionary time to respond to this stressor and there have also been significant changes in enhancer usage over evolutionary time. This experiment provides insights into the genetic pathways underlying the known differences in carcinoma rates between humans and chimpanzees.

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

Piecing together the cnidocyte gene regulatory network

Understanding the mechanisms that generate new/novel cell types remains a fundamental challenge in the advancement of cell biology. Because they are among the few clearly novel cell types, cnidocytes (the stinging cells in cnidarians) provide a valuable model for studies of novelty. We manipulated *in vivo* gene expression to assess the effect of several key transcription factors on the differentiation of cnidocytes in embryos of *Nematostella vectensis*, a model sea anemone. Morpholino knockdown of the homeobox transcription factor *paxA* resulted in loss of cnidocytes and knockdown of *soxB2* resulted in both loss of cnidocytes and in reduction of *paxA* expression in *N. vectensis*. Interestingly, neither of these transcription factors has yet been identified in the regulatory network of medusozoan cnidocytes. Because of the challenges associated with acquiring and manipulating embryos in these lineages, studies of medusozoan cnidocyte differentiation have largely utilized regenerating adult tissue. Using *in situ* hybridization, we have further identified *paxA* and *soxB2* transcripts in the ectoderm of the tentacle tips of *N. vectensis* polyps undergoing cnidocyte replacement, suggesting these genes may regulate differentiation of this novel cell type in both developmental and regenerative contexts among anthozoans. Importantly, amassing evidence from across cnidarian lineages suggests that several conserved families of transcription factors (e.g., bHLH, HMG, Sox, and both PRD−class and SIN−class homeobox genes) are required for the development of cnidocytes. Considering the structural elements of cnidocytes are encoded by lineage−specific genes, this system provides a unique opportunity to assess how conserved regulatory genes become integrated into networks of novel structural genes to regulate the development of novel cells.

28.4 BAILEY, EA*; MONROY, JA; NISHIKAWA, KC; Denison University, Northern Arizona University; *bailey_e3@denison.edu*

A role for titin in doublet potentiation

A single stimulus (doublet) added to a train of stimuli increases the force output of a muscle. However, current theories used to explain muscle contraction fail to accurately predict muscle force during doublet potentiation. Recent work has suggested that the sarcomeric protein, titin, may play a role. Here, we investigated the role of titin in doublet potentiation by using the muscular dystrophy with myositis (*mdm*) mouse, which is characterized by a deletion in the N2A region of the titin gene. Previous research suggests that upon activation, the N2A region binds to the thin filaments, which increases titin stiffness. We hypothesized that the absence of N2A−thin filament binding in *mdm* muscles reduces doublet potentiation. Using a servomotor force lever, we measured doublet potentiation at different muscle lengths *in vitro* from the soleus and extensor digitorum longus (EDL) muscles of wildtype and *mdm* mice. Potentiation was 20% lower in *mdm* than in wildtype soleus at all lengths ($p = 0.04$). In contrast to soleus, there was no difference in potentiation between wildtype and *mdm* EDL muscles ($p = 0.7$). In addition, potentiation was greater at optimum length than on the descending limb of the force−length relationship in both soleus and EDL wildtype muscles, but *mdm* muscles did not show length dependence. Results from soleus muscles are consistent with the hypothesis that titin plays a role in doublet potentiation and that the lack of titin−actin binding in *mdm* soleus muscles reduces doublet potentiation of muscle force. Differences in myosin isoforms, calcium flux, or titin isoforms, alone or in combination, may contribute to the observed differences between soleus and EDL in doublet potentiation.

P1.115 BAILEY, A.M.*; HALL, C.A.; DEMAS, G.E.; Indiana University, Univ. of North Carolina, Pembroke; *allibail@indiana.edu*

Food availability as a cue for seasonal reproduction: Effect of juvenile food restriction on adult seasonality in Siberian hamsters

Seasonally breeding animals respond to multiple environmental cues to determine optimal conditions for reproduction. Siberian hamsters (*Phodopus sungorus*) primarily rely on photoperiod as a predictive cue of future energy availability; when raised in long−day (LD) photoperiods, supplemental cues such as food availability do not trigger seasonal reproductive responses. Two RFamide neuropeptides, kisspeptin and RFamide−related peptide (RFRP) are hypothesized to function as integrators of environmental signals to coordinate seasonal reproduction. This study investigates whether a nutritional challenge during development subsequently results in altered adult seasonal responses, specifically whether LD adults recognize food availability as a relevant signal after this challenge, and whether this is caused by differential development and activation of kisspeptin and RFRP. Male and female hamsters were given either *ad libitum* food or 70% of *ad lib.* intake from weaning until 60 days of age. For five weeks after day 60, all hamsters received *ad lib.* food to provide a signal of abundant energy reserves. Then, hamsters were again assigned either *ad lib.* food or a mild food restriction of 80% of baseline intake for six weeks. Body mass and reproductive measurements (estrous cycling in females, estimated testis volume in males) were assessed regularly and will be presented. After six weeks, hypothalamic, gonadal, and adipose tissues were collected for analysis of gene expression of RFamide peptides and their receptors using quantitative PCR. Collectively, the results of this study will increase our understanding of the neuroendocrinology of seasonal reproduction in a relevant environmental context.

1.5 BAKER, JA; Clark University, Worcester, Massachusetts; *jbaker@clarku.edu*

Female size−offspring size allometries and the size−number trade−off

Identification of the fundamental trade−off between the size and number of offspring has been of enormous value in helping us understand the evolution of life histories. All else being equal, this trade−off leads to the prediction of an optimal offspring size. As we now know, the trade−off function, and thus the optimal offspring size, may show considerable plasticity, and may vary in a context−dependent manner. The plasticity may take surprising forms, such as when females adjust egg size to match male quality (Kindsvater & Alonzo 2014). It is also well documented that in a wide variety of organisms larger females produce larger offspring. Given the logic of the optimality approach, this observation is difficult to explain. If bigger females produce bigger offspring because bigger offspring are better, then smaller females should produce large offspring as well. This female−offspring relationship has been widely studied both theoretically and empirically without full success. Viewing it as a context−dependent phenomenon may offer some help. Roff (1992) predicted that reproductive effort (RE) in iteroparous organisms should increase with female size, producing allometric exponents for RE on body size greater than or equal to unity. If so, this could imply that larger females have "excess" reproductive energy compared to smaller females, which they may spend entirely on increased fecundity, on increased egg size, or on some combination. This may represent a special case of context−dependency in which the context is the size and the comparative amount of reproductive energy of the female herself. Here I explore this possibility using the model system of the threespine stickleback.

P1.76 BAKER, JD*; RYAN, EG; KOWALCYZK, CP; GASIOREK, IS; MAY, HE; KAUTZ, M; NAIR, J; University of Miami; *bakerjd@bio.miami.edu*

Mutations in a phylogenetically ancient synaptic gene cause early lethality in Drosophila melanogaster

Neurons and synapses are thought to have evolved well after metazoan life emerged, yet ancestrally derived animals, such as sponges, have many genes known for their roles in synapse development or function. One example of these, the cript gene, is highly conserved across phylogeny with likely orthologs present in some plants. To date studies of Cript protein have focused on its role in binding the third PDZ domain of Post Synaptic Density Protein 95 (PSD95) and microtubules. Mutations of the CRIPT gene in humans are a cause of Primordial Dwarfism, a severe syndromic form of dwarfism. We chose to ask what the non−neuronal functions of this gene might be by mutagenizing the cript locus in *Drosophila melanogaster* and studying the consequent phenotypes. Using transposon induced excision mutagenesis we recovered 5 independent alleles that fall into distinct phenotypic classes. Four alleles die as early embryos showing defects at or before gastrulation. The remaining allele survives to the late larval/early pupal stages, with a prolonged larval period, and large larval body size. Intriguingly this allele may phenocopy mutations in discs large (dlg) the fly ortholog of psd95. Ongoing experiments include sequencing of alleles, transgenic rescue, fluorescent tagging of cript and detailed cellular analysis of the mutants to elucidate the cellular and molecular bases of the observed phenotypes.

P3.31 BALABAN, J*; AZIZI, E; Univ. of California, Irvine; *jbalaban@uci.edu*

Muscle Atrophy and Contractile Properties in the Fence Lizard, Sceloporus occidentalis

Optimal organismal performance relies on the maintenance of muscle contractile properties. Just as humans weaken from prolonged bed rest, most animals lose muscle mass (atrophy) with significant disuse. However, some organisms have physiological solutions to mitigate the negative effects of being sedentary. Hibernating animals can go months at a time with little to no loss of muscle. Many mammals can marginally lower body temperature and activate physiological pathways during hibernation to not only limit muscle loss, but to prevent the common shift from slow to fast muscle fiber types. However, our knowledge on muscle atrophy resistance during hibernation is largely limited to endotherms, which necessarily maintain a high metabolic rate throughout hibernation. In order to understand the effects of metabolic rate and physiology on muscle atrophy and performance, we investigated a hibernating ectotherm, the lizard, *Sceloporus occidentals*. To better understand the role of metabolic rate on muscle atrophy, we denervated the sciatic nerve unilaterally and housed the lizards at 30 C for six weeks. At the end of this period, we quantified the morphological and contractile properties of the gastrocnemius muscles bilaterally, using the non−denervated side as a control. Denervated muscles were 15% lighter than control when controlling for body weight. Muscle atrophy is usually associated with a shift from slow to fast fiber types, but our data show a reduction in maximum shortening velocity of the atrophied muscles. These results suggest that ectothermic organisms maintained at high body temperatures are susceptible to muscle atrophy. By comparing these results to treatments at lower temperatures we aim to understand the effects of metabolic rate on the mechanism of muscle atrophy.

67.7 BALIGA, V.B.*; MEHTA, R.S.; Univ. of California, Santa Cruz; *vbaliga@ucsc.edu*

Kinematics of picking behavior in wrasses

In fishes, cleaning is a mutualistic behavior wherein a species will remove and consume ectoparasites from other organisms. Previously, researchers have described the mouth movements of cleaner fishes as precisely and repetitively "picking" ectoparasites off clients. The term "picking" has also been described in the kinematic literature as "forceps−like" movements of the upper and lower jaws by cyprinodontiform taxa to selectively grasp specific food items from the water column. Whether the functional morphology of picking in cleaner fishes is similar to the kinematics of picking in cyprinodontiforms has yet to be systematically studied, and details of exactly how cleaner fishes capture their prey are lacking. Here, we filmed lateral views (at 1000 frames/second) of individuals from four species of wrasses (cleaners and non−cleaners) feeding on attached prey. Our kinematic analyses revealed that cleaners exhibit smaller magnitudes of lower jaw rotation, cranial rotation and peak gape values. Additionally, when we examined the correlation of timing variables, we found a higher degree of coordination (indicated by high correlations) in upper and lower jaw movements in the picking behaviors employed by cleaners when compared to the biting behaviors of non−cleaning taxa in our study. These results indicate that the kinematic basis for cleaning behavior lies in low−displacement, highly−coordinated movements of the jaws that enables cleaners to selectively acquire prey items that are attached to a substrate.

82.7 BALL, H; CLEMENTZ, M; VINYARD, C; SAFADI , F; COOPER, LN*; NEOMED, Rootstown, OH, Univ. of Wyoming, Laramie; *l.noelle.cooper@gmail.com*

Characterizing the Unique Extracellular Matrix of Bat Wing Bones

Among mammals, the wing bones of extant bats are unusually resistant to fracture. Published studies have shown that, relative to terrestrial mammals, bat wing bones have thinner, rounded cortices with lower mineral composition. Unfortunately, no studies have identified the structural and developmental mechanisms that allow bat bones to bend with relative ease. Here we show that bat wing bones have a unique extracellular matrix composed of an abundance of organics that are organized generally into helical or longitudinal patterns along the length of the bone. Proximal elements known to be loaded in torsion display a helical wrapping of organics around the longitudinal axis of the bone, whereas those bones that primarily bend display a more longitudinal arrangement. In addition, our molecular assays show that bats, relative to rodents, have at least 10−fold greater expression in those genes associated with the synthesis of organics (e.g., Col1a1, Col1a2, Col5a1), and inhibitors of mineral deposition (e.g., VDR). Ongoing analyses will continue to identify unique gene expression patterns that ultimately create a mammalian limb with an extracellular matrix that is unusually resistant to fracture.

P2.152 BANDYOPADHYAY, S*; NAJJAR, M; FLEITES, V; SKROMNE, I; University of Miami, Coral Gables, * University of Miami, Coral Gables (graduated); *saptaparni@bio.miami.edu*
To understand the role of Cdx4 transcription factor in determining number and size of segments during trunk tissue patterning
The vertebrate body is metameric, each species having a characteristic number of segments. As repeating units are generated through segmentation processes, their identity is bestowed through patterning processes. Segmentation is regulated by dynamic morphogen gradients coupled to a molecular oscillator, the clock and wavefront' model postulated in 1976 by Cooke and Zeeman. Patterning, on the other hand, is regulated by processes that sequentially, in a 3' to 5' direction, activate *hox* gene transcription. The processes coordinating segmentation and *hox* gene transcription are poorly understood. We have investigated the role of a gene involved in patterning during the process of somitogenesis, the transcription factor Cdx4. Despite of the fact that Cdx4 deficient embryos have defective somite morphology, its function in somitogenesis has not been established. Our preliminary studies suggest that Cdx4 is important for somite formation through the regulation of the wavefront' or morphogen gradient, but not the period of the segmentation clock. Loss of wavefront regulation leads to changes in somite size and an overall reduction in embryonic axis length, without affecting the total number of segments. Thus, Cdx4 could potentially be the link regulating somite formation and somite identity. Cdx4's dual role in segmentation and patterning could prove important for understanding the evolutionary diversity of axis length in animals across various phyla.

110.7 BARAN, N.M.*; TOMASZYCKI, M.L.; ADKINS−REGAN, E.; Cornell University, Wayne State University; *nmb68@cornell.edu*
Organizational effects of vasotocin and V1aR on attachment, courtship and pair bonding in the zebra finch
Zebra finches (*T. guttata*) demonstrate selective affiliation between juvenile offspring and parents which, like affiliation between pair partners, is characterized by proximity, vocal communication and contact behaviors. In addition, they exhibit vocal learning, in which juvenile males learn courtship song through socially−guided feedback from adult tutors. This research investigates development of affiliative behavior and tests the hypothesis that the nonapeptide arginine vasotocin (AVT, avian homologue of vasopressin) and the V1a receptor subtype (V1aR) play organizational roles prior to fledging in species−typical vocal learning, courtship and affiliative behavior. Zebra finch hatchlings of both sexes received daily intracranial injections (posthatch days 2−8) of either AVT, Manning Compound (MC, a V1aR antagonist) or a saline control. We assessed affiliation through a series of behavioral assays throughout development. Profound differences were observed between the treatment groups on the first day following fledging and group differences continued throughout life. Once the subjects reached adulthood, we measured courtship and pair maintenance behaviors. We then tested whether administration of AVT or MC altered adult distribution of neurons expressing V1aR mRNA in the extended medial amygdala and whether the neurons expressing V1aR were active during pair maintenance behaviors by staining for the colocalization of ZENK, an immediate early gene. These results suggest that AVT and the V1aR are involved in the organization of social development, perhaps modifying early attentiveness to social stimuli or motivation, leading to downstream differences in socially−relevant behaviors.

33.5 BARBER, MC*; PALMER, EJL; RICHKUS, JS; RTI International, Washington, DC, Nautica Environmental Assoc., Abu Dhabi, UAE; *mbarber@rti.org*
Characterization of the Benthic Environment in Abu Dhabi
For the last 3 years the first author has been working in Abu Dhabi, UAE on issues related to the marine environment. Although the majority of Barber's career has been based in Washington, DC at the interface of science, management and policy, work in Abu Dhabi brings her closer to the field studies conducted as one of Sally Woodin's early graduate students. Abu Dhabi's coastline is approximately 1000 km along the Arabian Gulf where very high salinities (40 to 50 ppt), air and water temperatures (25° to 35° C) and alkalinity are the norm and freshwater input from precipitation (average 50 mm/year) or terrestrial sources is very limited. The area is relatively unstudied and historical data points are few. The presentation will provide an overview of the hydrodynamic, physical and chemical conditions in the Arabian Gulf and Abu Dhabi coastal waters in particular and describe the distribution and abundance of existing habitats (sand stretches, macroalgal and sea grass beds, coral communities, and mangroves) and benthic fauna found within these habitats. Diversity is relatively low and the region continues to be not well studied. Climate change is mentioned in the context of the high stresses already present in the environment.

115.1 BARDUNIAS, P. M.*; TURNER, J. S.; State University of New York College of Environmental Science and Forestry; *paulmb@ufl.edu*
Organizing Termite Construction without Cement Pheromone Mediated Stigmergy
Nest structures of termites arise from the aggregate labor of many individuals. Grassé proposed that the labor of termites is coordinated by stigmergy, an indirect mode of communication whereby the work product of a builder acts to guide subsequent workers. In his proposed framework, construction is driven by a positive feedback interaction between termites, mediated by "cement pheromone" used to stimulate additional construction at scent−labeled sites by other termites. Based on Grassé's initial work, and bolstered by a small number of empirical studies, many have produced virtual simulation models of termite construction or excavation that rely on agents imparting a label to work sites that decays in some fashion and orients the labor of subsequent agents at threshold concentrations. Recent work on subterranean termites has demonstrated that such scent labels are not necessary for the organization of cadres of termites excavating tunnels. Instead the excavation process is governed solely by the tactile interactions of termite excavators and patterns of traffic flow. The behavior of termites in queues of excavators awaiting access to the extending tips of tunnels is responsible for scaling tunnel width to traffic flow and results in the emergence of bifurcation. We present a scheme of tunnel excavation that does not invoke cement pheromone to organize labor. Additionally we present data from mound building Macrotermes spp. that questions the pheromone nature of scent imparted to soil deposited by termite during construction. Our work calls into question the key organizing factor of current dogma on insect construction.

87.3 BARFIELD, S.J.*; MATZ, M.V.; University of Texas, Austin; *sbarfie@g.clemson.edu*

Do somatic mutations contribute to genetic diversity in long−lived corals?

Corals with long sexual generation times are typically assumed to be incapable of adapting over short ecological time scales. However, old coral colonies that have experienced many rounds of cell division may accumulate considerable numbers of somatic mutations over the course of their lifetimes. It has been hypothesized that these mutant cell−lineages can contribute heritable genetic variation, which can be acted upon by selection in corals. We are investigating this hypothesis with innovative genotyping methods based on next−generation sequencing technologies. Two massive colonies of Orbicella (Montastrea) faveolata, estimated to be more than 300 years old, were sampled from the Flower Garden Banks in the Gulf of Mexico. Replicate samples of adult tissue and gametes were taken from opposite sides of each colony, as the greatest numbers of cell divisions are expected to separate these locations. All samples were genotyped using a modified 2b−RAD protocol that is capable of discarding PCR duplicates and thus measure the SNP frequencies with better precision. With these data we will identify new somatic mutations and estimate the frequency with which they accumulate. Moreover, we will determine whether these mutations are passed onto the next generation, thus contributing to genetic variation in the species. This project is the first experimental investigation into the impact of somatic mutation on genetic diversity in an ecologically important species. Results of this work have implications for models of adaptation and conservation in corals as well as other long−lived colonial organisms.

11.2 BARIS, TZ*; OLEKSIAK, MF; CRAWFORD, DL; University of Miami/Rosenstiel School of Marine and Atmospheric Science; *tara.baris@rsmas.miami.edu*

Adaptive Epistasis: Nuclear−mitochondrial interactions select for different genotypes

We are investigating the impact of nucleotide divergence on oxidative phosphorylation (OxPhos) metabolism among populations of *Fundulus heteroclitus*. The OxPhos pathway occurs in mitochondria and uses oxygen to produce the majority of ATP in a cell. This pathway consists of 5 large enzyme complexes with 45 to 4 proteins per complex and is the only pathway in which the proteins involved are coded by both mitochondrial and nuclear genomes. *F. heteroclitus* populations have sequence divergence in OxPhos genes in both mitochondrial and nuclear genomes. These populations are distributed along a steep thermal cline on the east coast of the United States and have evolved by natural selection to adapt to this clinal variation in temperature; thus, *F. heteroclitus* serve as a model species to enhance our understanding of the impact of nucleotide divergence on physiological function. Two distinct mitochondrial haplotypes exist along this thermal cline, a northern and southern haplotype with a break at the Hudson River. In northern New Jersey, there is an admixture of mitochondrial haplotypes with a frequency of about 60% southern haplotype and 40% northern. We have performed a genotyping by sequencing experiment in order to determine if there is an association between the mitochondrial and nuclear genomes. OxPhos measurements were performed on 180 individuals from the admixture population and these same individuals were also genotyped. We identified 16,489 single nucleotide polymorphisms (SNP), called in 70% of individuals. There are about 500 SNPs with significant F_{ST} values ($p < 0.01$) when haplotypes are used as a grouping factor. This is suggestive of an epistatic interaction between the mitochondrial and nuclear genome.

P2.163 BARRIOS, A/S*; SUMMERS, A/P; California Sate University, Fullerton, University of Washington; *asbbarrios@gmail.com*

Energy Required to Fracture Acellular and Cellular Bone in Fishes

Anosteocytic bone, bone that is characterized by the lack of osteocytes, has been observed in many higher order fishes. There is little difference in stiffness and strength between anosteocytic and normal bone, however there is an in vivo measurement showing higher strain rates than mammalian cellular bone. We supposed this might indicate a higher energy to fracture anosteocytic bone than cellular bone. A pendulum was constructed with a motorized release mechanism for a steel bob. The opercles of the great sculpin (*Myoxocephalus polyacanthocephalus*) and Chinook salmon (*Oncorhynchus tshawytscha*) were dissected, cut into a uniform size with a laser cutter, subjected to a Chapry Impact test, and recorded using high speed video. The laser cutter proved to be capable of very precise sample generation with minimal edge damage due to heat. Loss of kineic energy in fracturing the bone sample was reflected in a decrease in the height of the pendulum bob after striking the sample. The mean energy required to fracture acellular bone was 2430.6±390 J/cm^2. The mean amount of energy required to fracture cellular bone was 2040.1±530 J/cm^2. The amount of energy required to fracture acellular and cellular bone were not significantly different (p=0.35). We cannot support the hypothesis that anosteocytic bone is tougher than bone with a normal distribution of osteocytes.

24.1 BARRON, DG*; CRESPI, EJ; SCHWABL, H; Univ. of South Florida, Washington State Univ.; *douglasgbarron@gmail.com*

Meta−analytical evaluation of the Cort−Fitness Hypothesis

Ecologists frequently use baseline circulating corticosterone (CORT) concentrations as a physiological indicator of the state of wild animals. This reasoning is dependent upon the prevalent, yet unresolved, assumption of the Cort−Fitness Hypothesis that high baseline CORT concentrations signify individuals or populations with low fitness (reproduction and survival). In this study we employed a meta−analytical approach to evaluate the support for this hypothesis in birds, while also attempting to unravel the causes of discrepancies among studies. Our analysis of 30 studies across 8 taxonomic orders revealed a significant, yet weak, negative relationship between circulating CORT levels and fitness. This relationship was influenced by the species' body mass, with heavier birds exhibiting a more negative relationship between CORT and fitness. However, when analyzing only the order Passeriformes, in which there is the greatest diversity of species studied, the opposite pattern was observed. No other species attribute (sex, age, breeding vs. non−breeding, latitude, baseline CORT concentration) or characteristic of the study design (fitness metric, scope of comparison, correlative vs. experimental approach) related to the pattern. This quantitative assessment moves the field forward by validating the negative relationship between CORT and fitness yet challenging the continued use of this weak bioindicator, although the sources of variation among studies remain largely enigmatic. We propose that an increase in the monitoring of CORT levels across the lifespan is needed to capture dynamic patterns within and between populations before this measure can be relied upon to indicate individual or population fitness.

4.7 BARTOL, I.K.*; KRUEGER, P.S.; HOOMAN, F.; Old Dominion Univ., Norfolk, VA, Southern Methodist Univ., Dallas, TX; *ibartol@odu.edu*

Understanding locomotion in multi−propulsor squids using a 3D integrative approach

Studying movement in squids is challenging because they rely on the coordinated interplay between complex fin motions and a pulsed rotatable jet to locomote, and they are capable of swimming effectively in both arms−first and tail−first orientations. Understanding how this dual mode, i.e., jet and fins, system operates during locomotion requires (1) a full 3D platform for quantifying flows from the multiple propulsors/control surfaces and the corresponding body kinematics and (2) mathematical approaches for identifying and categorizing behavioral and hydrodynamic patterns of movements. Therefore, we are using defocusing digital particle tracking velocimetry to quantify 3D flows and high−speed videography to track 3D body motions while squid swim in water tunnels. Proper orthogonal decomposition and topological analysis utilizing critical point properties are also being performed on the 3D kinematic and 3D flow data, respectively, to quantitatively identify and categorize locomotive patterns and highlight essential elements of the swimming kinematics and flow hydrodynamics. Our results show that both the jet and fins contribute to propulsion to varying degrees depending on swimming orientation and behavior, though the jet often produces the most impulse, and isolated and interconnected vortex rings are prominent wake features. In general, the fins produce more complex wake patterns, more multifaceted kinematic fin modes with prominent flapping and traveling wave features, and greater impulse during arms−first than tail−first swimming. While critical point analyses are ongoing, early results indicate that this method has great promise for quantitatively identifying groups of wake features with similar performance benefits.

P1.55 BASHEVKIN, SM*; PECHENIK, JA; Tufts University, Univ. of California, Davis, Tufts University; *smbashevkin@ucdavis.edu*

Interactive effects of temperature and salinity on larval and juvenile growth in the marine gastropod Crepidula fornicata

Sea surface temperatures have been rising and are predicted to continue rising in coming years because of global warming. In addition, salinity has been decreasing in high latitudes and is expected to continue decreasing due to altered precipitation patterns and glacial melting caused by climate change. Early life stages (larvae and juveniles) should be especially susceptible to these environmental changes since they do not yet have fully developed adult defenses. In this study, we investigated the effects of reduced salinity (20 compared to a control of 30) and altered temperature (15, 20, 25, and 29°C) on the growth rates of juveniles and larvae of the gastropod *Crepidula fornicata*. Both larval and juvenile growth rates were significantly depressed by low salinity and elevated by higher temperatures. Moreover, the salinity that snails were exposed to as larvae significantly impacted their juvenile growth rates in 4 out of 6 experiments, an example of latent effects, but the magnitude and direction of this effect depended on rearing temperature and parentage. Salinity and temperature had little effect on relative rates of shell vs. tissue growth in juveniles, but had a measurable effect on larvae: the shell mass proportion of larvae reared at 20°C was 27% lower at a salinity of 20 than 30. In conclusion, *C. fornicata* may experience more favorable conditions in a warmer future: both larval and juvenile growth rates should increase, probably making larvae and juveniles more resistant to predation. However, in regions where salinity is decreasing, *C. fornicata* larvae and juveniles will likely grow more slowly, thereby increasing predation risk by forcing them to spend more time at more vulnerable smaller sizes.

9.2 BASTIAANS, E*; SWIM, P; WYCKOFF, L; TAN, X; SUKHARAN, D; ZUK, M; Univ. of Minnesota, Twin Cities, Salisbury University; *ejbastiaans@gmail.com*

Reproductive effort changes after immune challenge at varied life history stages in a cricket

Responding to an immune challenge is costly, and animals vary in how they deal with these costs. In some cases, individuals responding to an immune challenge appear to prioritize survival at the cost of reduced future reproduction. In other cases, individuals appear to interpret an immune challenge as a threat of death, leading to terminal (i.e., increased) investment in reproduction and decreased investment in immunity. Life history stage may influence which outcome occurs. We predicted that individuals who were juveniles when challenged should prioritize survival in order to reach reproductive age, even at the cost of reduced future reproduction. In contrast, individuals of reproductive age should be more likely to exhibit terminal investment. We challenged the immune systems of both male and female Pacific field crickets, *Teleogryllus oceanicus*, at four life history stages: last juvenile instar, immediately after adult molt, after reproductive maturity but pre−mating, and post−mating. We measured immune response with biochemical assays of two key immune system components. We measured reproductive effort by assessing time to reproductive maturity in individuals challenged as juveniles, responsiveness to mating opportunities in all individuals, and song characteristics in males. We found that an individual's age at immune challenge did affect both its immune response and behavioral responses to immune challenge, but not always in the predicted direction.

94.6 BATEMAN, T.F.*; MCLELLAN, W.A.; COSTIDIS, A.M.; HARMS, C.A.; ROTSTEIN, D.S.; PABST, D.A.; Univ. of North Carolina, Wilmington, North Carolina State Univ., Marine Mammal Pathology Services; *tfk9187@uncw.edu*

The anatomic distribution of Crassicauda within the pygmy sperm whale (Kogia breviceps)

Giant nematodes (>3m) of the Family Crassicaudidae are known to infect kogiid whales. Only two studies to date have provided detailed descriptions of these *Crassicauda* worms, based upon fragmented specimens including a female head (Johnson and Mawson, 1939) and a male tail (Dollfus, 1966). Both studies described worms within the neck region of kogiids, an unusual anatomic site for this family of nematodes. At SICB last year we demonstrated crassicaudids to be a species−specific parasite among kogiids, infecting only *Kogia breviceps*, and confirmed its primarily cervicothoracic distribution. To date, though, the exact anatomic location and potential transmission path of this parasite are unknown. Thus, our goal was to identify the worm's pattern of habitat use within *K. breviceps* using historic necropsy reports (n=64), detailed gross dissections (n=6), histology (n=2), and non−invasive imaging techniques (n=1). We discovered that a critical habitat for the worm is a previously undescribed exocrine gland, located at the terminus of the pigmented "false gill slit" in the ventral cervical region of the whale. Preliminary results suggest this is a compound tubuloalveolar gland with a central lumen. Male and female tails were found entwined and hanging freely within the lumen of this gland, and eggs have been observed in its presumed exudate, illuminating the potential transmission path out of the host body. The cephalic end of these worms are found, often meters away, embedded deep within the host's epaxial muscle. We describe in detail a single parasite's tortuous 312cm course from the gland to its termination in the contralateral epaxial muscle of its definitive host, *K. breviceps*.

3.6 BATESON, Z.W.*; WHITTINGHAM, L.A.; JOHNSON, J.A.; DUNN, P.O.; Univ. of Wisconsin−Milwaukee, Univ. of North Texas, Denton; *zbateson@uwm.edu*

Drift and selection shape MHC variation in prairie−chickens

As a result of habitat loss and fragmentation, many species now exist in smaller and more isolated populations which often results in decreased genetic variation and reduced fitness. One cause of lower fitness may arise from increased susceptibility to pathogens due to the loss of variation at immune genes, such as those of the major histocompatibility complex (MHC). MHC genes are well known for their critical role in the detection of pathogens and the activation of the adaptive immune system in vertebrates. In this gene complex the presence of specific alleles as well as the number of alleles within individuals is related to disease resistance. Therefore, it is important to examine how neutral (genetic drift) and non−neutral (selection) processes influence MHC variation in populations that vary in size and demographic history. To investigate the effects of genetic drift and selection on genetic variation, we compared variation at the MHC and six neutral microsatellite loci in six populations of greater prairie−chickens (Tympanuchus cupido) that varied in size (174 − 178,000 birds) across the geographic range. By examining these genetic markers, we found that small populations have lower MHC variation, consistent with the effects of genetic drift. However, there was also evidence that selection influenced MHC variation at multiple levels. At the sequence level, we found signatures of historical selection at specific sites across the MHC genes (dN/dS > 1). At the population level, there was greater population differentiation at the MHC than at microsatellite markers, suggesting that local adaptation to pathogens may be driving differences at the MHC among populations. In summary, we found each population contained a unique MHC repertoire, and that both genetic drift and selection are important mechanisms shaping MHC variation in prairie−chickens.

50.7 BATTELLE, B−A*; KEMPLER, K.E.; SARAF, S.R.; MARTEN, C; DUGGER, D.R.; SPEISER, D.I.; OAKLEY, T.H.; Whitney Lab., University of Florida, Whitney Lab., University of Floirda, Dept. Ophthalmology, University of Florida, Univ. of South Carolina, Univ. of California, Santa Barbara; *battelle@whitney.ufl.edu*

Three visible light sensitive opsins are specific to Limulus median ocelli and are co−expressed

The eyes of the American horseshoe crab *Limulus polyphemus*, a chelicerate arthropod, are major preparations for studies of vision. *Limulus* has three different types of eyes: lateral compound eyes, median ocelli and larval eyes. Much is known about the structure and function of *Limulus* photoreceptors. Recent work has focused on identifying the opsins they express. Previous studies showed that three visible light sensitive opsins, LpOps1, 2 and 5, are co−expressed in the retinular cells of the compound eye and giant photoreceptors of larval eyes and that LpUVOps1 and LpOps5 are co−expressed in small photoreceptors of larval eyes. The median ocelli or median eyes (ME) were known to be sensitive to both UV and visible light, and LpUVOps1 is expressed in a population of ME photoreceptors. However the visible light sensitive opsins expressed in ME photoreceptors were not identified. LpOps1, 2 and 5 are not detected in the rhabdoms of ME photoreceptors. Here we report that three previously unidentified visible light sensitive opsins, LpOps6, 7, and 8, are co−expressed in a population of ME photoreceptors that are different from those expressing LpUVOps1. We also show that these opsins are not expressed in the compound or larval eyes so they are unique to the ME. Differential expression of visible light sensitive opsins in compound eyes and ocelli has also been described in insects and crustaceans. Our results now show this is a feature common to all three major arthropod groups. Our results also show that in *Limulus*, all visible light sensitive photoreceptors express more than one opsin.

5.6 BATTISTA, NA*; LANE, AN; MILLER, LA; Univ. of North Carolina, Chapel Hill; *nickabattista@gmail.com*

Bumps and Ridges: Trabeculation in Heart Development

Trabeculae form in developing zebrafish hearts for Re on the order of 0.1; effects of trabeculae in this flow is not well understood. Dynamic processes, such as vortex formation, are important in the generation of shear at the endothelial surface layer and strains at the epithelial layer, which aid in proper morphology and functionality. In this study, CFD is used to quantify the effects of Re and idealized trabeculae height on the resulting flows.

105.6 BATTLES, AC*; KOLBE, JJ; AVILES−RODRIGUEZ, K; Univ. of Rhode Island; *andrewcbattles@gmail.com*

Performance Losses do not deter Anoles from Using Artificial Perches

Populations of *Anolis* lizards are successfully established in urban environments, which differ in structural aspects, among others, from natural habitats. However, urban habitats are diverse, comprising a complex matrix of natural and artificial substrates. We ask how often lizards use artificial substrates in urban areas and whether performance differs between smooth (artificial) and rough (natural) surfaces. We recorded perch use frequencies (natural vs. artificial) of *Anolis cristatellus* and *Anolis stratulus* in natural and human−disturbed (urban) sites on Guana Island in the British Virgin Islands and determined substrate roughness on a scale from 1 to 5. Lizards were found more frequently on artificial substrates than on natural ones (i.e. trunks and branches) at urban sites. Substrates in urban habitats were significantly smoother than those in natural habitats. We then tested experimentally, whether performance (i.e., maximum velocity) differed across substrates by running lizards on tracks varying in roughness and incline. Lizards sprinted faster on inclined and rough vertical tracks compared to smooth vertical tracks. This decrease in performance was particularly severe for male *A. cristatellus* because they are much heavier than female *A. cristatellus* or either sex of *A. stratulus*. Our results suggest that even though performance decreases on artificial substrates, lizards still frequently use these substrates in urban areas. Therefore, other aspects of the urban environment such as better escape opportunities or more efficient foraging may influence this choice.

P3.40 BEATRIX, B*; HARRIS, A; AKANDE, P; CARROLL, M.A.; CATAPANE, E.J.; Medgar Evers College; *catapane@mec.cuny.edu*

Histamine and Histamine Receptor Involvement in Sensory−Motor Integration of Gill Lateral Cell Cilia Activity in the Bivalve Crassostrea viginica

Gill lateral cells of *Crassostrea virginica* are innervated by serotonin and dopamine. The motor aspects have been well studied, but not the sensory side. Histamine (HIS) is a neurotransmitter and ligand for sensory receptors in invertebrates, but studies in bivalves are rare. We found HIS in ganglia and tissues of *C. virginica* and *C. virginica* can alter cilia beating in response to applying chemical including HIS to mantle. HIS does not alter cilia beating when applied to gill. We hypothesize HIS receptors are present in mantle and we can confirm the receptor type using Western Blot. We used HIS H1, H2 and H3 receptor agonists and antagonist at the mantle rim. Dose responses were conducted and cilia beating observed with stroboscopic microscopy. Results show H2 agonists and antagonists had the strongest effects on beating. For Western Blot, mantle body and mantle rim lysates were prepared by polytron disruption in NP−40 detergent buffer containing protease inhibitor, followed by centrifugation to obtain supernatant with solubilized mantle body and mantle rim membrane proteins. Up to 30 µg of protein was subjected to SDS−PAGE with 10% acrylamide gels and electroblotted onto nitrocellulose. H2 receptor immunoreactivity was revealed after incubation with primary antibodies followed by HRP−conjugated secondary antibody and resolved via colormetric development using CN/DAB substrate kit. Western Blot showed a strong band at 70 kD corresponding to HIS H2 receptors in both mantle body and mantle rim. The study shows mantle body and mantle rim of *C. virginica* contain HIS H2 receptors and further demonstrates a distinct physiological role of HIS in the sensory−motor integration of gill lateral cell cilia activity.

P2.192 BEAVER, M*; VON DASSOW, M; Texas A&M University at Galveston, Duke University; *morgie.beaver@yahoo.com*

Feeding the Masses: Mechanisms of Transport in Bryozoan Colonies

The transport system of cheilostome bryozoans is unusual among long−distance transport systems. In these colonial animals, a network of strands (the funicular system) carries nutrients to non−feeding individuals and to the growing edge of the colony. However a complex of cells appears to plug the pores that connect individuals. Focusing on the cheilostome, *Membranipora membranacea*, we used time lapse movies to test whether there were contractions/dilations of funicular strands, as expected if muscular pumping moves material through the strands, and to test whether cells or large vesicles moved directionally along the strands, potentially carrying nutrients. Neither contractions/dilations of the funicular strands, nor persistent movement of particles or other features along the strands were visible in time lapse videos (10 to 120 min at 4 to 10 sec per frame). The only visible movements were rare back−and−forth movements along the strands, or shaking of the strands. We injected materials that differed in molecular/particle size to investigate the specificity of transport at pore plates. Both fluorescein (367 Da; as sodium salt) and fluorescein−dextran (70,000 Da) moved between individuals; however 2.0¼m fluorescent polystyrene beads did not. The fact that both fluorescein and fluorescein−dextran were transported suggests that transmembrane channel or transporter proteins are not required for transport; however there may be an upper size limit (<2¼m) below the pore size. Our results are consistent with some transport mechanisms (e.g. paracellular diffusion or transcytosis at the pore plate) but inconsistent with others (muscularly−pumped flow along funicular strands, cell crawling, or transmembrane transport via transporter or channel proteins).

24.3 BEBUS, SE*; JONES, BC; ELDERBROCK, EK; SMALL, TW; SCHOECH, SJ; Univ. of Memphis; *sarabebus@gmail.com*

Neophobic behavior in free−living birds is highly repeatable and related to stress−induced corticosterone

Individual differences in behavior that frequently covary with stress responsiveness have been demonstrated in a number of taxa. We determined that individual differences in neophobic behavior are repeatable over multiple years in a free−living bird. Florida scrub−jays (*Aphelocoma coerulescens*) were categorized along a continuum of timid to bold based upon their response to novel objects. Individuals were tested repeatedly over 3 years and at different times of the year (i.e., life history stages). Degree of neophobia was highly repeatable in individuals tested 2 to 6 times ($R = 0.50$, $p < 0.000001$, $n = 134$). We considered several factors that may have influenced performance. There were no differences in scores based on test experience ($F_{3,64} = 2.080$, $p = 0.11$) or the size of the group present during testing ($F_{1,299} = 0.054$, $p = 0.82$). Even scores from young birds that were trapped one day prior to the novel object test did not differ from individuals that had never been trapped ($F_{1,30} = 0.91$, $p = 0.35$). We did, however, see a sex difference with males exhibiting bolder behavior than females ($F_{1,142} = 9.36$, $p = 0.003$). Stress−induced corticosterone levels of 1−year−old birds were correlated with neophobia, in that boldness was negatively related to stress responsiveness ($F_{1,46} = 6.88$, $r^2 = 0.13$, $p = 0.012$). Analysis of a fourth year of novel object tests is currently in progress. Another measure of the timid to bold continuum, approach distance to a researcher, was highly repeatable between years ($R = 0.57$, $p < 0.00001$, $n = 52$). Approach distance was positively related to neophobia scores, as birds that most closely approached a researcher were the boldest in the neophobia tests ($F_{1,111} = 13.32$, $r^2 = 0.11$, $p = 0.0004$).

P1.17 BECHER, C.R.*; GUMM, J.M.; Stephen F. Austin State Univ.; *cbecher15@gmail.com*

The Role of Sexual Selection in Hybridization between Pupfishes (genus Cyprinodon)

Hybridization is a driving force for the loss of biodiversity worldwide, and is of particular concern for freshwater fishes. Reproductive isolating mechanisms play a role in hindering hybridization, but for closely related allopatric species, reproductive isolating mechanisms can break down when the species come into secondary contact with each other. Pre−mating isolating mechanisms include those related to sexual selection. Typically, sexual selection includes female mate choice and male−male competition. This may not only occur within a species but also between species. To identify any break down in reproductive isolation that may facilitate hybridization, experimental studies of female preferences and male competition were conducted on two *Cyprinodon* species. *Cyprinodon rubrofluviatilis* is a common species in the Red and Brazos river watersheds, but the introduction of *C. variegatus* poses a threat to the status of *C. rubrofluviatilis*. *Cyprinodon variegatus* has been introduced to habitats of other *Cyprinodon* in the southwest United States, where hybridization and introgression has been extensive. Female preference trials quantifying association time were used to identify if either species prefer conspecific males to heterospecific males. Male−male competition trials replicated secondary contact and quantified aggressive behaviors. Males of many *Cyprinodon spp.* defend territories to attract females, therefore if one species is more aggressive, they may control more or higher quality territories at spawning sites. Understanding behavioral interactions that may promote heterospecific matings is critical to management strategies in systems threatened by hybridization.

36.5 BECKER, DJ*; HALL, RJ; Odum School of Ecology, University of Georgia; *dbecker@uga.edu*

Too much of a good thing: supplemental feeding alters infectious disease dynamics in urban−foraging wildlife

Provisioning of abundant food resources in urbanized landscapes can have profound effects on wildlife ecology, with important implications for pathogen transmission. While empirical studies have quantified the effects of accidental provisioning activities and supplemental feeding on host behavior and immune function, the net interactive effect of these components on host−pathogen dynamics is unknown. We use simple compartmental models parameterized with data from feral cat populations subject to varying levels of supplemental feeding and infection with feline leukemia virus to investigate how resource−induced changes to host demography, contact behavior, and immune defense influence pathogen invasion and persistence. Our simulations show that pathogen invasion success and long−term prevalence depend critically on how strongly supplemental feeding affects host resistance to infection and that moderate levels of these resource additions can lead to drastically different outcomes of pathogen extinction or maximizing prevalence far above levels of disease in unsupplemented populations. These results highlight the need for further empirical studies, particularly field experiments quantifying immune defense, to fully understand how supplemental feeding and other human−provided resources affect pathogen transmission in urbanized environments.

53.2 BECKERT, M.*; NADLER, J. H.; FLAMMANG, B. E.; Georgia Institute of Technology, Georgia Tech Research Institute, New Jersey Institute of Technology; *michael.culler@gatech.edu*

Remora Adhesion Mechanics

The remoras (Family Echeneidae) create rapid, robust, and reliable adhesion to a variety of marine hosts both natural and artificial. Several key systems which make up the remoras' suction pad include spinules, a fleshy lip, mucus, and articulating lamellae work in concert to overcome the difficult attachment conditions that are inherent in a submerged marine environment such as fluid drag, varying host surface topology, surface contamination, and attachment site deformation to name a few. Here structural characterization is combined with multi−scale mechanical modeling to evaluate the performance of the remoras' suction pad. Results suggest operating limits for the pad which are compared to behavioral observations. Understanding the roles of structure and material properties through mechanical models is a critical step toward translating the remarkable attachment ensemble of remoras into useful, bio−inspired applications.

42.1 BEDORE, CN*; JOHNSEN, S; PATEK, SN; Duke University; *christine.bedore@duke.edu*

Comparative function of a ballistic−style feeding mechanism in two species of cuttlefish

Rapid protrusion of prehensile appendages is used for prey capture by only a few disparate groups, namely the tongues of chameleons and salamanders and the paired feeding tentacles of decapod cephalopods. Behavioral descriptions and kinematics of feeding strikes have been reported for several species of lizards and salamanders, but studies on cephalopods are limited to the squid *Loligo pea lei*. Similarities in behavior exist among these groups, but broad−scale comparisons are difficult due to a lack of data regarding cephalopods. Using high−speed videography, we quantified kinematic variables of tentacular feeding strikes in two cuttlefish species of similar size, but which exhibit differences in morphometrics of the feeding tentacles. Flamboyant cuttlefish, *Metasepia pfefferi*, extended their long and slim tentacles up to 2.5 body lengths, whereas dwarf cuttlefish, *Sepia bandensis*, extended their shorter and wider tentacles a maximum of 2 body lengths. *Metasepia* completed the rapid strike in less than 10ms, two times faster than *Sepia*. Although most species of ballistic foragers share similarities in the phases of strike behavior (attention, positioning, and strike), cuttlefish tentacle extension exceeded that measured for all other species thus far. The longest reported extension of a ballistic feeding appendage occurs in *Chameleo* species, with a maximum extension of approximately 1.5 body lengths. *Metasepia* strike duration was similar to that of the fastest strikes of plethodontid salamanders, while *Sepia* strike duration was slightly slower and more similar to those of *Chameleo*. Our results suggest that the physical properties of water do not constrain performance of feeding strikes in these aquatic ballistic−style foragers and that differences in kinematics are likely due to morphological differences.

S4.3 BEKKOUCHE, Nicolas T.*; KRISTENSEN, Reinhardt M.; HEJNOL, Andreas; SØRENSEN, Martin V.; WORSAAE, Katrine; Copenhagen University, Natural History Museum of Denmark, Sars International Centre for Marine Molecular Biology; *nicolas.bekkouche@bio.ku.dk*

The jaw musculature of Micrognathozoa, function and evolution

Limnognathia maerski is the sole representative of the latest described phylum Micrognathozoa. The most conspicuous character of this microscopic animal is the complex set of jaws which resembles those of Gnathostomulida and Rotifera. Until recently, the musculature of Micrognathozoa was mostly unknown, leaving many gaps in the understanding of the jaw functioning. Here we present the detailed morphological assessment of the pharynx of Micrognathozoa, investigated by immunohistochemistry and confocal laser scanning microscopy. The musculature of the jaw apparatus are described and compared with other Gnathifera, illustrating some similarities between the jaw musculature of Micrognathozoa and Rorifera. Furthermore, this study reveals the prominence of the fibularium, the largest sclerite of the micrognathozoans jaw, and their central role in supporting the pharynx. The most conspicuous muscle of the pharynx is a ventral muscular plate, absent in other Gnathifera; presumably involved in moving the whole jaw apparatus, and lies ventral to the fibularium. Additionally, several muscles related to the fibularium are implicated in the opening of the main jaws. Moreover, the position of these muscles is more similar to those found in gnathostomulids. Inferences on the detailed movement sequence of the jaws, indicating how the jaw system functions are discussed relative to previous behavioural observations of this animal which includes both food grasping, and the so−called "vomit behaviour". These combined results and observations illustrate the necessity of detailed morphological descriptions to better understand how jaw systems function in such small and intricate organisms.

P3.101 BELANGER, RM*; PETERS, TJ; SABHAPATHY, GS; KHAN, S; ABRAHAM, NK; University of Detroit Mercy; *belangra@udmercy.edu*

The ability to localize a food odor source is diminished in crayfish (Orconectes rusticus) following an acute atrazine exposure

Crayfish are polytrophic meaning that they feed on and become prey for all levels of the aquatic food web as well as, being important for the transfer of energy between benthic and terrestrial food webs. Because crayfish are a keystone species, it is important to investigate any factors that may affect their population size. Crayfish are active at night and rely heavily on their sensory appendages (e.g. antennulues, maxillipeds and pereopods) in order to localize food sources. We have previously shown that herbicide exposure affects localization of female odors by male crayfish. In this experiment, we wanted to examine if changes in chemoreception following herbicide exposure extended to other odorants. We exposed male and female crayfish to environmentally relevant, sublethal levels of atrazine (80 ppb) for 72 hours and then examined the behavioral responses of both atrazine−treated and control crayfish to food odor delivered from one end of a test arena. We measured odor localization and locomotory behaviors of crayfish in response to food (fish) odor. We found that control crayfish spent more time in the proximal region of the test arena and at the odor source when compared to atrazine−treated crayfish. Further, there were no differences in the time spent moving and not moving, total distance travelled in the tank and walking speed (cm/s) when control and atrazine−treated crayfish were compared. Overall, this indicates that acute atrazine exposure alters chemosensory abilities of crayfish while overall motor function remains unchanged.

45.1 BELL, S.S.; University of South Florida, Tampa; *sbell@usf.edu*

Biological interactions and manipulative experiments in soft sediments: building on the Woodin foundation

Woodin (1974) presented one of the first studies that employed cages to examine processes organizing faunal community structure in marine soft sediments. Subsequently, Woodin (1978, 1981) highlighted how refuges provided by biogenic structure contributed to enhanced abundance of infaunal taxa. Combined, these results alerted ecologists to a new domain of biological interactions among macroinfaunal organisms and the utility of manipulative field experiments. Here I review selected work conducted in my laboratory that expands upon the framework found in these papers. Field experiments from mainly a subtropical setting have revealed that: 1) abundance of not only macrofaunal but meiofaunal−size organisms is influenced by biogenic structure within sediments; 2)seagrass shoot structure acts similarly to large tube−building polychaetes by modifying sediments and providing sites of attachment and refugia for meiofaunal and macrofaunal taxa; and 3)below−ground structure of rhizophytic algae and seagrass impacts densities of infaunal organisms although responses are highly species specific. The subtidal soft sediments along the west coast of Florida contain a diverse assemblage of both fauna and flora that remains relatively understudied but poised for new efforts to address questions concerning biological interactions, community assembly, and ecosystem functioning, embracing ideas introduced more than 40 years ago.

P2.92 BENITEZ, PG; BEDORE, CN*; Duke University; *christine.bedore@duke.edu*

Color vision and the optomotor response in the yellow stingray, Urobatis jamaicensis

Physiological analyses of color vision in elasmobranch fishes reveal that most batoids possess multiple visual pigments. While the presence of multiple distinct cone types in an organism is a strong indicator of color vision, only behavioral tests can elucidate the functional potential of a color vision mechanism. The yellow stingray *Urobatis jamaicensis* is a benthic stingray that inhabits shallow, clear, spectrally−rich tropical waters and has three visual pigments with spectral sensitivity peaks in the short, medium, and long wavelength regions of the visible spectrum. Here, we used an optomotor technique to determine the behavioral significance of multiple cone types in yellow stingrays. Stingrays were placed inside a tank surrounded by a rotating drum, which contained stripes of blue, green, or yellow that alternated with grey stripes of equal brightness. Stingrays demonstrated an optokinetic response to the green stimulus, indicated by a significant increase in the number of eye movements relative to the all−grey control drum. These results support the presence of a behaviorally significant color vision mechanism. Interestingly, responses to the blue and yellow stimuli were not different from the control, suggesting that motion vision in these stingrays is mediated by the medium wavelength channel. Peak spectral sensitivity in the electroretinogram also occurs in the medium wavelength region, alluding to a strong reliance on the green channel for visual tasks. Future studies regarding foraging behavior, intraspecific communication, and predator avoidance in yellow stingrays will help determine the importance of color vision to the ecology of the species.

47.3 BENNETT, W.A.*; DABRUZZI, T.F.; FANGUE, N.A.; University of West Florida, Univ. of California, Davis; *wbennett@uwf.edu*

Asymmetric Thermal Acclimation Responses Allow Sheepshead Minnow, Cyprinodon variegatus, to Cope with Rapidly Changing Temperatures

Thermal acclimation responses in sheepshead minnow, *Cyprinodon variegatus*, were quantified by transfer, and reciprocal transfer, of fish between 11.1 and 18.2 C, 18.2 and 25.7 C, or 25.7 and 32.8 C. Changes in thermal acclimation status were assessed by post−transfer, time−series determinations of thermal tolerance (i.e. critical thermal minima and maxima). In general, heat tolerance gain and loss was complete in 20 and 25 days, respectively. Cold tolerance gain was achieved ca. 24 days post−transfer, but attrition was complete after only 12 to 13 days. Heat tolerance was gained asymmetrically, with fish acquiring approximately one−half of their accruable tolerance at the lowest transfer temperature. Likewise, the majority of cold tolerance accruement occurred during the warmest temperature transfer. Relatively uniform losses of heat and cold tolerance were seen in reciprocal transfers. Acclimation patterns were related to initial acclimation temperature, final acclimation temperature, and acclimation time, and could be accurately modeled by multiple linear regression. The results suggest that sheepshead minnow accrue a majority of their high or low temperature tolerance early in the acclimation process well before potential damaging temperatures are likely to occur. This novel pattern of asymmetric heat and cold tolerance acquisition in sheepshead minnow may be a key adaptation for surviving rapid and unpredictable water temperature changes commonly encountered in their natural environment.

P1.85 BENNICE, C.O.*; BROOKS, W.R.; HANLON , R.T.; Florida Atlantic University , Florida Atlantic University, Marine Biological Laboratory ; *cbennice@fau.edu*

Niche Partitioning by the Mimic Octopus and the Common Octopus in a Tropical Sandy Habitat in Florida

Sympatric species have evolved ecological, morphological, and behavioral specializations in combination with spatial and temporal distribution to allow for coexistence. To determine how two species coexist, it must first be determined how each species exploits its niche and any occurrence of biotic interactions (intra− and interspecific competition). Two species of octopus (*Macrotritopus defilippi* and *Octopus vulgaris*) with similar resource requirements overlap in an intracoastal habitat. This study assessed (1) spatial distribution of octopus home or "den" space and (2) potential importance of microhabitat heterogeneity. Octopus den location is marked by GPS to quantify spatial patterns of both species and their spatial relationship to each other. The importance of habitat heterogeneity is measured by determining substrate make−up of the microhabitat and immediate den space for both species. Direct observations and underwater photoquadrats of microhabitat substrate make−up are analyzed in CPCe software to determine frequencies of substrate make−up. Results have identified spatial clustering of *O. vulgaris*. No spatial pattern has been identified for *M. defilippi* . Significance for substrate make−up of microhabitat and immediate den space has also been reported for both species. This study identifies ecological and behavioral components that facilitate coexistence of sympatric species, provide insight into cephalopod ecology, and provide baseline conservation requirements for these unique sand−dwelling organisms. This site may serve use as a mating and nursery habitat.

P2.116 BENTZ, AB*; NAVARA, KJ; University of Georgia, Athens; *abbentz@uga.edu*

The influence of social stimulation on maternal hormone allocation in zebra finches

Females allocate varying amounts of hormones to their offspring in response to the breeding environment and pre−natal exposure to these maternal hormones alters offspring phenotype in potentially adaptive ways (i.e., a maternal effect). In avian species, the positive effect social stimulation has on the allocation of testosterone to egg yolks is one of the most consistently supported environmental effects on female hormone allocation. However, to our knowledge, yolk testosterone has never been measured in zebra finch (*Taeniopygia guttata*) eggs after a social stimulation. Zebra finches would make an ideal study species for this maternal effect because they express aggressive behaviors, have quick sexual maturation, and their popularity for use in laboratory studies gives a context for findings. Furthermore, zebra finches have already been shown to alter hormone allocation based on laying order, male quality, and female quality. Therefore, we have collected entire clutches from female zebra finches prior to and during a simulated territorial intrusion to determine the effect of social stimulation on zebra finch yolk testosterone allocation. These findings will help create a model species for testing maternal effects and prepare the field for more in−depth questions concerning the mechanisms that mediate yolk testosterone allocation.

S8.4 BERGAN, J.F.; University of Massachusetts; *jbergan@umass.edu*

Sexually dimorphic processing of social signals in the medial amygdala

Animal−animal recognition within, and across species, is essential to guide social and defensive behaviors. Despite its essential role in orchestrating these responses, many basic principles of information processing in the vomeronasal system remain unclear. The medial amygdala occupies a central position in the vomeronasal pathway, just upstream of hypothalamic centers dedicated to defensive and social responses. We find that medial amygdala neurons display sexually dimorphic specificity for social stimuli that is not apparent in upstream sensory nuclei, and that develops near the time of puberty. I will discuss these findings, as well as, recent work investigating the neuromodulation of sensory responses to social stimuli.

103.1 BERGMAN, D.A.*; SWIFT, K.M.; WAALKES, W.C.; GAUTHIER, S.J.; Grand Valley State University; *bergmand@gvsu.edu*

The Effects of Nonylphenol Exposure on Crayfish: Toxicity Concentrations and Alterations of Orientation Behavior

Nonlyphenol is an organic compound used in detergents, pesticides and lubricants. It is a ubiquitous pollutant of both terrestrial and aquatic biospheres. Nonetheless, the majority of studies on pollutants and their effects on animals have been done on vertebrates, yet invertebrates make up over 95% of all animals on the planet. Crayfish are a model invertebrate as they serve as a base resource in many ecosystems' food webs. *Procambarus acutus* crayfish were exposed to varying concentrations of nonylphenol for 24 to 72−hours for short−term exposure, and up to 33 days for a more long−term exposure. Toxicological assays were used to demonstrate the lethal concentration of nonylphenol to crayfish when present in the water. When approaching a concentration of 0.6¼L of nonylphenol per liter of water, crayfish began to succumb to the effects and did not survive. The LC50 for crayfish appears to be between 0.75−0.90¼L/L, well below the current EPA standard. At a concentration of 1.2¼L/L, 100% of exposed crayfish expired. At sub−lethal exposure levels, we performed behavioral trials measuring crayfishes' ability to find food, which is an indication of olfactory function. Nonylphenol exposures resulted in significant impairment compared to control crayfish when orienting to a food source. Furthermore, recovery trials revealed that impairment due to nonylphenol exposure was persistent two weeks after exposure to minimal concentrations. These results indicate sub−lethal nonylphenol exposure impairs the ability of crayfish to find food and perhaps detect other biologically relevant odors.

7.2 BERGMANN, P.J.; Clark University; *pbergmann@clarku.edu*
Patterns of convergence in the body shape of Squamate reptiles
Convergent evolution is the evolution of similar phenotypes in distantly related taxa. It occurs at all biological scales, from genetics to ecology, and in all taxa. The availability of phylogenetic trees and advances in phylogenetic statistics have allowed for the development of methods to test for convergent evolution. Squamate reptiles (lizards and snakes) provide a rich collection of potential examples of convergent evolution, having evolved snake−like body shapes, dry adhesion, gliding, herbivory, and various other traits multiple times. Here, I quantify body shape for 636 species of primarily lizards and construct a phylomorphospace to test whether convergence in body shape has evolved in these various examples. I test for convergence by examining the degree of overlap among convergent taxa in the phylomorphospace and by examining the direction of evolution along convergent phylogenetic branches by comparing non−convergent ancestors and convergent descendants. I find evidence of convergence in body shape for snake−like taxa, gliding taxa, and sand−dwelling taxa. I find weaker evidence for body shape convergence in taxa that have evolved dry adhesion, and no evidence for body shape or size convergence in herbivorous taxa. My findings highlight that choice of traits used to test for convergent evolution affects whether convergence is found or not. For example, the evolution of a snake−like body is intimately related to body shape evolution, while the evolution of herbivory is not, although convergence of herbivores can be seen in skull and jaw shape. As approaches to identifying convergent evolution become more rigorous, researchers will be able to focus more on the functional and developmental mechanisms behind the convergence.

34.1 BERK, S.A.*; BREUNER, C.W.; University of Montana; *sara.berk@umontana.edu*
Measuring corticosteroid metabolites in feathers: 1) optimizing methods to reduce artifacts
Since first publication in 2008, feather corticosterone (CORT) has become a widely used metric of stress physiology in birds. Feather CORT has been correlated with various facets of avian biology including breeding success, coloration, and nutritional status. However, there remain substantial questions about how to most accurately measure feather CORT. Notably, we find that across species the amount of CORT (pg/mm or mg) declines exponentially with increasing amounts of feather. In fecal CORT methods, increasing the methanol to mg feces ratio has accounted for this problem. Here, we attempted to account for this by manipulating the methanol to feather ratio across both mg (feather weight) and mm (feather length). Unfortunately, pg CORT/mg or mm of feather continued to decline even at extremely high volumes of methanol, and this effect persisted across a wide range of feather weights and lengths. We will discuss considerations for measuring feather CORT in light of this, and make recommendations for future work.

57.5 BERKE, SK*; RICHMOND, CE; Siena College, Rowan University; *skberke@gmail.com*
Teaching about teaching: Sally Woodin's legacy in biology education
While Sally Woodin is best known for her many contributions to marine benthic ecology, her students and colleagues know her as both a scientist and as a committed, passionate teacher. Sally has long approached teaching with the same rigor and focus that she brings to research. Her pedagogical interests drove her to implement fresh approaches in the USC biology curriculum, always staying current in new developments in the field of science education. She provided a model for her students of an active researcher who is also an engaged, innovative, and thoughtful teacher. Sally's full−throated support of science education as an interesting and critical endeavor helped encourage many of her students to pursue teaching careers and to value teaching as an important complement to our research agendas. In this talk, we will honor Sally's role as teacher by illustrating some ways that her scholarship and mentorship continue to influence our own approaches with our students.

P3.189 BERLANT, ZS*; STAYTON, CT; Bucknell University; *zsb002@bucknell.edu*
Does the unique shell of kinosternid turtles promote unique patterns of morphological or functional evolution?
The turtle family Kinosternidae consists of 26 species in 4 genera. Members of this group are restricted to the new world, ranging from southern Canada to central South America. These turtles occupy a range of habitats, but all are aquatic or semiaquatic, and typically walk along the bottom of water bodies rather than swimming. They are mostly small turtles, with to carpace lengths of 105−380mm. These turtles have unique shell shapes and constructions (many species possess hinged plastrons). The goal of this study was to determine whether these unique shells also showed unique patterns of morphological or functional evolution among turtles. Data consisted of 3D landmark data captured from scute triple junctions of 214 specimens of 23 kinosternid species. The lineage density of kinosternids was not significantly higher or lower than those of other turtle species. We found strong evidence of phylogenetic signal in kinosternid shell shape, as with other turtles. There is a significant pattern of allometry among kinosternids, but, size explained very little variation in shell shape. The direction of allometry differed from that of other turtle families. We assessed shell mechanics using finite element modeling, and shell hydrodynamics, heat transfer, and stability by calculating a series of morphological indices known to be associated with those functions. Kinosternid shell performance does not fall outside the range of other hard−shelled turtles for any of those functions, but kinosternids do show a unique combination of strong carapaces, weak plastrons, and moderate streamlining, stability, and heat transfer ability. Despite their unique shell shapes, kinosternids do not show any unusual patterns of morphological evolution, although they do show a unique combination of shell performance measures.

P1.105 BERNHARD, MC*; GUILLETTE, LJ; KOHNO, S; College of Charleston, Medical University of South Carolina; *bernhardm@g.cofc.edu*

Effects of PPAR^{3}−RXR± signaling on the American alligator assessed via in ovo tributyltin exposure

For the majority of the last half of the twentieth century and into the early 2000s, tributyltin (TBT) was used as an antifoulant on boat hulls as well as in other products. It has recently been banned in numerous countries due to its endocrine disrupting effect on gastropods, wherein it causes imposex (induced growth of male reproductive organs on adult females). More recently, TBT has been investigated as an obesogenic endocrine disruptor via the peroxisome proliferator−activated receptor gamma (PPAR^{3}). PPAR^{3} forms a heterodimer with the retinoid x receptor alpha (RXR±), and together, they induce a signaling cascade promoting adipogenesis. TBT is an agonist for this in mammals. However, its effects in other animal groups, including non−avian reptiles are unknown. The American alligator (*Alligator mississippiensis*) is a good animal for studying endocrine disruption because like all crocodilians, it exhibits temperature−dependent sex determination (TSD), which makes it more sensitive to endocrine signaling during development than humans and other non−TSD organisms. To investigate the "developmental origins of adult disease" hypothesis for diseases including those such as obesity and those associated with reproductive issues, developmental exposure needs to be investigated. Therefore, alligators were exposed *in ovo* to TBT prior to the thermosensitive period for TSD. Endpoints investigated include sex ratios and liver morphology as well as gonadal and hepatic gene expression. *In vitro* transactivation assays for PPAR^{3}−RXR± were also completed to investigate specific receptor activation.

89.5 BERON, C.C.*; MURRAY, J.A.; University of Texas, Austin, California State University, East Bay; *celiaberon@gmail.com*

Behavioral and neural activity during magnetic stimulation of Tritonia tetraquetra imply conditional magnetotactic response

A variety of species are known to sense and respond to the geomagnetic field for navigation. The sea slug *Tritonia tetraquetra* (a.k.a. *Tritonia diomedea*) has been shown to respond to the magnetic field through both behavior and electrophysiological experiments. However, it remains unclear by which mechanism this sensory information is integrated into motor commands. Additionally, the purpose for a response to magnetic stimuli has yet to be determined. While it is hypothesized that the sea slug sometimes uses a cue−switching mechanism to navigate, ultimately relying on the magnetic field for orientation, laboratory experiments thus far have failed to demonstrate this behavior. The experiments here sought to test this cue−switching hypothesis by demonstrating a response to a local distortion in the geomagnetic field. However, the behavioral response observed was an increased turning frequency upon loss of an initial attractive odor, independent of magnetic distortion, which is inconsistent with the hypothesized straight, geomagnetic−guided crawling. Additionally, in electrophysiological experiments ciliary motor neurons Pd5 and Pd6, as well as sensory nerve CeN1, failed to demonstrate a response to rotations of the magnetic field, despite previous evidence that these units are involved in *T. tetraquetra*'s magnetic response. These results, when compared with previously demonstrated responses, may imply conditional parameters under which detection and use of the magnetic field may be employed.

P2.87 BERON, C.*; RUSSELL, J.; MAKAY, A.; VIDAL−GADEA, A.; PIERCE−SHIMOMURA, J.; University of Texas, Austin; *celiaberon@gmail.com*

Integration of parallel mechanosensory and thermosensory pathways provides mechanism for humidity sensation in the nematode C. elegans

All living organisms require moisture for cellular and other essential processes, which often directly relates to the moisture content of their environments. Despite its significance to survival, little is understood about the mechanism through which variation in humidity is sensed and transduced. The successful examination of a variety of other sensory modalities in the nematode *Caenorhabditis elegans* makes this model organism an ideal candidate for our study of humidity sensation. Changes in humidity affect these soft−bodied invertebrates, which are vulnerable to both dessication and overhydration. Using a novel assay to test the ability of worms to migrate in a humidity gradient (hygrotaxis), we found that *C. elegans* can sense very slight changes in humidity, and demonstrate behavioral plasticity in response to a humidity gradient. Worms preferentially migrated down the humidity gradient of a chamber when starved. The FLP neuronal pair has been identified as the mechanosensory contributor to this integrative sensory system, operating through the conserved DEG/ENaC/ASIC mechanoreceptor complex. A second neuron pair, namely AFDs, has demonstrated a role in thermosensation through cGMP−gated channel signaling, detecting differential evaporative cooling from the worms along the humidity gradient. In both the FLP and AFD neuron pairs, mutations and genetic ablations wholly or partially eliminated hygrotactic behavior. The presence of similar neurons and orthologous proteins in other animals, including humans, enable the possibility that this may be a highly conserved mechanism for hygrosensation.

P2.177 BHATTACHARYYA, KD*; MACIVER, MA; Northwestern University; *kiranbhattacharyya2013@u.northwestern.edu*

Inherent Dimensionality in the Dynamics of Locomotion in Larval Zebrafish and its Implications for Motor Control

The small larval zebrafish (4mm) is capable of a large array of movements ranging from fast ones used to escape from predators, to the fine movements necessary for prey−capture. Usually, these movements are classified by scoring them into qualitatively defined discrete classes (e.g. J−turn, C−turn, etc.). However, recent work has shown that the speed and magnitude of swim bouts from these fish are graded. In the work presented here, we explore an alternative method of analysis with no *a priori* set of classes. First, we compute the net axial muscle forces along the fish body during swimming using a simplified body−fluid interaction model. Then, we investigate the inherent statistical structure of these muscle forces along the body from a set of over 650 swim bouts produced during free−swimming, prey capture, and the opto−motor reflex, a movement response in the direction of whole−field visual motion. We demonstrate that a linear combination of just 3 characteristic patterns of muscle forces along the body axis, or eigenforces, can explain over 99% of the variance seen in axial forces for all of the swim bouts. Since the time evolution of the coefficients of these eigenforces can define a bout, we use frequency and time domain characteristics of the coefficients to discover a small set of eigenbouts which, in linear combination, can recreate all of the bouts in the data set. These eigenbouts can be used to quantitatively define swim bouts in a lower order space and relate muscle activity to translation and rotation in the environment. We demonstrate that the eigenbouts are linearly related to total displacement and change in angular orientation. This work finds a small set of activity patterns which can quantitatively describe swim bouts and provide insight into how a variety of motor behaviors may be produced.

S3.2 BHULLAR, B.−A.S.; The University of Chicago and Yale University; *bhart−anjan.bhullar@yale.edu*

The origin and developmental underpinnings of craniofacial divergence between crocodiles and birds, the two great archosaurian lineages

Crocodylians represent one of the two crown radiations of Archosauria, the ruling reptiles. Although much has been described regarding the series of transitions from the ancestral archosaur to the ancestral bird, somewhat less has been made of the gradual assembly of the similarly specialized crocodylian body and head. I use new CT data and new specimens from the stem of Archosauria and the stem of Crocodylia to trace the gradual assembly of the crocodile form, focusing on the skull. The divergence between the avian and crocodylian lineages was quickly marked by a distinctive lightening of the skull in the former and reinforcement in the latter, culminating in the heavy, solid crania of Crocodyliformes. The wide crocodylian facial region is a relatively recent innovation, which can be pinpointed with an expanded fossil record of Jurassic and Cretaceous taxa. Some of the molecular developmental underpinnings of the divergence between crocodile and bird faces are also now coming to light. New data implicate very early molecular patterning differences in the morphological divergence of the premaxillary region at the tip of the snout, the maxillary region in the middle of the head, and the brain and skull roof at the back of the cranium. This work, however, represents only a beginning. With the release of several crocodylian genomes, it might now be hoped that the upstream regulatory changes leading to crocodylian− or bird−specific gene expression and phenotype are within reach.

113.3 BIERI, T.*; PRINGLE, J.R.; Stanford University; *tamakib@stanford.edu*

Cellular Mechanisms of Cnidarian Bleaching

Several possible mechanisms of bleaching (loss of symbiotic dinoflagellates) have been reported in corals and sea anemones. These include *in situ* degradation of algal cells, exocytosis of algal cells, detachment of host cells containing algae, and death of host cells containing algae (by either apoptosis or necrosis). However, these mechanisms have not been studied in parallel, quantitative studies, and the observations were made in different species under different stress conditions. In addition, the molecular mechanisms underlying these four possible bleaching mechanisms remain unclear. We have developed assays to monitor all four possible bleaching mechanisms in parallel, using animals from a clonal population of the small sea anemone *Aiptasia* that have been exposed to a variety of precisely controlled temperature−stress and light−stress conditions. The overall bleaching responses are assessed by counting the numbers of algae remaining in the hosts using a flow cytometer that allows precise and rapid counting of a large number of samples. To distinguish exocytosis from host−cell detachment, cells in the seawater surrounding the stressed anemones are collected and examined by fluorescence and electron microscopy. To look at host−cell death and *in situ* degradation, we are using western blotting, immunohistochemistry, protease−activity assays, and qPCR to study the possible roles of different cellular pathways including apoptosis and autophagy. Under the several stress conditions tested (heat, cold, high light, and heat plus high light), it seems that host−cell detachment, host−cell death, and *in situ* degradation of algae contribute little to the overall bleaching of *Aiptasia*, and expulsion of algae appears to be the major cause of bleaching.

P2.105 BIERMAN, HS*; BOUSLOG, C; STREETS, A; ZHANG, G; CARR, CE; Univ. of Maryland, College Park; *hilaryb@umd.edu*

Behavioral evidence for sound localization in Alligator mississippiensis

Alligator mississippiensis vocalizations and sound localization are thought to be important for maternal care and group cohesion in young animals (Hunt and Watanabe 1982), and neurophysiological and acoustical studies have demonstrated that these animals are capable of sound localization (Carr et al. 2009; Bierman et al. 2014). Behavioral evidence of localization is, however, lacking. We therefore used psychophysical techniques to determine if juvenile *A. mississippiensis* could localize sound in the laboratory. We trained and tested the alligators in a large tank with speakers and food sources placed on opposite sides. The alligators learned an association between a 1,000Hz tone with a food reward at the tone source. Super−threshold tones were played at random, sparse intervals to prevent habituation to the sound. Every tone represented a trial. Responses were scored if they occurred within 3 seconds of the offset of the tone. Consistently, across animals, trials, and speakers, most movements were towards the side of the tank with the speaker playing the tone.

85.6 BIGA, PR*; FROEHLICH, JM; GABILLARD, JC; SEILIEZ, I; Univ. Alabama at Birmingham , INRA, Rennes, INRA, St−Pee; *pegbiga@uab.edu*

In vitro myotubes derived from zebrafish myogenic precursor cells upregulate Pax−3 and −7 following starvation.

The zebrafish (*Danio rerio*) remains the teleost fish of choice for biological investigations due to the plethora of molecular tools available for use in this system. However, its somatic growth is not representative of other teleost fishes, most of which are able to grow throughout their lives (termed indeterminate growth) while the zebrafish possesses a rather limited growth potential (determinate growth). In vertebrate skeletal muscle, growth is largely regulated by protein turnover, with the balance between protein synthesis and degradation governing whether myofibers hypertrophy or atrophy. To better describe the potentially divergent mechanisms of skeletal muscle atrophy in this species, we developed a primary myotube culture system generated from isolated myogenic precursor cells (MPCs) from adult zebrafish. Using a media devoid of serum and amino acids, we induced the expression of many genes associated with autophagy. Interestingly, paired−box transcription factor (*Pax3/7*) expression increased concurrently with myocyte enhancing factor−2ca (*Mef2c*) upregulation when *de novo* myotubes were subjected to starvation. From these results, it suggests that zebrafish myotubes, cultured from primary myoblasts, can be induced to express early myogenic biomarkers using nutrient alterations.

106.2 BILANDZIJA, H.*; CETKOVIC, H.; JEFFERY, W.R.; Rudjer Boskovic Institute, Zagreb, Croatia, University of Maryland, College Park; *hbilandz@irb.hr*

Evolution of Albinism in Caves

The regression of melanin pigmentation (albinism) has evolved in all animal phyla that have successfully invaded cave habitats. The mechanisms of albinism are only known in *Astyanax* cavefish. In this system, oca2, a gene that acts at the first step of melanin synthesis pathway, is subject to different loss−of−function mutations in independently evolved cavefish lineages. Likewise, a block in the first step of melanin synthesis has been discovered in a diverse group of albino cave animals, including mollusks, annelids, arthropods, and vertebrates. In these animals, exogenously applied L−DOPA can restore melanin pigmentation patterns resembling those of pigmented surface relatives. Therefore, albinism has evolved via convergent evolution by interfering with the first step of melanin biosynthesis pathway in a diverse assemblage of cave animals. What are the evolutionary processes that result in a block at the same step of the pathway in different animals? Studies with *Astyanax* cavefish suggest an explanation: blockage at the first step maybe be advantageous because it results in shunting excess L−tyrosine from the melanin pathway to a branch pathway leading to catecholamine synthesis. Several adaptive traits such as changes in feeding, foraging and sleep behaviors that evolved in cavefish are under the control of catecholaminergic systems. Furthermore, our results show that a number of cave invertebrates (bivalve, polychaete, leech, diplopod and insect) have significantly increased catecholamine levels when compared to their closest surface relatives. It seems that the loss of melanin may have a beneficial effect on survival of cave animals in inhospitable underground habitats.

98.6 BLACKBURN, D.C.*; STANLEY, E.L.; California Academy of Sciences; *david.c.blackburn@gmail.com*

Can we predict the effect of species discovery on macroevolutionary inferences?

We are in an exciting era of development of new and powerful tools for understanding large−scale macroevolutionary patterns. At the same time, we readily acknowledge that most species diversity remains undescribed and seek approaches to accelerate taxonomic descriptions. However, we are also caught in the conundrum of being uncertain how future additions to species diversity will alter the inferences we want to make today. To approach this problem, we utilize previously assembled large−scale phylogenies and ask how diversification statistics based on these phylogenies would be different if "rolled back" to previous time−points in taxonomic knowledge. This work reveals that over multiyear time−scales (especially in recent decades) species are often added non−randomly to the phylogeny. While precise estimates of the tree−shape statistic λ vary through time as species are added, the way in which these values vary over time is similar among different taxonomic groups and provides a framework for assessing the relative completeness of major lineages within a phylogeny. Using this approach, we can estimate when there is sufficient taxonomic knowledge to make macroevolutionary inferences. While it is impossible to predict the effect that discovery of specific lineages will have on large−scale patterns, we can make general predictions about how adding species to a taxon's phylogeny will alter our inferences depending on its taxonomic history.

41.2 BLACKLEDGE, TA*; GREGORIC, M; JAIN, D; AMARPURI, G; OPELL, BD; DHINOJWALA, A; Univ. of Akron, VA Tech; *blackledge@uakron.edu*

Intelligent Adhesives: The Structure and Function of Humidity Responsive Spider Aggregate Glues

The evolution of viscid aggregate glues is associated with the radiation of orb−weaving spiders. Aggregate glue forms the sticky droplets on prey capture threads and is a composite of viscoelastic glycoproteins and organic salts. While the glycoproteins are the primary adhesive, the salts absorb atmospheric water, thereby plasticizing the threads, and directly solvate the proteins, helping the glycoproteins to spread across surfaces. The high extensibility of the droplets allows them to extend in a "suspension bridge" system that also recruits adhesion across the entire thread's length. Here, we explore how each of these elements is responds responsive to humidity and results in the capture threads of diverse species of spiders function optimally at different humidities. We argue that the chemical composition of the organic salts is a highly evolvable mechanism that "tunes" orb function to particular microhabitats.

P3.90 BLADOW, RA*; ROSS, C; OLSEN, K; PIERCE, R; University of North Florida, 1 UNF Drive, Jacksonville, FL 32224, United States, Smithsonian Marine Station, 701 Seaway Drive, Ft. Pierce, FL 34949, United States, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, United States; *rachel.bladow@unf.edu*

Non−target effects of mosquito control pesticides on the sub−lethal stress response of the reef−building coral Porites astreoides

The declining health of coral reefs is intensifying worldwide at an alarming rate due to the combined effects of land−based sources of pollution and climate change. Despite the persistent use of mosquito control pesticides in coastal populated areas, studies examining the physiological impacts on non−targeted organisms such as corals are limited. In order to better understand the effects of mosquito control pesticides on adult corals, specimens of *Porites astreoides* were exposed to ecologically relevant concentrations of two major pesticide ingredients, naled and permethrin. Following an acute exposure period of 24 hours, specimens were allowed to recover for either zero, one, or two days. Coral samples were assessed for photosynthetic efficiency and sub−lethal signs of stress using cellular biomarker assays. Biomarker and photosynthetic responses to pesticide exposure were variable and contingent upon the pesticide type as well as the specific biomarker being employed. Furthermore, the time of recovery usually had a significant impact on the endpoints examined. The importance of considering the complexity and differential responses encountered with this resilient species of coral will be discussed.

P2.115 BLAKE, B.E.*; MCCOY, K.M.; East Carolina University ; *bevinblake@gmail.com*

Organization of Social Behavior by Prenatal Hormones

Fifteen percent of US children have neurodevelopmental disorders (NDDs), and incidences are increasing. Affected children, such as those with autism spectrum disorders (ASDs), often present atypical reciprocal social interactions that impair many important aspects of childhood development. NDDs arise from complex gene x environment interactions, and exposure to the correct hormonal milieu during specific developmental windows is critical for normal neuronal programming. Indeed, recent work indicates that several NDDs are associated with altered hormone concentrations during development, including ASDs and hyperactivity. One prominent hypothesis regarding the relationship between prenatal hormones and ASD is the extreme male brain theory, which suggests that excessive levels of prenatal androgens give rise to a hypermasculinized brain and autistic behavioral phenotype. Testosterone masculinizes the brain through binding to androgen receptor (AR) directly, or can be converted into one of two main metabolites: 5± dihydrotestosterone, which also binds AR, or estradiol, which binds estrogen receptor. To test the hypothesis that sex hormones influence neural organization underlying social behavior, we exposed pregnant Sprague−Dawley rats to dihydrotestosterone propionate, estradiol benzoate, or a vehicle on embryonic days 15.5−17.5 to target a critical window of sex−specific neurodevelopment. Offspring were assayed for a suite of behavioral tests used to indicate changes in social behavior (juvenile social play and social approach test), anxious behavior/hyperactivity (open field test), and spatial learning (Morris water maze). This work will take an important step toward understanding how hormone disruption during fetal development can lead to NDDs that are increasing in prevalence in our population.

P2.172 BLIAMPTIS, J.P.*; HALE, M.E.; Univ. of Chicago; *mhale@uchicago.edu*

How fish control pitch and roll: investigating pectoral fin behavior associated with destabilization in larval zebrafish.

In their natural environments, fishes are faced with diverse flow patterns that require regular behavioral stabilization. Here, we investigate the behavioral responses to destabilization in fish and their mechanical and neural bases. We examined behavioral and physiological responses to pitch and roll in larval zebrafish. To generate roll, we developed two preparations in which the fish were either embedded in agar with the fins freed, or completely free in a small tank. We analyzed the kinematics of pectoral fin movements, and we measured the degree of roll, the angular velocity, and the angular acceleration of the animal. The fish exhibited consistent pectoral fin beating correlated with angular acceleration in the roll direction. The fin beat pattern resembled that of slow swimming, with either a synchronous or asynchronous first fin beat followed by alternating fin beating. We saw a higher incidence of asynchronous abduction in the initial beat than is typical of slow swimming. The duration of the first beat cycle remained consistent, and did not vary significantly with the strength of the stimulus. In contrast, zebrafish did not show a significant pectoral fin response to pitch movement in the embedded preparation. The lack of pectoral fin movement in response to pitch demonstrate that the pitch and roll neural circuits produce different motor output in larval zebrafish. To understand this, we examined the neurophysiology of the responses. In our previous work, cranial transections indicated that hindbrain input is sufficient to elicit this response. Calcium imaging in the hindbrain suggests some candidate regions in which the stimulus may be processed and converted into motor output.

79.4 BLOOM, S.V.*; DEBAN, S.M.; University of South Florida; *svbloom@mail.usf.edu*

Going ballistic: an intermediate tongue−projection mechanism in the plethodontid salamander Hemidactylium scutatum

An elastic−recoil mechanism of tongue projection in plethodontid salamanders provides benefits to terrestrial feeding including high−powered dynamic movements and thermal insensitivity, advantages not found in non−elastic, muscle−powered movements such as tongue retraction. This high−powered feeding mechanism evolved independently within the Plethodontidae by modification of an existing non−elastic mechanism. We examined feeding performance and morphology of the plethodontid salamander *Hemidactylium scutatum* and compared its functional morphology to its close relatives *Batrachoseps* and Bolitoglossini. Morphological examination, high−speed imaging (10 kHz), and inverse dynamics analysis reveals that *Hemidactylium* utilizes elastically powered tongue projection (~6000 W/kg muscle mass) and has muscle−powered, non−elastic tongue retraction, yet retains some ancestral morphological characters compared to its close relatives. The intermediate morphology of *Hemidactylium* provides insight into how elastic mechanisms have evolved in plethodontids and which components are necessary to increase tongue−projection performance.

P2.101 BOBEK, JE*; AMDAM, GV; Arizona State University; *jonathan.bobek@asu.edu*

Testing robustness of epigenetic marks of honey bee (Apis mellifera) behavior

Honey bees (*Apis mellifera*) are known for age−based differentiation of labor, where adult female workers engage in nursing and other in−hive tasks until they begin foraging after about three weeks. Herb et al. (2012) utilized comprehensive high−throughput array−based relative methylation (CHARM) confirmed with whole genome bisulfite sequencing (WGBS) to determine candidate genes which are subject to differently methylated regions (DMRs). 57 genes are similar in percentage methylation between nurses and reverted nurses, but differ between reverted nurses and forager bees. We used a single−cohort model in order to capture nurses and precocious foragers (age matched at day 13) immediately at their first sign of foraging behavior. Using our own DMR parameters, we narrowed the 57 candidates to 3, examining expression levels and possible alternative splicing events within full−brain and fat body dissections. Due to our nature of phenotyping, gene candidates and their degrees of methylation may resolve causes or effects of the transition to foraging behavior.

P3.136 BODEN, AL*; WISE, T; SCHWALBE, MAB; TYTELL, ED; Tufts University; *alexandra.boden@tufts.edu*

Co−contraction of Red Muscle During Acceleration in Bluegill Sunfish (Lepomis macrochirus)

Carangiform swimmers, such as the bluegill sunfish (*Lepomis macrochirus*), engage in an undulatory swimming motion that propels them forward primarily via the movement of the caudal region. However, counterintuitively, the majority of the musculature in a bluegill sunfish is located in its anterior body, not near the tail. For effective transmission of the force from the anterior muscle to the tail, ideally the peduncle region just anterior would be relatively stiff. However, bluegill, like many fishes, have relatively flexible bodies. One way they may be able to resolve this problem is by actively stiffening their body by co−contraction of muscles on opposite sides of the body, particularly during high speed swimming or rapid linear accelerations, when fluid dynamic forces are large. To test this hypothesis, we measured muscle activity, acceleration, and kinematics of bluegill sunfish swimming steadily and performing accelerations at flow speeds of 1−2.5 body lengths per second. To measure accelerations and body kinematics, we attached a small six−axis inertial measurement unit and filmed each fish using high speed cameras. We measured muscle activity using standard fine wire electromyographic electrodes implanted in the red muscle and measured duty cycle, or the fraction of the cycle period during which the muscle is active. Duty cycle increases with speed and during acceleration, sometimes exceeding 0.5. Duty cycles greater than 0.5 indicate that muscle activity on opposite sides of the body is overlapping, and thus that the fish is actively stiffening its body during swimming.

P1.15 BODENSTEINER, B.L.*; JANZEN, F.J.; Iowa State University; *bodenbro@iastate.edu*

Reproductive investment and senescence in the painted turtle Chrysemys picta

Senescence is defined as the decline in an individual's prospect of survival and reproductive rate with increasing age. In the lab and in wild populations of vertebrates, the theory of senescence has illustrated links between onset of reproduction, reproductive effort, and later survival. Even so, studies of reproductive senescence in wild populations of long−lived oviparous organisms are relatively rare. Turtles are well suited for investigating this issue because they display variation in reproduction, indeterminate growth, and are long−lived organisms. We used a long−term data set focusing on a specific subset of adult females from a wild population of painted turtles (*Chrysemys picta*) to explore long−term fitness consequences of reproductive strategies and aging. This was done by statistically evaluating females of known age classes and comparing egg, offspring, and nesting characteristics over many years across entire reproductive lifetimes. We provide results that offer insights into the interactions of age, reproduction, and fitness.

107.3 BOERMA, DB*; TRESKATIS, TL; CHENEY, JA; SWARTZ, SM; Brown University, Westfälische Hochschule Bocholt; *david_boerma@brown.edu*

Recovery from an Aerial Stumble in Seba's Short−Tailed Bat

Flying animals must skillfully navigate and respond to turbulence from other flyers, discrete perturbations such as gusts of wind, and complex flows that arise from air movement around static structures to safely travel, forage, and migrate. Bats may accomplish this task differently from other flyers because their wings are notably heavier. By coopting the many bones and muscles of the hand, arm, and hindlimb for the skeletal framework of the wing, the wings comprise nearly 30% of total body mass in *Carollia perspicillata*. Theoretically, through rapid and asymmetrical modulation of their relatively heavy wings, bats can use wing inertia to perform complex aerial maneuvers without generating aerodynamic force. To record the kinematics of a perturbation response and to explore the importance of wing inertia during recovery from a gust−induced aerial stumble, we trained several *C. perspicillata* to fly through a window that placed them in the path of a gust of wind from above. A synchronized array of six high−speed cameras recorded both the perturbation and the subsequent wingbeats required to restore flight to that resembling control, unperturbed trials. We performed detailed analysis of kinematics of the body and wings during the perturbation and response. We then explored the relative contributions of wing inertia and external forces to body reorientation. To recover from perturbations that induced body roll, bats flapped their wings asymmetrically and were able to rapidly reorient their bodies within two wingbeats. Our findings suggest that through asymmetrical flapping flight, bats may use wing inertia to recover from perturbations and improve flight stability.

49.4 BOETTGER, S.A.*; BARLETTA, A.T; West Chester University, Pennsylvania; *aboettger@wcupa.edu*

Effect of reproductive effort on neoplasia development in the soft−shell clam, Mya arenaria.

Disseminated neoplasia a leukemia−like disease in bivalve mollusks characterized by highly mitotic hemocytes is one of the six most destructive molluscan diseases. It has been extensively investigated in the economically valuable soft−shell clam *Mya arenaria*. The current study examines the reproductive output of *Mya arenaria* compared to overall disease development. Native and deployed *Mya arenaria* from Machias, Maine were collected, disease status determined and samples prepared for histological analysis. Gonadal tubules, oocyctes diameters and mature spermatozoa were measured in ¼m and stereology was conducted for oocyte/sperm versus nutrient cells. Development of terminal neoplasia increases significantly during the spring in deployed animals, which is the onset of the first reproduction. Females did not display a significant difference (p=0.075) in oocyte and tubule diameter between deployed and native animals. Tubule diameter was increased in males during reproductive season in the fall in natives (p=0.026) and in the spring (p=0.041) in deployed animals. Amounts of sperm were elevated in the spring in deployed compared to native neoplastic animals. Spring would have been the first onset of reproduction for deployed animals. Deployed neoplastic males displayed on increase in their reproductive output. Increasing the output in neoplastic females does not occur, possibly because it is too energetically costly.

32.8 BOLAND, L.M.*; TANG, Q−Y.; LARRY, T.; HENDRA, K.; BELL, J.; CUI, M.; YAMAMOTO, E.; LOGOTHETIS, D.; Univ. Richmond, Richmond, VA, Virginia Commonwealth Univ., Univ. Richmond , Univ. Richmond, Univ. of San Diego ; *lboland@richmond.edu*

Comparative physiology of ion channels: How nature's mutations influence the lipid regulation of potassium channels

This project uses the consequences of nature's mutations − the source of evolutionary change − as a way to understand ion channel structure and function. Inwardly rectifying potassium (Kir) channels are critically to the control of cellular resting membrane potential and excitability. In vertebrate species, all Kir channels are regulated by the membrane lipid, phosphatidylinositol 4,5−bisphosphate (PIP2). We used Kir channels cloned from the sponge, Amphimedon queenslandica, a valuable model organism, as a way to understand PIP2 regulation of Kir channels. Using patch clamp experiments, sponge Kir currents decreased over time following patch excision. In two electrode voltage clamp, co−expression and activation of a voltage−sensitive phosphatase led to rapid decreases in sponge Kir current and wortmannin pre−treatment to lower endogenous PIP2 levels significantly reduced sponge Kir current amplitudes. While these are characteristics of the PIP2−dependence of vertebrate Kir channels, direct application of the lipid to the cytosolic side of membrane patches could not reactivate the sponge Kir currents. However, mutagenic substitution of two residues in the sponge Kir channel restored high affinity PIP2 reactivation of Kir currents in excised patches. The functional impact of these experimental mutations which recapitulate nature's changes in the channel's structure can be explained using a homology model of the sponge Kir channel. This research helps resolve the protein/phospholipid interactions required for Kir channel activation and how a phospholipid binding pocket evolved specificity for PIP2, as observed in vertebrate Kir channels.

81.5 BOMPHREY, RJ*; NAKATA, T; DAWSON, IL; WALKER, SM; Royal Veterinary College, University of London, University of Oxford, University of Oxford; *rbomphrey@rvc.ac.uk*

Behavioural clustering and the kinematic modes used by Drosophila in flight

Fruit flies are a model system for animal flight studies from the perspective of muscle physiology, sensory control, flight dynamics and fluid mechanics. Their flight is often described as bouts of straight trajectories punctuated with saccadic turns, although more recent studies have shown their behavioural repertoires to be more diverse. We characterised the typical free−flight behavioural modes of flies as they explored an arena. These modes were identified by a clustering analysis that objectively revealed the combinations of translational and rotational velocities and accelerations of the body that were most commonly observed. Once the collection of principal behaviours had been identified, we looked in more detail at the symmetric and asymmetric wingbeat kinematics that effected those motions. We used an automated algorithm based on voxel carving that allowed for a large sample size to be collected that included information on the twisting of the wings during each stroke cycle. The wingbeat kinematics associated with each mode we identified were subsequently used as the input for a computational fluid dynamics analysis to determine the power, forces and torques on the body.

P2.89 BONKA, A*; HERNANDEZ, M.H.; WIBBELS, T; MARTINEZ, L.S.; MARTINEZ, M.A.C.; NAJERA, B.M.Z.; ILLESCAS, F; PENA, L.J.; BURCHFIELD, P.M.; SCHROEDER, B; POSSARDT, E; Univ. of Alabama at Brimingham, Gladys Porter Zoo, Brownsville, TX, Univ. of Alabama at Birmingham, CONANP, Mexico City, Mexico, CONANP, Rancho Nuevo, Mexico, CONANP, Ciudad Victoria, Mexico, CDEN, Tamaulipas, Mexico, NOAA, Silver Spring, MD, US Fish and Wildlife Services, Arlington, VA; *abonka@uab.edu*

Sea−finding Orientation of Hatchling Kemp's Ridley (Lepidochelys kempii) Sea Turtles at the Natural Nesting Beach at Rancho Nuevo, Mexico

An important event in the life history of sea turtles is the sea−finding orientation of hatchlings following emergence. This event is critical to the survival of hatchlings and is therefore of biological, behavioral, and conservational interest. The current study evaluated sea−finding behavior in hatchlings produced in the Bi−National Kemp's Ridley Recovery Program. Sea−finding behavior was evaluated in orientation arenas on the natural nesting beach. The orientation arena facilitated the quantifying of hatchling movements. Trials were conducted using two different horizon regimes and three different time periods in the early morning during the 2014 nesting season at the primary nesting beach located at Rancho Nuevo, Mexico. Trials were run with ten to fifty hatchlings per time period and all hatchlings were used only once per trial. The results indicate that factors such as openness of horizon and the surrounding light−field affected hatchling orientation. These findings suggest that visual cues represent important components in sea−finding behavior. The results have implications for the biology and conservation of the Kemp's ridley sea turtle.

P3.146 BONNAN, M.F.*; SHULMAN, J.; VARADHARAJAN, R.; GILBERT, C.; HORNER, A.; BRAINERD, E.L.; Richard Stockton College of New Jersey, California State University San Bernardino, Brown University; *Matthew.Bonnan@stockton.edu*

An Exploratory Kinematic Study of the Rat Forearm Using XROMM: Implications for Forelimb Kinematics in Early Fossil Eutherians

The earliest eutherian mammals were small−bodied locomotor generalists with a forelimb morphology that strongly resembles that of extant rats. If form follows function, understanding the kinematics of the humerus, radius, and ulna of extant rats can inform and constrain hypotheses concerning typical posture and mobility in early eutherian forelimbs. Although rodent locomotion, especially that of the Norwegian rat, *Rattus norvegicus*, has been extensively studied for evolutionary and biomedical research, the three−dimensional (3−D) kinematics of the bones themselves remains under−explored. Here, for the first time, we use markerless XROMM to explore the 3−D kinematics of the humerus, radius, and ulna in three adult male Sprague−Dawley rats (*Rattus norvegicus*) as they walked across a horizontal platform. Not surprisingly, our data show that rats maintain a crouched forelimb posture throughout the step cycle, with an elbow joint angle never exceeding 130°. Most forelimb posture and movement is dictated proximally at the glenoid through a combination of flexion/extension, abduction/adduction, and long−axis rotation of the humerus that maintains a caudally−facing elbow throughout the step cycle. For all practical purposes, movements of the ulna on the humerus are constrained to flexion and extension only. The radius was shown to be capable of small but significant long axis rotational movements that contributed to pronation and supination. We tentatively suggest, based on qualitative morphological similarities, that early eutherian mammals had forelimb bone kinematics similar to rats.

P2.48 BOOTH, L.S.*; RUBENSTEIN, D.R.; Columbia University; *lsb2137@columbia.edu*

Has prevalence and diversity of avian malaria changed with a changing climate?

The introduction of avian malaria parasites *(Haemosporidia)* has been shown to cause declines of naïve bird populations and to put previously stable populations at risk of extinction. As global temperatures rise and precipitation patterns become more variable, the ranges of avian malaria parasites and their mosquito vectors are predicted to increase in latitude and altitude. Thus, bird populations living at high altitudes in the tropics may be vulnerable to higher prevalence and diversity of infections than ever before. Although studies have assessed the effects of climate change on haemosporidian distribution over limited timescales, no study has examined patterns of avian malaria prevalence and diversity in a tropical system for >10 years. Here, we evaluate whether prevalence and diversity of avian malaria parasites have changed from 2001 to 2013 in a population of superb starlings *(Lamprotornis superbus)* living in the highlands of central Kenya. We used PCR to estimate *Haemosporidia* prevalence, and sequenced a portion of the cytochrome *b* gene to identify avian malaria haplotypes using a threshold of 1% sequence divergence. Our results showed high levels of infection in most years, and a diversity of *Haemosporidia* species in all years. Based on these findings, we suggest that the effects of global− or continental−scale climate change on avian malaria may be difficult to discern. Additional information about local effects of climate change on mosquito vectors is needed to determine climate−mediated risks of avian malaria spread in the tropics.

S7.10 BORAZJANI, Iman; SUNY Buffalo; *iman@buffalo.edu*

Unsteady Aquatic Locomotion Simulations: From unsteadiness in straight−line swimming to fast−starts

Unsteady aquatic locomotion is not an exception, but how animals swim most of the time. It includes fast−starts (C− or S−start), escape maneuvers, turns, acceleration/deceleration, and even during steady locomotion the swimming fluctuates, i.e., there is unsteadiness. Here a review of the recent work on unsteady aquatic locomotion with emphasis on numerical simulations is presented. First, the swimming speed's unsteady fluctuations during straight−line swimming is reviewed, and the effect of body shape, fins, and motion on such fluctuations is discussed. These fluctuations are typically less than 3% of the average swimming speed, but recent simulations show that body shape affects fluctuations more than body kinematics, i.e., changing body shape generates larger fluctuations than changing body kinematics. Next, previous work on fast−starts and turns is reviewed, and the role of fins during such maneuvers is discussed. Recent simulations show that the kinematics during C−start is the optimum kinematics to achieve maximum acceleration. Furthermore, another set of simulations, which are validated against experimental flow measurements, investigate the role of fins during the C−start. The simulations showed that most of the force is generated by the body of the fish (not fins) during the first stage of the C−start when the fish bends itself into the C−shape. However, in the second stage, when it rapidly bends out of the C−shape, more than 70% of the instantaneous hydrodynamic force is produced by the tail. The effect of dorsal and anal fins was less than 5% of the instantaneous force in both stages, except for a short period of time (2 ms) just before the second stage. Therefore, the active control and the erection of the anal/dorsal fins might be related to retaining the stability of the sunfish against roll and pitch movements during the C−start.

P3.203 BORMET, A.K.*; POLLY, P.D.; Indiana University; *akbormet@indiana.edu*

Environmental adaptability and skeletal plasticity: effects of captivity on the distal limbs of ruminants

Skeletal elements can reshape to resist forces encountered in the environment. This response may allow the shape of a bone to adapt plastically in parallel to the way natural selection would allow it to adapt evolutionarily. We studied the degree of shape difference in the distal digits (unguals) of wild and captive ruminants (Mammalia, Artiodactyla) to determine the extent to which plastic responses are expected in the locomotor system. Zoos have a greater proportion of cement, packed earth, and other hard materials many ruminant species would not naturally traverse; therefore we would expect a significant difference in the ungual shape of captive animals, regardless of species, if plastic response is an important mechanism of locomotor specialization. We analyzed shape differences in the plantar surface of two unguals from three wild and three captive individuals of 13 ruminant species. Outlines with 100 semilandmark points were Procrustes superimposed to produce shape variables for subsequent analysis. On average there was no difference between captive and wild individuals ($p=0.15$, permutation test). However, species varied significantly in the degree to which ungual shape responded to captivity ($p= 0.0316$, species × captivity interaction, two−way MANOVA). Captivity had the greatest effect on giraffids and the least effect on big horned sheep. Surprisingly the magnitude of the effect does not appear to be related to the degree of difference between natural and captive environments. Compared to between species mean differences, the effects of captivity were small. Results suggests that ungual plasticity is not as significant in locomotor specialization as long−term adaptation, but still reveal that plasticity is higher in some species for reasons that are not yet apparent.

43.5 BORSTEIN, S.R.*; MCGEE, M.D.; WAINWRIGHT, P.C.; Univeristy of Tennessee, University of California, Davis; *sborstei@vols.utk.edu*

Mouthbrooding does not constrain craniofacial diversity in Tanganyikan cichlids

Mouthbrooding is a parental care strategy in which the eggs or larvae are incubated in the mouth and has been hypothesized to have a negative influence on craniofacial diversity in multiple lineages of teleost fishes. We examined the impact of mouthbrooding on the craniofacial morphology of the cichlid fishes of Lake Tanganyika in E. Africa. This radiation consists of 200 species with a deep phylogenetic split between a clade of substrate−spawning cichlids and multiple mouthbrooding cichlid lineages. We used geometric morphometric methods and the TPS family of programs to digitize a set of 25 sliding semi−landmarks along the outline of the head in lateral photographs of Tanganyikan cichlid species. Relative warps analysis was performed and the broken stick criterion used to retain axes that explained more variation than expected by chance. We retained three axes which explained 88% of the total variation. Head elongation vs. deepening was the major axis of diversity accounting for 60% of variation. Mouth angle and mouth size accounted for the other two axes and explained 16% and 12% of the variation respectively. Morphospace occupation was determined using Morphospace Disparity Analysis to examine the occupation of both mouthbrooding and non−mouthbrooding sister lineages using 10,000 bootstrapped samples to calculate the mean Euclidean pairwise distance. We find that mouthbrooders exhibit a significantly higher mean euclidean pairwise distance and are 2.4 times more diverse than non−mouthbrooders. Our results demonstrate that contrary to previous interpretations mouthbrooding has not impeded craniofacial diversity in Tanganyikan cichlids, and may indirectly enhance diversification of mouthbrooding species because it allows them to occupy habitats not suitable for substrate brooding.

P2.83 BOSTWICK, C.J.*; YANG, Q.; KOHN, A.B.; HAWKINS, R.D.; MOROZ, L.L.; University of Florida, Columbia University; *bostwick@ufl.edu*

Transcriptomic analysis of single neurons comprising the siphon−withdrawal circuit within the sea hare, Aplysia californica

The sea hare *Aplysia californica* is a highly suitable model for the genomic analysis of learning and memory at the level of individual, functionally identified neurons. Multiple forms of learning and memory are recognizable in this organism, including both associative (classical conditioning) and non−associative (sensitization or habituation) learning. We conducted an extensive RNA sequencing (RNA−seq) analysis of single neurons residing within the siphon−withdrawal circuit of *Aplysia californica*. This was done to gain a better understanding of the dynamics and diversity of the molecular components orchestrating the neuroplasticity that accompanies learning and memory. Multiple transcriptomes were obtained from sequencing LE sensory neurons, LFS motor neurons, and L29 interneurons. Comparison of the transcriptomes allowed us to detect differentially expressed transcripts both within cell types and between trained and control neurons. A large portion of the differentially expressed transcripts encoded already known proteins, such as neuropeptides, cellular ion channels, membrane receptors, and transcription factors. Many transcripts did not code for any known proteins, but are various forms of non−coding RNA species, which may serve to regulate the learning and memory process. These differentially expressed protein−coding transcripts and non−coding RNAs provide clues to identify the molecular players involved in the neuroplasticity that takes place during learning and memory.

P2.82 BOTTUM, G/D*; DAYAN, D/I; OLEKSIAK, M/F; CRAWFORD, D/L; University of Miami; *g.bottum@umiami.edu*

Acute Thermal Compensation of Fish Escape Response Performance

The limits of thermal tolerance depend on the effect of acute environmental changes on physiological and organismal performance. While thermal acclimation over days to weeks often allows for compensation of organismal performance traits, rapid recovery of performance over an acute timescale is not well known. This study examined the escape response fast−start in teleost fish *Fundulus heteroclitus* after exposure to variable temperatures over an acute time course. The escape response in twenty *F. heteroclitus* individuals acclimated to 20°C was recorded 3 and 60 minutes after exposure to 20°C and 12°C. Maximum angular velocity of escape responses performed at 12°C was significantly lower than at the 20°C acclimation temperature after 3 minutes. While no measures of escape response performance varied significantly among fish assayed at the 20°C acclimation temperature, maximum angular velocity significantly improved among fish assayed at 12°C after 60 minutes. These observations demonstrate that *F. heteroclitus* modify escape response performance over an acute timescale. For organisms that inhabit environments with fluctuating temperatures, such as *F. heteroclitus*, the role of such a rapid recovery may be adaptive and broadly relevant considering the link between increased thermal variability and global climate change.

42.3 BOUILLIART, M*; TOMKIEWICZ, J; LAUESEN, P; OKAMURA, A; ADRIAENS, D; Ghent University, Belgium, Technical University of Denmark, Billund Aquaculture, Denmark, IRAGO Institute, Japan; *mathias.bouilliart@ugent.be*

Between the jaws of the leptocephalus larva: biomechanically approaching a rarely observed organism

Being part of the Elopomorph group of fishes, Anguillidae species have a leptocephalus larval stage. Unfortunately, due to (mostly) unknown deep−water marine birthplaces, a catadromous lifestyle, and a transparent body morphology, these *Anguilla* larvae are rarely encountered in nature. Therefore, information regarding the early development of these larvae, including the exogenous feeding strategy and feeding performance, is rather scarce. To get some insight into these early ontogenetic changes and their influence on the functionality of the developing feeding apparatus, an ontogenetic series is put together from two artificially bred Anguillids. Throughout this series, graphical three−dimensional reconstructions (based on histological sections) of the musculoskeletal system of European (*Anguilla anguilla*) and Japanese eel (*Anguilla japonica*) larvae provide detailed descriptions of the changing feeding apparatus. Subsequently, theoretical bite forces are calculated for every reconstructed phase, using 3D data of joints, levers, and muscles derived from these reconstructions. Although the expected increase in bite force is observed with progressing age of the larvae, the obtained forces remain rather small. As a result, leptocephalus larvae are hypothesized to be anatomically constrained to feed only on soft and/or small food particles, which is in line with the current observations of small and/or gelatinous prey items (Hydrozoa, Thaliacea, Ctenophora, Polycystenia) in the guts of these larvae.

P3.163 BOUILLIART, M*; PAIG−TRAN, M; CROFTS, S; FARINA, S; SUMMERS, A; Ghent University, Belgium, University of Washington, Cornell University, New York, Friday Harbor Laboratories, Washington; *mathias.bouilliart@ugent.be*

Body plate morphology of armored Agonidae fishes: how far do the modifications go?

The family Agonidae comprises a variety of marine bottom−dwelling fishes whose scales have been modified into bony plates. Being part of body armor, these plates have to be hard and strong to exercise a protective function. However, to prevent agonids (who lack a swimbladder) to be stuck at the bottom under heavy armor, these plates better be low in weight. To investigate how agonids deal with this mechanical trade−off, armor plates of a common species of the Northeastern Pacific Ocean (*Agonopsis vulsa*) are examined microscopically. Using a combination of scanning electron microscopy and CT−scanning, a network of interconnecting bony trabeculae is observed in all investigated plates along the body. This network, being founded upon a solid surface of concentric bands of bone and supporting a solid posteriorly directed spine in every plate, creates cavities throughout the central mass of the plate, reducing it in weight. To examine the protective capacity of the plates, a finite element analysis is performed. This analysis shows not only that the observed composition of these plates is highly efficient in dealing with external forces, but also that trabeculae are oriented in such a way that potential failure points of the plates under external pressure are structurally reinforced. Additionally, scanning electron microscopy images of the plates of two closely related species (*Bathyagonus alascana* and *Anoplagonus inermis*) are made to find out whether closely related Agonidae species deal similarly with this trade−off. These images show that macroscopically similar plates do have microscopically different surfaces within this family of armored fishes.

P2.159 BOUWMANS, L*; STONE, AD; MILLER, T−A; TULENKO, FJ; DAVIS, MC; Kennesaw State University; *mdavi144@kennesaw.edu*

Expression of Lhx and Pax genes during development of the American paddlefish Polyodon spathula

Limb and digit formation provide an important system for studying the mechanisms of molecular patterning and morphogenesis during development. Members of the LIM−homeobox (*Lhx*) and Paired−homeobox (*Pax*) families of transcription factors have been shown to mediate essential signaling interactions during limb bud development in amniotes, and when experimentally inactivated result in dramatic abnormal phenotypes. For example, knockout studies in mice demonstrate that in the absence of functional *Lhx2* and *Lhx9*, or the LIM−HD cofactor *Ldb1*, the zeugopod is greatly reduced and the autopod lacks a normal complement of digits. Likewise, mice deficient for *Pax9* exhibit preaxial digit duplications in both fore− and hindlimbs, along with other defects in the developing autopod. The conserved patterning roles of *Lhx* and *Pax* genes in other organ systems (e.g. nervous system and tooth development, respectively) begs the question as to the ancestral role of these genes in paired appendage development prior to the origin of the autopod. Here we present transcriptome and gene expression data for paired fin development in the American paddlefish Polyodon spathula, a basal actinopterygian. Specifically, we compare the expression profiles of the LIM−homeobox genes *Lhx2, Lhx9*, and *Lmx1b*, and the Paired−homeobox gene *Pax9*, with other genes previously described for their role in fin compartmentalization. These data will inform our understanding of fin patterning in actinopterygians, and when placed in a comparative context fuel new hypotheses on how the gene regulatory networks underlying appendage development may have been altered during the fin to limb transition and the origin of digits.

100.1 BOWLIN, MS; University of Michigan−Dearborn; *mbowlin@umich.edu*

Temperature−dependent ectothermic escape response: An undergraduate laboratory exercise

Here, I describe a new laboratory exercise designed for an undergraduate comparative animal physiology course. Students measure the burst performance of wolf spiders (Lycosidae) held at three different temperatures (5°, 21°, and 35°C) in order to determine how temperature affects ectothermic performance. We use 1m sections of plastic gutter lined with pea gravel and covered in tulle as spider runways.' Students encourage the spiders to run by blowing on them, simulating a predation attempt. Each group of students then calculates burst performance from distance run and time taken for six different wolf spiders at all three temperatures in a randomized blocked design. Afterwards, the students perform an ANOVA with Bonferroni−corrected follow−up T−tests and find that burst performance increases considerably between 5 and 21°C, but not between 21 and 35°C: the enzymes involved in ectothermic escape responses are temperature−dependent, but not as temperature−dependent as enzymes involved in behavioral responses less closely correlated with survival. This inquiry−based laboratory exercise allows students to directly observe the effects of temperature on ectotherms and gives them the opportunity to interact with live animals, which may or may not cooperate with the experiment or behave according to the students' hypotheses and predictions. As a result, the experiment represents both a valuable and an enjoyable learning experience (even for arachnophobes!).

P2.142 BOYD, M.L.*; AMATO, C.M.; YANG, J; MCCOY, K.A.; East Carolina University; *boydm13@students.ecu.edu*

Morphology of the Developing Fetal Testes Affected by Endocrine−Disrupting Chemicals

Studies have shown that disorders associated with testicular dysgenesis syndrome (TDS) like hypospadias (mis−localized urethra) are increasing in prevalence, which is likely due to the increased use of endocrine−disrupting chemicals. Fetal Leydig cells are interstitial cells within the testes that are the primary source of androgens, and therefore play an important role in the development of the genitalia. However, the link between altered fetal Leydig cell function and altered genitalia development is unclear. To begin to understand the coordination between testis form and function and genital form and function we conducted a dose response experiment with the model anti−androgen vinclozolin that is known to induce hypospadias and measured morphological endpoints within the testes. We hypothesize that fetal Leydig cells will be hypertrophic and hypermorphic and that germ cells, seminiferous tubules, and Sertoli cells will show dose dependent effects. To test this hypothesis we exposed pregnant dams (N=3) at embryonic days (E) 13.5−16.5 to either a corn oil control (0), 100, 125, or 150 (mg/kg). Histological samples of the testes at E 18.5 were sectioned at 10¼m and examined for morphological changes. Our findings will begin to characterize the link between fetal testis function and genitalia development. Understanding how endocrine−disrupting chemicals break the linkages between these organs could lead to advances in the treatment and prevention of testicular digenesis syndrome.

P2.154 BOYLE, MJ; CARRILLO−BALTODANO, A*; RICE, ME; MEYER, NP; Smithsonian Tropical Research Institute, Clark University, Smithsonian Marine Station; *acarrillobaltodano@clarku.edu*

Reevaluation of the hypothesized loss of segmentation in sipunculans through in−depth analysis of neural development in Themiste lageniformis

Recently placed within a clade containing segmented annelids, sipunculans provide a unique opportunity to study the evolutionary loss or gain of an important feature of animal body plans: segmentation. Neural segmentation is evident in ventral nerve cord (VNC) formation in many annelids, including *Capitella teleta*. On the other hand, neural development in sipunculans has not been well−studied, and reports range from no evidence of segmentation to vestigial segmentation based on a few pairs of serially−repeated neuronal cell bodies in the VNC. We performed an in−depth comparative analysis of neural development in the indirect−developing sipunculan *Themiste lageniformis* and the segmented annelid *C. teleta* using a combination of in situ hybridization (ISH) and immunohistochemistry to examine pan−neuronal, neuronal sub−type and axonal markers. We hypothesize that sipunculans do not show signs of segmentation during development and that serially−repeated neuronal subtypes or neurites are not in phase with each other or other tissues (i.e. are irregularly distributed from anterior to posterior). Homologs of *C. teleta* and *T. lageniformis synaptotagmin1* were cloned and used for ISH. *Cte−syt1* is expressed throughout the CNS (brain and serially−reiterated VNC ganglia) and in peripheral neurons. *Tla−syt1* is also expressed throughout the CNS, but expression in the VNC does not appear segmented. Two paired clusters of serotonergic neurons in the VNC are not spatially restricted. Our initial results are congruent with our hypothesis, but data from ongoing experiments will further elucidate the possible loss of segmentation in sipunculans.

P1.74 BOYLE, MJ*; COLLIN, R; RICE, ME; Smithsonian Tropical Research Institute, Panama, Smithsonian Marine Station at Fort Pierce, Florida; *boylem@si.edu*

Comparative Development, Transcriptomics and Life History Evolution in Sipuncula

Sipuncula is an ancient clade of marine annelid worms with an unsegmented body plan. Development exhibits unequal quartet spiral cleavage, conspicuously large prototroch cells, a postoral metatroch, paired introvert retractor muscles, and a U−shaped digestive organ system. There are four distinct life history patterns, and they have evolved a unique metazoan larval type, the pelagosphera. Evidence of morphological segmentation within organ systems along the anteroposterior axis during development is questionable, and under investigation. Using CLSM and gene expression, we highlight developmental differences between two species with contrasting life histories: *Phascolion cryptum* develops directly without ciliated trochal bands, buccal organ or terminal organ; *Nephasoma pellucidum* develops indirectly through lecithotrophic trochophore and planktotrophic pelagosphera larvae with a buccal organ, lip gland, functional gut and retractable terminal organ. Based on recent phylogenetic hypotheses, planktotrophy is part of the ancestral life history pattern in Sipuncula. We also introduce preliminary results from *de novo* developmental transcriptomes of both species, which generated an average of 22,106,986 reads per sample, assembled into an average of 42,104 annotated transcripts per sample with an assembly N50 of 3,432 bp. We find genetic evidence for many critical developmental programs within and between species and life history patterns. Thus, with unique developmental morphology, new comparative genomic data for evo−devo, and well−characterized life history patterns, sipunculans are emerging as valuable research models, and will provide a deeper understanding of the evolutionary history of Annelida, Spiralia and Metazoa.

AMS.1 BOYLE, Michael J.; Smithsonian Tropical Research Institute; *BoyleM@si.edu*

Comparative development of life history diversity in Sipuncula: a microscopic view

Sipuncula (peanut worms) is an ancient group of marine worms with a global distribution, divergent life histories and a unique larval form, the pelagosphera. Life history patterns range from direct development without a larval stage to a conspicuous diversity of pelagic larval forms. Adult characteristics include a retractable introvert with a crown of tentacles, and a U−shaped digestive architecture. Recently, the unsegmented Sipuncula were relocated to an early branch within the tree of predominantly segmented annelid worms, such as polychaetes and earthworms. If they are truly members of Annelida, sipunculans provide an appropriate contrast for investigating the evolution of segmented body plans, and yet another example of flexibility among a broader group of animals that share a similar and directly comparable program of early development known as spiral cleavage (e.g. mollusks, annelids, nemerteans, sipunculans). In this presentation, confocal and compound light micrographs will showcase developmental diversity of sipunculan life history characteristics, with an emphasis on comparing ciliary, muscular and digestive organ systems. Comparative development of representative characters such as ciliary bands, circular and retractor muscles, or a functional gut suggest there are life history−specific developmental priorities' in the timing of essential behaviors such as swimming, crawling or feeding, respectively. Thus far, developmental evidence of segmentation within these and other organ systems is questionable. Complementary molecular studies are also in progress, and those efforts will be introduced to show how gene expression patterns and recent next−generation sequencing projects on comparative developmental transcriptomes are moving sipunculan worms forward as valuable research models.

109.7 BRACE, AJ*; MCCUE, MD; MARTIN, LB; University of South Florida, St. Mary's University; *abrace@mail.usf.edu*

The relationship between immune costs and parasite protection: is more really better?

Parasite exposure typically results in the energetically costly activation of the immune system. Despite the necessity of these responses, there is great variation in costs incurred during immune activation within and among populations. Such costs are likely driven by factors including differences in host ability to obtain resources, environmental pressures and history of exposure. This lack of consistency in costs can lead to variation in how hosts respond to and cope with an infection, ultimately affecting host−parasite dynamics (e.g., parasite virulence). While it has been well demonstrated that immune activation is costly, the relationship between costs of activation and the immune protection that results remains poorly understood. In order to better predict parasite virulence and how parasites will move through communities, we need to gain a better understanding of variation in the cost−benefit ratio associated with parasite exposure. Here, we used experimental malaria (*Plasmodium sp.*) infections in brown anoles (*Anolis sagrei*) to explore if high costs of immune activation ultimately result in better protection from parasites. Cost was determined during the acute phase of infection by measuring the amount of oxidized tracer from an oral dose of ^{13}C−labelled glucose and correlating oxidization with parasite load 7 days later. We hypothesized that individuals that experienced higher costs of activation during the acute phase would experience greater parasite protection and consequently have lower parasite loads at 7 days post infection compared to individuals that experienced lower costs. Our results will be some of the first to demonstrate the relationship between cost of immune activation and parasite protection, paving the way for a greater understanding of how host immune responses affect host−parasite co−evolution.

105.4 BRACISZEWSKI, A.R.*; CARRILLO, A.; HORN, M.H.; CARTER, A.; GERMAN, D.P.; Univ. of California, Irvine, California State Univ., Fullerton, California State Univ., Fullerton; *alyssarb@uci.edu*

How do you like your eggs? Egg cannibalism and digestibility in the California grunion, Leuresthes tenuis (Teleostei: Atherinopsidae)

California grunion (*Leuresthes tenuis*) spawn on the beach during spring tide events. In preparation for spawning, adult grunion fast and have empty guts. Recently, grunion have been found with conspecific eggs in their intestines after spawning, leading to a hypothesis that their eggs provide a potential food resource. However, grunion eggs are structurally resilient, withstanding up to six developmental weeks buried in beach sand, and in vitro tests have failed to destroy eggs with formalin or commercial digestive enzyme preparations. We examined egg digestibility in grunion to determine if the fish can digest their eggs. Grunion were separately fed fertilized and unfertilized eggs, and serially dissected over 10 hours. Comparisons of egg numbers, and egg visual quality, in the proximal, mid, and distal intestine showed eggs being broken down and disappearing (i.e. digested) during the experiment. The amount of force (N) needed to crush eggs taken from grunion digestive tracts was significantly lower than that needed to crush uneaten fertilized and unfertilized eggs. Analysis of aminopeptidase activity showed a characteristic increase moving distally along the intestine, which correlated with a significant decrease in protein concentration of digested eggs. Additional digestive enzyme activity assays in separate intestinal sections, as well as lipid and carbohydrate content of eggs recovered from the intestinal tracts, are underway and should further affirm egg digestibility. Overall, our study confirms that grunion are capable of digesting their eggs, and thus, this food resource may be important after spawning.

P3.54 BRADLEY, HK; Siena College; *HarleyKBradley@gmail.com*
What We Learned In Mississippi
In June 2014 eleven high school students from the Albany area traveled to Mississippi on a Civil Rights Study Tour organized by Dr. Paul Murray. For eight days the students met with veterans of the civil rights movement, visited historic sites associated with the movement, attended memorial services for civil rights workers murdered in the summer of 1964, and participated in the 50th anniversary celebration of Freedom Summer. They also sang the Freedom Songs that were an essential part of the movement. This film follows the students and their chaperones on this journey. Viewers will listen as the students discuss what they learned and how the trip affected their understanding of the civil rights movement.

45.5 BRANNOCK, P.M.*; WAITS, D.S.; SHARMA, J.; HALANYCH, K.M.; Auburn University, University of Texas at San Antonio; *pmb0010@auburn.edu*
Characterization of meiofauna community composition in northern Gulf of Mexico using high−throughput sequencing approaches
Metagenomic approaches are widely used to examine prokaryotic community composition, but less often applied to eukaryotic organisms. We have been using a novel high−throughput Illumina sequencing approach to characterize meiofauna community composition within the northern Gulf of Mexico (GOM). Meiofauna are generally described as metazoan animals 45 µm to 1 mm in size that live between sediment grains. These animals play an important role in food webs and nutrient exchange between the benthos and water column. The Deepwater Horizon Oil Spill dramatically affected meiofauna in both intertidal and subtidal GOM locations. Unfortunately, knowledge of seasonality and variability of meiofauna communities in most of the GOM is lacking. To better understand the spatial and temporal variation in GOM meiofauna communities as a whole, high−throughput amplicon sequencing targeting the eukaryotic specific hypervariable V9 region of the small subunit ribosomal RNA (SSU rRNA) gene was employed to examine intertidal and subtidal communities. Results show similar to pre−spill communities, annelid, nematode, and arthropod taxa dominated samples, with fungal species in low abundances. Samples cluster mostly by site rather than season, and seasonal variation was site dependent. In addition, this research provides a fundamental baseline to examine community impacts of future natural and anthropogenic disturbances in the Gulf of Mexico region and suggests the community shifts seen in sites impacted by the spill cannot be attributed to seasonal or geographic variability.

P1.38 BRANSON, D.R.*; MAHON, A.R.; HALANYCH, K.M.; Auburn University, Central Michigan University; *drb0017@auburn.edu*
Visual Analysis of Benthic Megafaunal Community Structure Along the Western Antarctic Continental Shelf
A high level of endemism and diversity of benthic invertebrates is found on the Antarctic shelf, comparable to that seen in tropical ecosystems. This endemism is attributed to isolation effected by the oceanographic barrier of the Antarctic Polar Front. Together with the Antarctic Circumpolar Current immigration/emigration of benthic organisms is impeded. The isolation is increasingly being minimized by anthropogenic disturbances. Despite more than 200 years of interest in Antarctica, very little is known about community composition and biodiversity of the benthic fauna due to the inherent difficulty of working in the area. The typical sampling methods of benthic trawls and sediment cores, while effective in providing samples for phylogenetic and phylogeographic analysis, are poor at providing a clear picture of community structure. To establish a baseline portrait of the benthic community along the western shelf we performed seafloor photographic surveys aboard the RVIB N. B. Palmer in 2013 (cruise NBP12−10). One kilometer transects using a yoyo cam were conducted at 16 stations in depths of 335−1111m to evaluate and compare benthic megafaunal abundance, community structure, and species diversity. Simpson's Diversity values indicate high levels of ± diversity within transects, with nMDS indicating high levels of ² diversity among abundant echinoderms between sites and regions. Multivariate analysis of abiotic/biotic factors show depth as a potential influence while water chemistry appears to have little impact on community composition. This investigation should help to inform future studies of the anthropogenic pressures rapidly impacting the Antarctic continent.

P2.121 BRAZEAL, KR*; HAHN, TP; U. of Nebraska, Lincoln, U. of California, Davis; *krbrazeal@ucdavis.edu*
Sensitivity to testosterone as a mechanism underlying individual variation in timing of the breeding−molt transition in House Finches
Appropriate timing of the transition between breeding and plumage molt is vital to fitness in most birds. Delay of this transition provides increased reproductive opportunities at a cost to future survival, since delayed molt can lead to increased molt rate and decreased feather quality. Within some species, individuals vary in how they mediate this trade−off, as evidenced by wide ranges of molt onset dates. Despite its importance, understanding of the proximate mechanisms underlying molt timing is limited. One important hormonal regulator of this transition is testosterone (T), which maintains reproductive physiology and delays molt. Individual variation in plasma T levels may contribute to variation in molt timing. However, a previously unconsidered alternative mechanism may also play a role: peripheral sensitivity to T (e.g. via variation in receptor density/specificity and/or concentration of enzymes and hormone binding globulins). To test the relative importance of T levels versus T sensitivity, we administered T implants of varying doses prior to molt (late June) in male House Finches and observed molt responses. After removing implants in December, we continued the study through the following year. We found extensive variation in molt delay and suppression, which was not well−explained by T levels delivered by the implants. T treatment during the first year led to a small but significant delay of molt in the second year, compared with controls (empty implants). Greater T sensitivity during the first year significantly predicted greater carry−over of molt delay between years. These results suggest that individual variation in T sensitivity may be more important than variation in T levels for determining timing of the breeding−molt transition as well as long−term effects on molt timing.

33.6 BRENCHLEY, G.A.M.*; Retired; *brenchley20@comcast.net*

Life after the mudflat: adventures of a scientist, lawyer and artisan

Scientists today have many career options. One of the biggest challenges after academia is identifying which career(s) comport to one's skills, personality, and interests. Entry into some alternative careers can be challenging yet frustrating. Many careers share logic similar to science, while the approach in others, *e.g.*, law, is often the antithesis of the scientific approach. A mentor who provides a stimulating and interactive educational environment, challenges her students intellect, and builds their confidence, is important. Using the context of my education under the tutelage of Dr. Woodin, and my transition from soft−sediment ecology to law and eventually to woodworking, I provide insights for both advisors and students on how to navigate the challenges of selecting and pursuing satisfying non−academic professional careers.

P1.168 BRESSMAN, N/R*; FARINA, S/C; GIBB, A/C; Cornell University, Northern Arizona University; *nrb66@cornell.edu*

Visual navigation and locomotor behaviors of Fundulus heteroclitus in a terrestrial environment

Mummichogs (*Fundulus heteroclitus*) are intertidal fish that exhibit amphibious traits, such as the ability to breathe air and locomote on land. Our goals were to characterize the terrestrial jumping behaviors of *F. heteroclitus* and determine their method of navigation towards water in an unfamiliar terrestrial environment. We used high−speed video (210 fps) to record behavior during stranding trials. Similar to observations in other Cyprinodontiformes, *F. heteroclitus* primarily uses a tail−flip jump during terrestrial locomotion. Additionally, we found that *F. heteroclitus* will prop themselves upright between each jump on their caudal and pectoral fins, although sometimes for only a fraction of a second. They then rotate their bodies to point the tail in the direction of the water, fall onto their lateral aspect, and then leap into a caudally−directed ballistic flight path. During experiments to determine the sensory stimulus used to locate a body of water, *F. heteroclitus* were placed on a platform with four sides, with one side adjacent to a sea table. In ambient light, *F. heteroclitus* move towards the sea table more often than towards the other edges of the table (Ç^2 = 20.62, p = 0.0001). Under low−light conditions, *F. heteroclitus* are less successful at reaching the sea table (z = 2.42, p = 0.0078). When the surface of the water is replaced with reflective foil, *F. heteroclitus* will move towards it as if it were a body of water (Ç^2 = 11.92, p = 0.0077). These results suggest that *F. heteroclitus* primarily uses visual cues, specifically the reflection of light, to orient towards water. Uprighting behaviors during terrestrial locomotor bouts may provide an opportunity for fish to receive visual information that allows them to safely return to the water.

34.2 BREUNER, CW*; BERK, SA; The University of Montana; *creagh.breuner@umontana.edu*

Measuring corticosteroid metabolites in feathers: 2) biological relevance?

Since first publication in 2008, feather corticosterone (CORT) has become a widely used metric of stress physiology in birds. Feather CORT has been correlated with various facets of avian biology including breeding success, coloration, and nutritional status. However, we still know very little about how measures of metabolites in feathers relate to circulating CORT levels. Two studies have evaluated the relationship between plasma CORT and feather CORT metabolites, but have only noted a relationship when animals with CORT implants are included in the analysis. This is not especially surprising, as plasma CORT levels represent one brief moment in time, while the feather is grown over a period of days to weeks. The variation in CORT experienced by the animal over this extended time frame is unlikely to be represented in the one time−point measured in the plasma. We used a more integrated measure of CORT secretion − fecal glucocorticoid metabolites (FGM) − to look for relationships between feather CORT and general glucocorticoid status in individuals. To this end, we brought house sparrows into captivity, pulled two tail feathers, and collected fecal samples over the next 3−4 weeks of feather growth. We are currently measuring the fecal glucocorticoid metabolites in the samples, and will compare individual variation in FGM to individual variation in feather CORT metabolites.

P3.49 BROADHEAD, GT*; RAGUSO, RA; Cornell University; *gtb49@cornell.edu*

Sensory tests of hawkmoth associated floral volatiles

Floral chemistry characterizing different pollination syndromes suggests that there are some specific floral volatiles with more significance to certain classes of pollinator. For example, the scent associated with flowers within the hawkmoth pollination syndrome is described as white floral' and often contains nitrogenous volatiles and other characteristic compounds. From this comes the hypothesis that hawkmoths (and other distinctive pollinators) may exhibit stronger olfactory responses to key compounds characterizing their respective pollination syndromes, and this may be due to adaptations in peripheral receptor populations or central olfactory processing. Yet, floral volatiles vary markedly in volatility and differential responses to certain compounds may result from signal intensity rather than sensory adaptations or receptor differences. The predicted vapor pressures of common floral volatiles can range from several kilopascals (~24 mmHg) to less than 1/5th of a single pascal (0.0015 mmHg) at room temperature. This vapor pressure variation translates into a difference of several orders of magnitude in airborne odorant concentrations generated from equimolar solutions. In order to compare responses between olfactory stimuli with different physical properties, the stimuli should be presented at equal concentrations in the vapor phase. Non−standardized stimuli limit the inferences and interpretations that can be drawn from electrophysiological and behavioral experiments. Using methods adapted from dynamic headspace sampling of floral volatiles, we are able to quantify the airborne stimuli created by odorant compounds in order to standardize stimulus intensity and conduct electroantennographic assays (EAGs) to determine how standardization of these olfactory stimuli might change olfactory responses at the peripheral sensory level. We are using this method to carry out comparative tests to determine if the hawkmoths *Hyles lineata* and *Manduca sexta* actually do exhibit increased responsiveness to key compounds characteristic of their pollination syndrome.

S3.1 BROCHU, C. A.*; BURKEY, M. R.; JOUVE, S.; MILLER−CAMP, J. A.; NARVÁEZ, I.; PRITCHARD, A. C.; PUÉRTOLAS PASCUAL, E.; TURNER, A. H.; WILBERG, E. W.; University of Iowa, Museum 'Histoire Naturelle de Marseille, Universidad Nacional de Educación a Distancia , Stony Brook University, Universidad de Zaragoza, Georgia Southern University; *chris−brochu@uiowa.edu*

When Past is Not Prologue: Neosuchian Phylogeny and the Origin of Crocodylia

Crocodylians have long been viewed as the modern expression of a stable evolutionary core that has maintained a conservative ecomorphology since the Jurassic. From this core, more specialized groups with distinct environmental preferences (semiterrestrial, marine) or feeding styles (piscivorous, durophagous) arose independently. New discoveries reveal unexpected complexity in neosuchian phylogeny. Although groups outwardly resembling modern crocodiles and alligators (e.g., goniopholidids) and gharials (e.g., pholidosaurids) were present throughout the Jurassic and Cretaceous, the closest relatives of Crocodylia were generally small (approximately 2 m) durophagous animals with short, robust snouts and bulbous posterior teeth. They resembled early alligatorids, which suggests that character states currently diagnosing Alligatoroidea and subordinate clades may be plesiomorphic at more inclusive levels; this, in turn, might help resolve the ongoing debate over the phylogenetic relationships of modern gharials as a rooting problem. The outwardly generalized ecomorphology of modern crocodylians represents multiple specializations from a differently specialized common ancestor. Features previously used to characterize crocodylians, such as a secondary palate and vertebral procoely, had more complex histories with multiple gains and losses; indeed, they may precede the origins of Crocodyliformes. Groups unlike modern species, including semiterrestrial predators and small durophagous forms, arose within Crocodylia multiple times throughout the Cenozoic and even into the Neogene, falsifying the popular image of crocodylians as evolutionary static living fossils.

P3.185 BRODSKY, S.D.*; BELY, A.E.; University of Maryland, College Park; *sbrodsky@umd.edu*

Examining evolutionary correlates of starvation resistance in the Naidids: What is the impact of both regenerative and metabolic capabilities?

While there is an abundance of literature addressing how starvation resistance causes biological tradeoffs, such as changes in longevity, fecundity, and cell death, there is surprisingly little research addressing the role of evolutionary change in regulating this critical metabolic process. The Naidids are a family of Annelids (segmented worms) that have independently lost the ability to regenerate a head (anterior regeneration) 3 separate times. We attempt to determine if there is a correlation between the ability to regenerate a head (anterior regeneration) and starvation resistance. To gain insight into the physiological processes used to overcome stress, we assess worm metabolic rate under caloric restriction. Due to the size of Naidid worms (typically less than 8 mm in length), traditional analysis using dissolved gas probes is largely ineffective at reliably recording Annelid metabolic processes. Using a Membrane Inlet Mass Spectrometer (MIMS), we measure the depleting O_2 and increasing CO_2 levels in laboratory worm cultures. Median survival time is determined under starvation conditions for 7 species of Naidids: 4 anterior regenerating and 3 non−anteriorly regenerating, in cut and uncut worms, and at 2 different temperatures. Resistance to starvation varies considerably among species and across temperatures. We found that starvation resistance is, usually, similar across cut and uncut Naidids and present other possible correlates of starvation resistance, including rate of wound healing, fission rate, and lifespan of posterior zooid.

P3.73 BROOKS, C.A.C.*; GUMM, J.M.; Stephen F. Austin State University; *brooksca@titan.sfasu.edu*

Territoriality and 'dear enemy' recognition between heterospecific pupfishes (genus Cyprinodon)

Territorial animals are aggressive towards other individuals, but territorial aggression can vary among species or based on the identity of the competitor. Some territorial species exhibit "dear enemy" recognition; where lower levels of aggression are directed at neighboring, territorial individuals compared to intruders or unfamiliar individuals. The sheepshead minnow, *Cyprinodon variegatus*, is more aggressive than and can outcompete closely related species. Territorial males of this species also exhibit dear enemy' recognition. Recently, *C. variegatus* has been introduced into the home range of *Cyprinodon rubrofluviatilis*, leading to hybridization between the species. We test the hypothesis that territorial males of these two *Cyprinodon* species differ in expression of dear enemy recognition. We also examine territorial formation between heterospecifics and evaluate if heterospecific neighbors express dear enemy' recognition towards each other. We present preliminary data from laboratory experiments testing these hypotheses. Understanding the dynamics between territorial males of different species may help identify what is driving hybridization and ultimately inform conservation strategies.

71.1 BROTHERS, C.J.*; HARIANTO, J.; BYRNE, M.; MCCLINTOCK, J.B.; Univ. of Alabama at Birmingham, Univ. of Sydney; *brotce@uab.edu*

The effects of ocean warming and acidification on the immune response of the sea urchin Heliocidaris erythrogramma

Climate−induced changes including increasing surface seawater temperatures and decreasing pH are occurring rapidly around the world. It has been suggested that in these near−future ocean conditions, marine organisms will become more vulnerable to infectious diseases. However, no studies have examined the effects of both warming and acidification on the immune response of sea urchins, an ecologically important taxon across many marine ecosystems. This study investigated the effects of warming and acidification on the sea urchin *Heliocidaris erythrogramma*, a species commonly found in eastern Australia, a region that is experiencing rapid climate−induced change. Sea urchins were exposed to treatments at current and near−future seawater temperature (17 and 23°C) and pH (8.2 and 7.6). After three experimental exposures (1, 15, and 30 days), coelomocyte (cells associated with innate immunity) number and phagocytic capacity (a measure of immune response) were measured (n=5 per treatment). The number of coelomocytes present in coelomic fluid was not significantly different among treatments or exposure. However, at all three exposures the phagocytic capacity of coelomocytes from sea urchins exposed to seawater at ambient temperature and reduced pH was one−third lower than that of sea urchins held at control conditions. Additional data are presently being analyzed to determine the bactericidal activity of these coelomocytes against a common marine pathogen *Vibrio anguillarum*. Collectively, these parameters provide an evaluation of the ability of *H. erythrogramma* to respond to immune challenges in a rapidly warming and acidifying marine environment. Supported by the NSF, Australian Academy of Sciences, and the NSW Environmental Trust.

48.5 BROWN, T*; RODRIGUEZ−LANETTY, M; Florida International University; *tbrow102@fiu.edu*

Molecular mechanisms underpinning immunological memory in a basal metazoan (Cnidaria).

Coral diseases outbreaks have been rapidly increasing on reefs worldwide. Our understanding of how corals respond to the agents causing these diseases remains limited. It is unknown if corals possess a form of immunological priming which would allow them to respond faster to secondary encounters with the same pathogen. In order to test this hypothesis we used the cnidarian model system, *Exaiptasia pallida* and challenged the anemones with the coral pathogen *Vibrio coralliilyticus* under sub−lethal conditions followed subsequently with a lethal challenge. The results indicate that *E. pallida* displays a form of immunological memory as primed anemones showed an increased survival compared to non−primed anemones during a lethal challenge. We further aimed to identify proteins involved in this immunological memory response by comparing anemones that were exposed to a sub−lethal bacterial challenge to those that we not prior to the lethal challenge. The lapsed time between sub−lethal and lethal challenge was 4 weeks. Total extracted proteins were examined using a 2D DIGE expression profile. The analysis revealed that a molecular response was significantly associated with the immunological priming phenomenon. We discovered 88 differentially expressed proteins between the treatments with 50 of them up regulated in primed anemones. Of these differentially expressed proteins identified on the gels, 25 were selected for further identification using mass spectrometry. The molecular response associated with the immunological priming documented in this study suggests a complex cellular regulation involving various proteins, including heat shock protein 70, ribosomal protein 10 and sacsin. Furthermore we propose a working model to explain the molecular mechanism mediating immunological memory in this basal metazoan.

49.6 BROZEK, J. M. *; SCHNEIDER, J. E. ; KEEN−RHINEHART, E; Lehigh University, Susquehanna University; *jeremy.brozek@gmail.com*

Energetic challenges experienced by the mother during gestation alter growth patterns and adult traits related to energy balance in Syrian hamsters (Mesocricetus auratus).

Energy intake, storage, and expenditure can be programmed by the energetic status of the mother. Maternal programming is most often studied in the context of human obesity and diabetes, but maternal programming may play a role in the expression of adaptive traits, especially those that show a high degree of plasticity. In these cases, the energetic environment experienced by the mother can prepare the offspring to be more likely to survive in those particular environments. Syrian hamsters might be particularly susceptible to maternal programming by environmental energy because pregnant Syrian hamsters fail to increase their food intake above pre−pregnant levels and lose up to 40% of their body lipid content during gestation. To study the effects of maternal energy availability on offspring traits, *ad libitum* daily food intake was measured in adult female hamsters. All females were mated and pregnant hamsters were either: 1) allowed unlimited access to rodent chow placed inside their cages for easy access, 2) limited to the pre−pregnant daily intake placed in the food hopper outside the cage (which required them to expend energy to gain access to the food) for the final 2/3 of gestation. Food−limited females gave birth to pups with significantly lower body weights at birth, but significantly higher daily food intake, weaning weight, and NPY immunoreactivity in the arcuate nucleus of the hypothalamus as adults. Thus, even subtle differences in the pregnant mother's energy expenditure during food acquisition can have long−term effects on offspring energy intake, storage, and expenditure.

8.4 BRYCE, C.M.*; WILLIAMS, T.M.; Univ. of California, Santa Cruz; *cbryce@ucsc.edu*

Locomotive costs of domestic canids: exploring breed−specific energetic economy

The broad diversity in morphology and geographic distribution of the 35 free−ranging members of the family *Canidae* is perhaps only rivaled by that of the domesticated dog, *Canis familiaris*. Considered to be among nature's most elite endurance athletes, both domestic and wild canids provide a unique opportunity to examine the limits of mammalian exercise performance and energy expenditure. These animals exhibit peak aerobic performance roughly three times greater than those of equivalently−sized mammals. To explore the effect of artificial selection on running gait and efficiency, we investigated the kinematics and energetics of three large (>20kg) dog breed classes (northern breeds (n=7, 35.2±11.6 kg), scent hounds (n=5, 24.8±1.78 kg), and retrievers (n=5, 35.5±2.5 kg)) representing relatively strong, medium, and weak artificial selective pressures for endurance tasks, respectively. By filming all individuals moving freely along a 10m level transect, distinct kinematic relationships for preferred gait transition speeds, stride frequency, and stride length emerged for each breed class. A subset of dogs within each class was successfully trained for treadmill metabolic trials to measure oxygen consumption (VO_2, mL O_2 kg^{-1} min^{-1}) during steady−state exercise across a range of speeds. Though each class showed linear increases in VO_2 with running speed, mass−specific transport cost (COT, J kg^{-1} m^{-1}) was significantly lower for northern breed dogs than hounds or retrievers (ANCOVA $F_{5,144} = 24.02$, $p<0.001$) for speeds greater than 0.6m s^{-1}. These results suggest that intensive artificial selection for endurance running in certain domestic canids confers an energetic efficiency perhaps similar to that of their wild, cursorial ancestor *Canis lupus*.

P1.151 BUDDEMEYER, K.M.*; ALEXANDER, A.E.; SECOR, S.M.; University of Alabama , University of Alabama; *kmbuddemeyer@crimson.ua.edu*

Negative calorie food: fact or fiction?

Frequent among nutritional websites and on−line discussions are the existence of negative calorie foods'; foods (e.g., celery, iceberg lettuce, and watermelon) that require more energy to digest and assimilate compared to the calories it provides. Despite these reports, there have been no scientific studies to support or refute these claims. To determine the validity that there are foods that generate a negative balance of energy, we fed celery to omnivorous bearded dragons (*Pogona vitticeps*) and quantified net energy balance. Following the consumption of meals equaling 5% of lizard body mass, we measured rates of oxygen consumption to quantify specific dynamic action (SDA). Lizards responded with a 75% increase in metabolic rate and a SDA equivalent to 55% of meal energy (determined by bomb calorimetry). From the collection and bomb calorimetry of feces and urate, lizards lost 20% and 14.5% of meal energy, respectively, to feces and urate. After accounting for the loss to SDA and the apparent loss to feces and urate, lizards retain 10.5% of the energy from the celery meals to be allocated to metabolism and growth. Although the net energy gained from eating celery is relatively modest, these findings challenge the widespread claims that celery is a negative calorie food.

P2.80 BUENO CORREA, A*; TRACY, CR; California State University, Fullerton; *AlexisBuenoC@csu.fullerton.edu*
Scaling of water loss rates with body mass and temperature in chuckwallas (Sauromalus spp)

Increases in temperature and changes in the timing and quantity of rainfall in desert habitats due to climate change may pose a threat to desert lizard species by restricting the area of thermally suitable habitat and altering water needs. In common chuckwallas, *Sauromalus ater*, seasonal increases in temperature do not appear to restrict activity. However, water loss rates in this species have not been widely investigated in the context of changing climate. Investigating how water needs vary with body mass and temperature is important to assess how chuckwallas may be impacted by climate change. Total evaporative water losses (EWL) of chuckwallas (body mass: *S. ater* 20−240g; *S. varius* 500−1000g) acclimated to 15°C, 25°C, and 35°C, were measured using a flow−through respirometry system. Standard metabolic rates were also measured since rates of oxygen consumption (VO_2) and carbon dioxide production (VCO_2) can be obtained using flow−through respirometry. Preliminary results indicate that total evaporative water loss increased with body mass as predicted by the surface area to volume ratio. However, the effects of temperature on water loss rates were unclear and require additional measurements. Scaling exponents for standard metabolic rates at the three temperatures were 1.31 and 0.80 for VO_2 and VCO_2, respectively. These metabolic rates were not significantly different ($p<0.05$) from metabolic rates obtained at the same three temperatures in a previous study by Pirtle and Todd. It is possible that chuckwallas may have mechanisms to modify either respiratory or cutaneous water loss to maintain overall water loss rates when temperature changes.

P3.147 BURCHER, SJ*; DISHONG, I; NISHIKAWA, K; Northern Arizona University; *sjb388@nau.edu*
Interspecific differences in anuran impact forces during landing behavior

Frogs are known for their saltatorial locomotion, which is comprised mainly of repeated jumps and landings. We wished to determine how the characteristics of these landings vary between two species that differ in body masses and lengths: Lithobates pipiens (means=65g, 9.8cm) and Lithobates catesbeianus (means=272g, 16.3cm). We used a force plate and ADInstruments LabPro Software to measure the magnitude and duration of impact forces. Landing forces for each species were almost always characterized by two main peaks, the first during forelimb contact and subsequent deceleration, and the second when the bulk of the body hits the ground. L. catesbeianus had greater peak impact forces in the horizontal and vertical directions than L. pipiens, as well as longer total durations. However, when normalized for mass, L. pipiens had significantly higher maximum impact forces per gram than its larger counterpart, with the smaller pipiens reaching approximately 2.4 times their body mass, and catesbeianus topping out at 1.7. Lithobates pipiens absorbed much more of the impact with its forelimbs, as the second peak showed a larger decrease from the initial impact force. When size was accounted for in timing, we found that the two species showed differences in the manner of their deceleration. Per gram, L. catesbeianus spend significantly more time braking on the vertical axis than L. pipiens, while L. pipiens, decelerated significantly more on the horizontal axis during landing. Per centimeter, L. pipiens spent more time decelerating in both directions. It should also be noted that, while almost all timing variables showed significant differences between the species, the time between the initial and second peaks did not differ, suggesting that frogs share deceleration behaviors regardless of mass, and may hint at limitations of the endurance of muscle contractions in their forelimbs.

P2.34 BURGAN, S/C*; GERVASI, S/S; MARTIN, L/B; University of South Florida; *sarahburgan@mail.usf.edu*
Age−dependency of avian cytokine balances in response to West Nile Virus

Infectious pathogens are ubiquitous in natural environments, and coping with them involves physiological, immunological, and behavioral responses. Expression of immune responses may vary with age, within the context of immune system development and immunosenescence. Immature and elderly individuals often experience more severe illness in response to infection than those in young adulthood. Ontogenetic differences in immune response may result in differential contribution of age classes to disease transmission. Whether these host responses are aimed at preventing infection (resistance) and/or mediating damage caused by pathogens (tolerance) may also play a significant role in mediating disease dynamics. Cytokines are important agents in both host resistance and tolerance, but anti−inflammatory cytokines in particular have been identified as mediators of host tolerance, mitigating damage due to inflammation. Here, we investigated the balance of pro−inflammatory and anti−inflammatory cytokine responses, representative of tolerance, of three age groups of Zebra finches. Pro−inflammatory cytokines IFN−³ and IL−6 and anti−inflammatory cytokines TGF−² and IL−10 were tested. We hypothesized that tolerance would be reduced in very young and very old individuals. Specifically, we predicted that fledged and old−aged finches would have a higher level of pro−inflammatory cytokines relative to anti−inflammatory cytokines. We further predicted that recently matured individuals would have a relatively higher level of anti−inflammatory cytokines, and therefore higher tolerance. Because pathogen load is typically unaffected by tolerance, recently matured individuals may be highly competent and experience increased transmission efficiency. Ultimately, this study aimed to elucidate the age−dependent role of cytokine expression in mediating disease dynamics in natural ecosystems.

P3.115 BURGESS, M/T*; SIMS, R/J; SMITH, K/M; CHILDRESS, M/J; Clemson University; *mtburge@clemson.edu*
Rescuing the Reef: Monitoring the impacts of macroalgal competition and parrotfish grazing on coral transplants

In response to the Caribbean wide decline in coral cover, many researchers have put their efforts towards transplanting reef building coral species in hopes that they will replenish these ecosystems. Previous studies suggest that these transplants are susceptible to competition from macroalgae, which can out−compete corals for essentials such as nutrients and space. Studies have also found that parrotfish play an important role in the overall health of coral reefs through their grazing behavior. In order to test the impacts of macroalgal competition and parrotfish grazing on coral transplants, we compared the survival of two species of transplanted corals on seven reefs in the middle Florida Keys over one year. In the summer of 2013, six *Siderastrea siderea* and six *Porites asteroides* coral fragments (10−75 cm^2) were epoxied to bare substrate at each of the seven reefs. Each fragment was caged in either an open or closed Vexar mesh cage (2500 cm^2). Our results show that the abundance of *Scarus* parrotfishes were negatively correlated with macroalgae abundance and positively correlated with coral condition in cages left open to grazing activity. These preliminary results suggest that parrotfish grazing may positively benefit corals in the Florida Keys. These results may help us to understand the conditions necessary for successful coral restoration.

S11.2 BURMESTER, T.; Institute of Zoology, University of Hamburg; Germany; *thorsten.burmester@uni−hamburg.de*

Evolution of respiratory proteins across the Pancrustacea

Respiratory proteins serve for the transport and storage of oxygen. Two types of respiratory proteins occur in the Pancrustacea: hemocyanin and hemoglobin. The copper−containing hemocyanin evolved from phenoloxidases in the arthropod stemline. Hemocyanins were only known from the malacostracan crustaceans but have recently been also identified in Remipedia and Ostracoda. Hemoglobins are common in Branchiopoda, but rare in other crustacean classes. Respiratory proteins had long been considered unnecessary in insects because of the tracheal system. Only chironimids, some backswimmers and the horse botfly, which all live under hypoxic conditions, were known exceptions, which possess hemoglobin. However, recent data suggest that hemocyanins occur in most ametabolous and hemimetabolous insects. Phylogenetic analyses showed a close relationship of hemocyanins of insects and Remipedia, suggesting a close relationship of these taxa. In "higher" hemimetabolous insects (e.g., cockroaches and grasshoppers), hemocyanin function is restricted to the developing embryo while in adults oxygen is supplied solely by the tracheal system. The pattern suggests that hemocyanin was the oxygen transport protein in the hemolymph of the last common ancestor of the pancrustaceans, but has been lost several times independently in taxa. The loss was probably associated with miniaturization, a period of high oxygen availability (e.g. in the Carboniferous period), a change in life−style or morphological changes. Once lost, hemocyanin could not be regained. When a respiratory protein was again required, it evolved several times independently from cellular hemoglobins. It is unlikely that these cellular hemoglobins had a respiratory role, but may rather be involved in signaling or ROS defense. Supported by DFG BU 956/14.

P3.10 BURNAFORD, JL*; CASEM, ML; DICKSON, KA; FORSGREN, KL; HOESE, WJ; SWARAT, S; California State University Fullerton; *jburnaford@fullerton.edu*

BURST FORTH: A pilot program incorporating authentic biology research experiences into freshman orientation

Biology departments nationwide are grappling with high enrollments in introductory majors' courses but disappointing retention rates. Part of the problem stems from mismatches in student vs. department expectations of effort, engagement, critical thinking, quantitative reasoning, and problem solving skills. Undergraduate research experiences engage students, promote retention, and increase graduation rates. In summer 2014 we piloted the Biology Undergraduate Research Scholars Training program Freshman Orientation Research Training Hour (BURST FORTH), incorporating a mentored, authentic research experience into freshman orientation as a way to better align student and departmental expectations. Using a stratified sample design, over three days we split 153 incoming biology majors into participant and non−participant groups. Non−participants received a campus tour, while participants spent 75−90 minutes investigating the effect of temperature on development and hatching success of an endemic fish, the California grunion. Students made measurements and made conclusions from pooled data. We used a team of undergraduate and graduate peer−mentors to introduce new students to the culture of the biology department. Intensive promotion through multiple media outlets (including a dedicated Facebook page and campus website) and invitations to campus administrators, who worked alongside student participants in the lab, fostered integration across academic and co−curricular elements. Surveys administered to participants, non−participants, and peer−mentors allowed us to assess immediate outcomes, and ongoing assessment will track student performance, retention rates, and attitudes about biology in the first year courses and beyond.

P3.129 BURNETT, NP; University of California, Berkeley; *burnettnp@berkeley.edu*

Growth responses of the kelp Egregia menziesii to damage from different types of herbivores

In the intertidal zone, structural damage from herbivory, abrasion, and hydrodynamic forces can limit the growth and survivorship of seaweeds. Despite these limitations, the kelp *Egregia menziesii* is able to grow to large sizes: individual fronds can reach lengths over 6 m and the cumulative length of fronds on a single kelp can exceed 75 m. Herbivory from limpets is known to facilitate frond breakage, reducing the total *E. menziesii* size and altering its subsequent growth. Smaller individuals are better able to survive stronger currents and larger waves that might otherwise dislodge the kelp, demonstrating a mutualistic relationship between the herbivore and kelp. However, it is unknown how the location of the frond break affects the kelp's growth, which is especially relevant because herbivores commonly found on *E. menziesii* occupy and graze different areas along the fronds. To answer this question, I characterized the spatial distribution of herbivores on *E. menziesii* fronds from intertidal populations in northern California. In early summer, I simulated frond breakage caused by grazing limpets (broken near the holdfast) and amphipods (broken 1 m from the holdfast) on separate sporophytes of similar size. Growth rates of intact fronds and the generation of new fronds were recorded for two months after the initial breakage. Frond breakage location did not affect growth rates of remaining fronds, but sporophytes that experienced amphipod damage produced more new fronds than those with limpet damage.Therefore, different herbivore types can uniquely affect the structure and growth of *E. menziesii* depending on where they graze. The effects on *E. menziesii* structure directly translate to the kelp's ability to form habitat for smaller organisms, and the magnitude of this effect can change with the local herbivore species composition as well as the nutrient and thermal properties of the ambient seawater.

S11.9 BURNETT, K.G.*; BURNETT, L.E.; College of Charleston; *burnettk@cofc.edu*

Respiratory consequences of mounting an immune response in crustaceans

Crustaceans rely on a wide spectrum of innate immune mechanisms to maintain their physiological integrity in aquatic environments that teem with high densities of microorganisms (> 10^6 culturable bacteria and 10^8 viruses/mL seawater). A successful immune response requires recognition of a foreign microbe, often mediated by pattern recognition proteins or lectins, linked to a defensive response that can sequester, inactivate, degrade and/or externalize the microbe. Like the insects, crustaceans rely on interplay between clotting, production of antimicrobial proteins and melanization to prevent hemolymph loss and microbial spread at sites of injury. In response to injected gram−negative bacteria, crustacean hemocytes aggregate and rapidly move to the site of injection, where they sequester, but do not immediately inactivate or degrade the injected microbes. Some hemocyte aggregates and bacteria become trapped in the microvasculature of the gills and other tissues, where they are melanized by the prophenoloxidase cascade and eliminated at the molt. Several lines of evidence show that these trapped hemocyte aggregates interfere with the gill's normal function in respiration, including decreased O_2−uptake, impaired movement and reduced oxygenation of hemolymph, along with the disappearance of a pH change across the gill. Consistent with this observation, blue crabs injected with bacteria fatigue more rapidly than saline−injected controls in measures of performance on a treadmill. For crustaceans that live in microbially−rich, but oxygen−poor aquatic environments, there appear to be distinct tradeoffs based on the gill's multiple roles in respiration, ion balance and immunity (NSF IOS−1147008).

80.2 BURNETT, J.*; SLOAN, T.; KERFOOT, J.; TURINGAN, R.; Florida Institute of Technology, Melbourne, Union University, Jackson, Tennessee; *jburnett2010@my.fit.edu*

The effects of temperature on feeding kinematics through ontogeny in the invasive pike killifish, Belonesox belizanus.

The alarming, rapid spread of tropical invasive species toward higher latitudes has underscored the urgent need to understand their biology and ecology. What is missing in contemporary invasive−species research is information that advances our understanding of how the effects of environmental temperature on organismal performance is confounded by body size or ontogeny. It is hypothesized that a 10°C change in environmental temperature results in a twofold change in the rate of muscular contraction. It is also expected that performance metrics that are driven by rate processes reflect this relationship. We examined the effects of temperature on the feeding kinematics in the invasive pike killifish, *Belonesox belizanus*, from the neonate stage (17.9mm) to the adult stage (100.7mm) to address the question, "How does the temperature−performance relationship change through ontogeny?" Duration and timing of kinematic events scale with body size and ontogenetic stage in the pike killifish. This relationship remained consistent across all environmental−temperature conditions examined. Environmental temperature has little, insignificant effects on the prey−capture performance of pike killifish through ontogeny. It is hypothesized that the ability of pike killifish, *Belonesox belizanus* to spread its range of distribution in Florida is enhanced by the thermal independence of its prey−capture kinematics and behavior regardless of its life−history stage of ontogeny.

74.6 BURNETTE, M.F.*; ASHLEY−ROSS, M.A.; Wake Forest University; *burnmf0@wfu.edu*

Stake your claim: foraging archer fish rely on aggression rather than kinematic changes to deter intraspecific theft of prey

Archer fishes are social animals that forage for terrestrial insect prey by spitting streams of water from their mouths, causing prey to fall to the water surface, where it can be grabbed and consumed by the shooter. The fish must rotate its entire body in a vertical direction, so that the snout will protrude from the surface of the water, fire its shot, then return to a horizontal orientation so it can swim and capture the dislodged prey. We understand from previously published research that shooters are highly susceptible to conspecific theft of falling prey. It was the goal of the current investigation to quantify archer fish foraging behaviors, in order to determine if shooters can modify any aspect of their foraging behavior in order to reduce intraspecific theft. We investigated the following behaviors in the lab using individual and paired foraging archer fish: (1) maximum vertical rotation during spitting, and (2) vertical rotation time. We predict that altering rotation kinematics might allow shooters to gain an advantage over bystanders, perhaps catching a thief off guard. In pairs of foraging fish, we also investigated (3) time spent under prey, and (4) chasing, which we predicted would give shooters an advantage by patrolling or guarding locations where prey appear. Preliminary data for (2) vertical rotation time indicates that shooters do not alter the speed of rotation in a group compared to foraging alone. Data from (3) and (4) suggests that when in pairs, one aggressive individual will patrol beneath locations where prey will appear and will chase off the bystander, allowing sniped prey to be captured without contest. Overall, our findings suggest that archer fish use aggressive tactics, rather than kinematic changes, to reduce competition for prey when in pairs.

78.7 BURNS, R.T.*; BIGGERS, W.J.; PECHENIK, J.A.; Tufts University, Wilkes University; *robert.burns@tufts.edu*

Menaquinone−6 produced by the marine bacterium Desulfovibrio oceani stimulates metamorphosis in larvae of the deposit−feeding polychaete Capitella teleta.

Larvae of many marine invertebrate species are powerless to swim against ocean currents; they spend hours to weeks suspended in the water column searching for a suitable habitat to complete juvenile development. Larvae are stimulated to metamorphose by a settlement cue − an environmental stimulus that signals the presence of mates, an appropriate food source, or an appropriate environment for juveniles. While the chemical settlement cues are unknown for the majority of species, many species have been found to metamorphose in response to microbial biofilms. Here, we investigated whether the polychaete *Capitella teleta* would metamorphose in response to biofilms made by bacteria isolated from their native salt marsh sediment, which is also their food source. A single anaerobic bacterial colony was found that stimulated larvae of *C. teleta* to metamorphose in less than 30 minutes. We determined that the inductive bacterium is *Desulfovibio oceani*. To determine the inductive chemical produced by *D. oceani*, we separated extracts of the salt marsh sediment and *D. oceani* biofilm by TLC. We found one dark purple spot present with the same retention factor for both the salt marsh sediment and *D. oceani* biofilm. The chemicals in this spot stimulated larvae of *C. teleta* to metamorphose in under 30 minutes. It was found that the sediment purple spot contained menaquinones 6, 7, 8, 9, and 10, while the spot isolated from *D. oceani* contained only menaquinone−6. After testing a number of menaquinones, only menaquinone−6 successfully induced metamorphosis. These results suggest that larvae of *C. teleta* are using menaquinone−6 produced by *D. oceani* as a settlement cue indicating the salt marsh sediments they inhabit.

P2.120 BURNS, S*; BONIER, F; Queen's University, Kingston, ON; *s.burns@queensu.ca*

Does capture method introduce bias in studies of free−ranging birds?

A common assumption underlying many biological studies is that the data we collect from a subset of individuals are representative of the population of interest. However, in studies of free−ranging animals, capture method might skew samples towards individuals with specific morphological, physiological, and/or behavioral traits. For example, in studies of free−ranging birds, bolder individuals might be more likely to enter nets and traps commonly used in capture. We sought to explore this possible bias by comparing individual birds sampled using two different capture techniques. We caught free−ranging black−capped chickadees (*Poecile atricapillus*) using Potter traps baited with seed and mist nets paired with an audio stimulus (chickadee mobbing calls) and determined sex, body condition, baseline and stress induced glucocorticoid levels, behavioral response to a novel object, and behavioral response to a predator. Differences between individuals captured using the two methods have implications for the design of studies aimed at understanding the physiology or behavior of free−ranging animals, as well as laboratory−based studies when genetic stock is derived from wild caught individuals. Understanding the potential for capture method induced bias will allow for more appropriate and informative sampling of populations.

44.3 BUSTAMANTE JR., J.*; PANZARINO, J.F.; RUPERT, T.J.; LOUDON, C.; University of California, Irvine; *bustamaj@uci.edu*

Characterization of mechanical properties of bed bug cuticle (Cimex lectularius)

As a result of the plant−herbivore coevolutionary arms race, plants have evolved a variety of physical and chemical defenses against insects and other herbivores. Nonglandular trichomes are microscopic plant hairs that provide an important and effective physical defense against some insects. By coincidence, trichomes on leaves from bean plants (*Phaseolus vulgaris*) have been shown to pierce and entrap bed bugs (*Cimex lectularius*), although bed bugs and bean plants do not share any evolutionary association. In recent years, bed bugs have reemerged globally as a major pest. Therefore there is general interest in the development of control methods, particularly environmentally−benign physical methods that do not involve insecticides. In order to understand the requirements of a biomimetic physical control method based on the piercing trichomes, the mechanical properties of bed bug cuticle have been characterized using nanoindentation. Nanoindentation was performed on the underside of bed bug tarsi (distal segments on the legs), including the pretarsal claw area. Only specific locations have been documented to be pierced. These locations were chosen for nanoindentation in addition to adjacent non−pierced areas, in order to identify the causes of mechanical vulnerability. Some areas of the pretarsal claws were easier to pierce (required a lower force) than the cuticle of the tarsal subsegments, and required a smaller displacement of the probe before piercing occurred.

P2.88 BUTLER, J.B.*; MARUSKA, K.P.; Louisiana State Univ; *jbutl48@lsu.edu*

Role of the mechanosensory lateral line in aggressive interactions in an African cichlid fish

Fish must integrate information from multiple sensory systems to mediate adaptive behaviors. Visual, acoustic, and olfactory cues provide contextual information during social interactions, but the role of mechanosensory signals detected by the lateral line system during aggressive behaviors is unknown. The aim of this study was to first characterize the lateral line system of the African cichlid fish *Astatotilapia burtoni*, and second, to determine the role of mechanoreception during agonistic interactions. The *A. burtoni* lateral line system is similar to that of many other cichlid fishes, containing lines of superficial neuromasts on the head, trunk, and tail, and mostly narrow canals, with the exception of some wide branches from the infraorbital and preopercular canals. These wider canal portions may enhance mechanoreceptive capabilities on the head, possibly to improve detection of water movements during social behaviors. *A. burtoni* males actively defend their territories from other males using aggressive behaviors that we classified as non−contact or contact. We pharmacologically and physically ablated the lateral line system prior to forced territorial interactions, and quantified pre−fight and fight behaviors compared to sham−handled fish. During typical aggressive encounters, *A. burtoni* rely more on non−contact than contact behaviors, but fish lacking mechanoreception used more contact than non−contact behaviors. These ablated fish also spent more time within one body length of each other without performing any aggressive behaviors and were more likely to become submissive than to engage in a territorial fight, suggesting a decrease in fight motivation. To our knowledge, this is the first study to implicate the lateral line system as a mode of communication necessary for agonistic interactions.

50.2 BUTLER, MA*; SCALES, JS; RIVERA, JA; WALGUARNERY, J; SCHROEDER, R; University of Hawai'i; *mbutler@hawaii.edu*

Color vision in the Hawaiian damselfly Megalagrion xanthomelas: how to see better in a highly heterogeneous environment

Sending and receiving signals in a forest understory environment can be quite challenging because the light environment is heterogeneous. Hawaiian damselflies of the genus *Megalagrion* provide an excellent model system for examining how visual behavior and environmental heterogeneity influence visual performance. *Megalagrion xanthomelas* is a forest understory species that lives on small flowing streams that are heavily shaded. It is highly territorial and brightly colored species. Using microspectrophotometry in single−cell recordings, we determined that Megalagrion xanthomelas has at least 4 photoreceptor classes: UV, blue, green, and red−sensitive. We measured the light environment at individual perch sites in the forward, up, and lateral directions to model the animals' visual capabilities at the locations where individuals chose to perch. We modeled visual capabilities at these selected locations compared to random locations and found that individuals chose particular views and orientations that enhanced their visual performance.

15.2 BYRUM, CA*; SMITH, J; EASTERLING, MR; BRIDGES, MC; College of Charleston; *byrumc@cofc.edu*

Does Nuclear Transport Influence Neurogenesis in Sea Urchin Embryos?

In eukaryotes, karyopherin−alpha (KPNA) importins assist in transfer of transcription factors and other molecules into the nucleus. It has become increasingly evident that learning more about KPNAs may benefit human health as their expression is misregulated in late−stage cancers, viral diseases, and several neurological disorders. The sea urchin embryo is an excellent model for these investigations and should be promoted as a tool to learn more about roles of nuclear transport in intact organisms. BLAST searches of Lytechinus variegatus pre− and postgastrula embryonic transcriptomes revealed three KPNA sequences: KPNA1/5/6, KPNA2/7, and KPNA3/4. Using wholemount in situ hybridization, mRNA distribution was examined between fertilization and pluteus stages. LvKPNAs1/5/6 and 3/4 were both clearly present during cleavage, however varied in staining. Blastulae were ubiquitously stained and transcripts in mesenchyme blastulae were restricted to vegetal cells with lower levels throughout. In gastrulae, expression was observed in the archenteron and, by prism/pluteus stages, was restricted to the gut and oral territories. Studies in vertebrates suggest these two KPNAs may regulate assembly of the mitotic apparatus (Trieselmann et al., 2003). Also, like vertebrate KPNA1, LvKPNA1/5/6 may influence neurogenesis (Yasuhara et al., 2013). Like SpBrn1/2/4 and SpSynaptotagmin B, two genes associated with neural differentiation, LvKPNA2/7 was found in patches of ectodermal cells ultimately associated with the ciliary band. Studies in mouse embryonic stem cells (Yasuhara et al., 2013) suggest that KPNA2 maintains pluripotency in neural precursors by preventing nuclear localization of the transcription factors Brn2 and Oct6. LvKPNA2/7 may play similar roles in neural differentiation of the sea urchin. LvKPNA2/7 was also present in the archenteron/gut.

37.2 CABALLERO, JL*; MAZO, C; RODRIGUEZ−PINTO, I; THEOBALD, JC; Florida International University; *jcaba009@fiu.edu*

A visual horizon modifies fruit fly bar tracking responses

In order to navigate effectively in three dimensions, flying insects must gauge distances to objects around them. Humans use a variety of visual cues that provide information for estimating depth, however, insects are constrained to a reduced range of possible depth cues due to their smaller size and fixed eyes. Flying fruit flies are able to use motion parallax to gauge relative distances of nearby objects, but motion parallax becomes less viable of a strategy across longer distances. For humans, a useful method of estimating depth across longer distances makes use of the horizon; an object that appears closer to the horizon is presumed to be far away. We set out to determine if flying fruit flies, like humans, gauge objects that are near the horizon as farther off. Tethered flies respond strongly to moving objects that they perceive as close, thus we measured responses while varying the apparent elevation of virtual objects in a virtual environment. We found wide−field responses are unaffected by relative horizon elevation, but responses to vertical bars are strongly increased by reducing the apparent elevation of the bar against a virtual horizon. This strong response could indicate that fruit flies are able to assess the distance of far off objects in the natural world by comparing them against the salient natural horizon.

P1.65 CAHILL, JW*; ROSE, CS; James Madison University; *rosecs@jmu.edu*

Isolating T4 and T3 effects on cartilage growth and shape change in Xenopus tadpoles

Investigators of how thyroid hormones (TH) regulate frog metamorphosis often apply TH to induce metamorphic changes precociously in tadpoles. However, precociously induced remodeling of skeletal tissues might not resemble natural remodeling for many reasons. Remodeling might be induced before larval tissues become competent to fully respond to TH or before they attain the shapes at which natural remodeling starts. Remodeling might also be induced during faster growth than in metamorphosis. Further, induced remodeling means applying exogenous TH at fixed concentrations, which does not simulate the changing T3 and T4 levels during metamorphosis. To test how precocious induction affects remodeling, this study quantifies the stage−dependency of size and shape changes induced in two pharyngeal arch cartilages (Meckels cartilage or MC and ceratohyal or CH) by TH. We treated *Xenopus* tadpoles at early, mid and late tadpole and early metamorphic stages (NF 46, 53, 57 and 59/60) with 50 nM T4 or T3 or no hormone and measured the changes in body size and size and shape of the MC and CH. Treated and control specimens at NF 53, 57 and 59/60 were pretreated with methimazole to arrest them and methimazole and iopanoic acid were applied during experiments to block endogenous TH production and prevent T4 or T3 being converted to other forms of TH. Animals were photographed before and after treatments, cleared and stained for cartilage and bone, and their MC and CH dissected and photographed. Body sizes and final cartilage sizes and shapes were quantified from photographs; initial sizes and shapes were estimated from allometric relationships for controls. Cartilage dimensions responded similarly to both T3 and T4 at all stages, though the magnitude of change and impact on shape varied with stage and TH type.

P3.204 CALDWELL, ME*; SLATOFF, LG; LEMA, SC; Cal Poly, San Luis Obispo; *slema@calpoly.edu*

Evidence for contemporary morphological diversification between populations of Amargosa pupfish

Changes in morphological diversity among populations are possible when the environmental conditions of one population's habitat shift via either natural or anthropogenic causes. Recently, we collected data suggesting that a population of Amargosa pupfish *Cyprinodon nevadensis amargosae* in an isolated thermal spring in the Death Valley region, USA, experienced a contemporary change in body morphology related to alterations to the physical structure and thermal regime of their habitat. Collections of fish from the thermal spring's outflow channel and associated marsh in 2007−2008 indicated that fish in this isolated thermal spring habitat exhibited a similar distribution of body sizes as conspecifics in the nearby Amargosa River. Collections of pupfish from these same allopatric populations in 2013−14, however, revealed a shift in both the body size and morphological shape of pupfish occupying the thermal spring habitat. These collections indicated that pupfish in this habitat were now on average 12.3% smaller in body length and 48.1% less in mass than in 2008. These collections also revealed that 33.8% of pupfish within the thermal spring population now exhibit either complete or partial (only 1 pelvic fin) loss of the paired pelvic fins. This finding contrasts with greater than 99% of pupfish having both pelvic fins in this habitat in 2008, as well as in the nearby Amargosa River population. Landmark−based, geometric morphometric analyses further revealed differences in body depth between the thermal spring and Amargosa River populations. Body depth is a sexually dimorphic trait in *Cyprinodon* spp. with males exhibiting deeper bodies than females; the thermal spring population, however, shows a distinct reduction in body depth sexual dimorphism compared to the Amargosa River population.

93.5 CALHOON, E.A.*; WILLIAMS, J.B.; Ohio State University; *calhoon.18@osu.edu*

Connections between mitochondrial and non−mitochondrial phospholipid fatty acid composition, metabolic rate, and life history in temperate and tropical birds

Temperate birds tend to have a fast pace of life, having short life−spans with high reproductive output and high metabolic rate, whereas tropical birds tend to have a slower pace of life, investing fewer resources in reproduction and having higher adult survival rates with lower metabolic rates. How these differences in life history at the organismal level are rooted in differences at the cellular level is a focus of current research. Increases in the saturation level of fatty acids in the phospholipids of cell membranes has been implicated in decreasing metabolic rate and oxidative stress, but this connection has been challenged and its validity may depend on which organelle the increase in saturation is in. Several studies have looked at the fatty acid content of phospholipids in whole cells and in mitochondria, but none have compared the effects of different saturation levels between mitochondrial and non−mitochondrial membranes on metabolic rate. Here, we cultured fibroblasts from phylogenetically−paired tropical and temperate bird species, isolated the mitochondria from the other organelles, and then compared mitochondrial and non−mitochondrial membrane lipids between tropical and temperate birds using high−performance liquid chromatography−mass spectrometry. Additionally, previous studies in our lab have measured the metabolic rate of the same cell lines, so we were also able to compare the effects of mitochondrial and non−mitochondrial phospholipid fatty acid composition on cellular metabolic rates.

S8.11 CALISI, RM; Barnard College, Columbia University; *rcalisi@barnard.edu*

Neuroendocrine dynamics of reproductive hormones GnRH−I and GnIH in response to seasonal, social, and rapid changes in behavior

How does the vertebrate brain regulate sexual and reproductive behaviors? Gonadotropin−releasing hormone (GnRH−I) and gonadotropin−inhibitory hormone (GnIH) are key hypothalamic hormones that mediate vertebrate reproductive endocrinology, yet we have much to learn regarding how their actions affect and are affected by behavior. This type of information is particularly lacking for GnIH, due to its relatively recent discovery in 2000. First, I will review how these peptides vary in cell abundance and gene expression in accordance with reproductive stage in birds and mammals. In seasonally breeding European starlings (*Sturnus vulgaris*), GnRH−I and GnIH cell bodies are most abundant in males and females during the breeding season (spring) as opposed to the non−breeding period (fall), indicating increased function during this time. Then I will present how changes in GnIH peptide cell abundance, soma size, and peptide concentration are associated with changes in social and ecological cues during the breeding season in European starlings. GnIH peptide cell abundance also changes at the onset of parental care in European starlings and female rats (*Rattus norvegicus*). These observations provide a powerful base from which to generate and test hypotheses experimentally, clarifying the role of GnRH−I and GnIH in sexual and reproductive behaviors. Finally, I will introduce the common pigeon (*Columbia livia*) as a powerful model to advance these investigations. Specifically, I will report validated methodology in pigeons that will help elucidate the rapid effects that GnRH−I, GnIH, and other neural substrates have in response to changes in social, reproductive and ecological environments.

P1.50.5 CAMACHO, M.C.*; SCHAFER, T.B.; OSBORNE, T.Z.; Whitney Laboratory for Marine Bioscience, University of Florida; *monicacamacho1214@yahoo.com*

Impacts of climate change induced vegetation shift on estuarine food web structure

Avicennia germinans (Black Mangrove) coverage has doubled in the last three decades in Northeast Florida's salt marshes due to climate change (fewer cold days). These marshes were originally dominated by *Spartina alterniflora* (Smooth cordgrass), but now they are being outcompeted. This research focuses on how the influx of *A. germinans* impacts the ecosystem biogeochemically in the carbon and nitrogen it contributes, as well as biologically in the organisms it supports. Animal and vegetation tissues were collected between Marineland and St. Augustine, Florida. Stable isotope analysis was used to determine from which vegetation organisms were obtaining nutrients. Macro−scale trials with fiddler crabs and periwinkle snails were conducted to investigate which vegetation they preferred. The majority of organisms studied obtained their nutrients from *S. alterniflora*, although the *A. pisonii* (mangrove tree crab), *G. demise* (ribbed mussel), and *C. virginica* (oyster) fed on detritus derived from both plants. Furthermore, fiddler crabs preferred *A. germinans* soil whereas periwinkle snails preferred *S. alterniflora* vegetation. In conclusion, *A. Germinans* expansion will alter the ecosystem's food web and species distribution.

P1.123 CAMACHO, N.M.*; POWERS, D.R.; WETHINGTON, S.M.; CORMIER, T.A.; GRAHAM, C.H.; GOETZ, S.; George Fox Univ., Newberg, OR, HMN, Patagonia, AZ, Woods Hole Research Ctr., Falmouth, MA, Stony Brook Univ., Stony Brook, NY; *ncamacho12@georgefox.edu*

Can Subtle Differences in Thermal Landscapes Impact Energy Expenditure in Migratory Hummingbirds

In summer, Chiricahua Mts (CM; SE Arizona) temperatures can be >40ÚC. The CM supports migrating hummingbirds whose numbers and behavior differ on the west slope (WS) vs. east slope (ES) possibly due to the impact of thermal landscapes on energy expenditure. We studied variation in thermal landscapes between the WS and ES of the CM, and how differences might alter hummingbird energy budgets. To characterize thermal landscapes we recorded ambient (T_a) and operative (T_e) temperature along transects sampling all vegetation types in our WS (~1700m−2000m) and ES (~1500m−1750m) sites. Mean daytime T_a did not differ between sites (WS 28.6±1.8 ÚC; ES 28.6±2.3ÚC). Mean nighttime T_a was slightly higher on the ES (17.8±2.4ÚC) than the WS (17.2±1.7ÚC). WS hourly daytime T_a was higher in morning (0.4−2.1ºC) and afternoon (0.7−1.6ºC), but lower at midday (0.2−2.3ºC) relative to the ES. Maximum T_a (T_{max}) occurred at 1400 on the WS and 1200 on the ES. Minimum nighttime T_a for both sites was at 0400. Prior to T_{max}, T_a increased 2.3ÚC/hr on the WS compared to 3.3ÚC/hr on the ES. Following T_{max}, WS T_a declined 2.0 ÚC/hr compared to 1.7 ÚC/hr on the ES. On the WS mean T_a is never above the predicted lower critical temperature (LCT) of small (~3g) hummingbirds, whereas larger (~7.5g) species are predicted to spend ~8 hours within their thermal neutral zone (TNZ). On the ES, small species are predicted to spend 4 hours within their TNZ compared to ~7 hours for large species. These data suggest that the differences in thermal landscapes are likely to have a greater impact on energy budgets of small hummingbirds than larger hummingbirds.

S12.2 CAMP, A.L.*; BRAINERD, E.L.; Brown University; *ariel_camp@brown.edu*

Reevaluating musculoskeletal cranial linkages in suction feeding fishes with X−Ray Reconstruction of Moving Morphology (XROMM)

During suction feeding in fishes, musculoskeletal linkages and levers transform muscle shortening into cranial expansion. These linkage theories were developed from morphology, manipulation and modeling, and assessed *in vivo* with high−speed film, video and 2D cineradiography. Now a new X−ray imaging method, X−Ray Reconstruction of Moving Morphology (XROMM), is making it possible to determine the 3D motions of bones and examine the proposed linkages directly. To explore the utility and limitations of XROMM, we have analyzed the opercular linkage, one of several linkages thought to contribute to lower jaw depression. In this linkage, shortening of the levator operculi muscle is hypothesized to rotate the operculum caudodorsally about the operculohyomandibular joint, generating retraction of the interoperculum and the interoperculomandibular ligament, and resulting in depression of the lower jaw about the quatromandibular joint. From XROMM animations of largemouth bass feeding on goldfish, we confirmed that the operculum rotates relative to the suspensorium while the levator operculi shortens, as predicted. However, when kinematics were viewed relative to the fish's body, the suspensorium clearly rotated rostrodorsally away from the operculum as the neurocranium elevated, and the operculum was stabilized by the levator operculi. Thus, while skeletal motions conform to the expectations of the opercular linkage, the epaxial muscles elevating the head provided the motion for jaw depression, rather than the levator operculi. We expect that the function of this linkage will vary substantially in other species, and that XROMM can be used to assess this and other linkages. However, this method is limited as it is currently time−consuming and can only be applied to fairly large fishes.

P1.99.1 CAMPBELL, AB*; PASACHNIK, SA; MAPLE, TL; Florida Atlantic University, Institute for Conservation Research, San Diego Zoo Global; *acampb27@fau.edu*

Habitat Utilization of the Roatan Spiny−tailed Iguana (Ctenosaura oedirhina) and Its Implications for Conservation

Resources available for *in situ* species conservation are limited. In order to make the most of what is available, habitats must be prioritized for protection. Biodiversity hotspots are one form of prioritization, identifying areas with many endemic species that are threatened by habitat loss. Within these larger areas, the habitats that make up the range of endemic species can also be prioritized in order to use limited conservation resources most effectively. With data gathered from use/availability surveys, resource selection functions (RSFs) can identify habitats and environmental variables associated with the presence of a species. Roatán Spiny−tailed Iguanas (*Ctenosaura oedirhina*) are a narrow range endemic native to the island of Roatán, Honduras. Two years of data produced RSFs that indicated this species is more likely to be found in anthropogenic areas than in undisturbed locations. Though certain environmental variables did influence the distribution of this species, our results indicate that protection from harvesting is the most important factor determining their distribution across the island. While it is illegal to hunt this species, the law is not enforced and hunting for consumption is very common. Areas where they still exist in high densities are protected only at the grassroots level. In order to protect this species and insure its persistence in the wild, regulation and enforcement of harvesting must be applied.

64.5 CAMPBELL, D.*; JACHEC, S.; WALTERS, L.; University of Central Florida, Florida Institute of Technology; *d.campbell@knights.ucf.edu*

Quantifying the Effects of Boat Wakes on Intertidal Oyster Reefs in Florida

The 2008 Indian River Lagoon Comprehensive Conservation and Management Plan and Canaveral National Seashore's Water Resources Management Plan (2001) express concerns about the negative impacts of recreational boating activity in the Indian River Lagoon (IRL), and more specifically the northernmost part of the IRL, Mosquito Lagoon (ML). Our research is focused on the direct impacts of boat wakes on intertidal reefs formed by the eastern oyster *Crassostrea virginica*. There has been a 24% loss of oyster habitat in ML since 1943, where natural oyster reefs have been replaced by dead reefs which do not serve the same ecological function. All dead oyster reefs were found adjacent to channels with boating activity which were too narrow to generate significant wind−driven wave action. However, no studies to date have confirmed dead reefs can be a direct result of boat wakes. Therefore, we addressed the following questions in ML: "What wake heights and intensities do different boat types generate that contact intertidal oyster reefs?," and "What amount of sediment erosion, dislodgment, and oyster movement do these boat wakes generate?" A series of boat pass experiments in ML addressed the first question; these results were utilized in experiments at Florida Institute of Technology's wave tank to observe oyster movement at specific wake heights. The field and wave tank experiments combined provide compelling evidence to conclude that wave energy resulting from boat wakes in ML is sufficient to dislodge oyster clusters from sediment and ultimately cause them to move, resulting in dead reefs. Model selection is being used to determine which variables most influence the observed responses.

74.3 CAMPOS, E.O.*; BRADSHAW JR., H.D.; DANIEL, T.L.; University of Washington, Seattle; *eocampos@uw.edu*

3D−printed flowers reveal strong sensitivity of animal feeding performance to corolla curvature

Flower morphology is an important contributor to a pollinator's ability to find and exploit the nectar source. Our previous research suggests that hawkmoth foraging performance is poor when attempting to feed from flowers whose corollas form a flat disk, but substantially better when the corolla is given even a small degree of trumpet−like curvature. To explore the relationship between floral form and nectar feeding success (a form of floral fitness landscape), we measured how corolla curvature influences pollinator foraging ability using the hawkmoth *Manduca sexta* and 3D−printed artificial flowers whose lateral profiles were mathematically specified. In foraging trials featuring a 36−flower array containing 6 different corolla shapes, hawkmoths were not able to exploit all flower morphs equally (ANOVA, $N = 21$, $p < 0.01$) despite visiting all flower morphs with equal frequency (ANOVA, $p = 0.85$) and spending equal amounts of time at all morphs (ANOVA, $p = 0.74$). These results corroborate earlier findings suggesting that trumpet−like corolla curvature can act as a mechanical nectar guide for nocturnal and crepuscular hawkmoths. By altering other shape parameters in our mathematical model of floral shape, we build upon these results to construct a foraging performance landscape for hawkmoths as a function of differences in floral form.

P1.125 CANEPA, J.R*; SHANKAR, A.; POWERS, D.R.; SCHROEDER, R.J.; GRAHAM, C.H.; George Fox Univ., Newberg, OR, Stony Brook Univ., Stony Brook, NY; *jcanepa11@georgefox.edu*

Changes in Hummingbird Daily Energy Expenditure Along an Elevational Gradient

Higher temperatures associated with climate change in landscapes used by hummingbirds might increase thermoregulatory costs and alter foraging patterns resulting in increased daily energy expenditure (DEE). Because hummingbirds are key pollinators, changes in behavior or distribution could alter ecosystem dynamics. One response might be to move to higher elevation where reduced daytime temperature would allow better control of thermoregulatory costs. Moving to higher elevation might not be an energy−neutral transition as ecosystem shifts such as change in resource type/distribution, cooler nighttime temperature, decreased air density, and new competitive interactions could result in higher DEE. In this study we measured DEE in hummingbirds at different elevations as a first step in understanding energetic costs associated with high−elevation ecosystems. To do this we used doubly labeled water (DLW) to measure DEE in hummingbirds at two sites along an elevational gradient on the west slope of Andes Mts. in Ecuador. We studied 2 hummingbird species (mass 7−8.7g) at our low−elevation site (~1300m, LE) and 1 species (9.40−9.70g) at higher elevation (~1900m, HE). Mean CO_2 production was 17.4−20.5 mL CO_2 $g^{-1}h^{-1}$ at LE, and 21.7−24.6 mL CO_2 $g^{-1}h^{-1}$ at HE. HE DEE was ~6−30% higher depending on species compared. DLW does not segregate energy costs, but many factors could promote higher DEE at HE. Also, torpor is used more frequently at LE, which might make the difference in DEE smaller. Potential taxonomic differences between species also cannot be ignored.

P1.101 CAPELLE, P.M.*; SEMENIUK, C.A.D.; HEATH, D.D.; HEATH, J.W.; LOVE, O.P.; University of Windsor, ON, Yellow Island Aquaculture Ltd., BC; *capelle@uwindsor.ca*

Differences in diel cortisol rhythms in outbred stocks of juvenile chinook salmon (Oncorhynchus tshawytscha)

Although the practice of selective breeding in aquaculture facilities has been essential for maximizing growth and survival, it has also led to increased differentiation from wild strains and a loss of genetic diversity, with potential deleterious effects. Understanding how outbreeding with wild stocks impacts the mechanisms underlying fish growth and survival in captivity is therefore vital for maximizing aquaculture success. Cortisol is a major energetic hormone that oscillates with a circadian rhythm in response to diel variation in energetic demands. We hypothesized that if different outbred crosses between wild and captive chinook salmon stocks manage cortisol differently across the day, this may impact growth rates, and therefore terminal size and potentially survival. We measured baseline plasma cortisol levels across a 24−hour period in pre−smolt individuals from hybrid (outbred) stocks created via crosses between eggs from domestic (captive) females and multiple individual males within each of seven different wild stocks (using cryopreserved milt). While all stocks showed a clear diel rhythm in baseline plasma cortisol levels, we found a significant additive genetic effect of the sire on the management of baseline cortisol across the 24−hour cycle. We will next investigate whether these stock−level differences in cortisol impact early growth to determine the influence of outbreeding on salmon fitness and aquaculture productivity.

P2.143 CAPLIN, A. S.*; BENOWITZ−FREDERICKS, Z. M. ; Bucknell University, Bucknell University ; *asc011@bucknell.edu*

Effects of elevated yolk testosterone on gonadal gene expression in young chickens (Gallus gallus domesticus).

Maternally−generated variation in the embryonic endocrine milieu affects many physiological functions in offspring. Whereas effects of elevated *in ovo* testosterone exposure on growth, behavior, immune function and endocrine function have been explored in many avian species, very little is known about potential molecular bases for changes in these suites of traits. We tested the hypothesis that changes in hypothalamo−pituitary−gonadal (HPG) axis function induced by exposure to elevated yolk testosterone are regulated in part by changes in gene expression in the gonads, and that these changes are apparent early in post−natal development. We injected eggs with 10 ng of testosterone in oil ("T−treated"), or an oil vehicle alone ("control"), and then used quantitative real−time PCR to measure expression of a suite of genes relevant to HPG axis function in the testes and ovaries when chicks were 3 days old. T treatment had no effect on average plasma testosterone levels, but a significantly larger proportion of chicks from T−treated eggs had undetectable levels of plasma testosterone. Although T treatment did not affect gonadal gene expression, male and female chicks exhibited marked sex differences in expression, indicating sex−specific variation in HPG axis activity at this age. Our results suggest that organizational effects of maternal androgens on the HPG axis, at least at the level of the gonads, may not manifest until reproductive maturity.

S10.2 CARDE, R T*; BAU, J; University of California, Riverside, University of Vic; *ring.carde@ucr.edu*

Optimal strategies for finding a resource−linked odor plume: theories and lessons from flying insects

Male moths locate females by navigating along a plume of her pheromone, often flying 100s of meters en route. As the first male to find a calling female is apt to be her mate, this can be termed "a race to find the female" and it is assumed to be under strong selective pressure for efficiency and rapidity. Locating a distant, odor−linked resource involves two strategies. First, contact the outer envelope of the odor plume. When wind direction is relatively invariant, the plume stretches out and then a strategy may favor crosswind flights, although upwind and downwind paths may be optimal when wind direction shifts over 60 degrees. Alternatively, the path may be random with respect to the direction of wind flow, with periodic changes in direction as in a Lévy Walk or a Random Walk. After first odor detection, a second strategy follows where moths navigate along the plume by heading upwind when odor is detected with crosswind casting to re−establish contact if the plume is lost. These mechanisms are well established from wind−tunnel manipulations. This orientation path is not straightforward in nature, because atmospheric turbulence fragments the plume creating large odor gaps. Further, a shifting wind direction can lead the responder out of the plume. One way to explore which strategies are optimal for enabling initial plume contact and subsequent plume tracking is through simulation modeling of plume dispersal and flight strategies. Our simulations suggest that search strategies similar to Lévy Walks are most apt to result in quick plume contact. While a searching trajectory aimed predominately crosswind performed almost as well in certain conditions, downwind trajectories did not prove as successful. These results are in accord with the behavior of moths flying in the field.

1.3 CARDILLO, MG*; RAYOR, LS; Cornell University, Ithaca, NY; *mgc63@cornell.edu*

Plasticity in development associated with sociality in spiders: What factors influence developmental patterns in spiders?

Spiders remain in the egg sac as 1^{st} instars and emerge as 2^{nd} instars, which soon begin to hunt for prey. This universal' pattern of spider development is seen in 26 solitary Australian huntsman species (Sparassidae: Deleninae). However, the three known social huntsman species exhibit a different pattern of development, such that 2^{nd} instars of the social species, *Delena cancerides* and *D. lapidicola*, are non−feeding and retain 1^{st} instar characteristics: shorter legs and more abdominal yolk. Only in the 3^{rd} instar do social species morphologically resemble adult huntsman spiders and begin to hunt. We examined differences in physiological variables to determine which factors account for the developmental differences between two social and four solitary huntsman spider species. We measured the number, volume, and mass of social and solitary spider eggs and spectrophotometrically measured differences in protein, lipid, and carbohydrate content of yolk. Standard metabolic rates of 1^{st}, 2^{nd}, and 3^{rd} instar spiders were measured using stop−flow respirometry, along with the number of days spent in egg, 1^{st}, 2^{nd}, and 3^{rd} instar stages. To see whether the delayed developmental pattern of social species gives them an advantage in growth, we measured changes in leg length, carapace width, and abdomen volume. Our results indicate that social species have more egg yolk, shorter developmental periods, and lower metabolic rates, enabling them to remain non−feeding as 2^{nd} instars and giving them an advantage in leg length growth from 2^{nd} to 3^{rd} instar. Similar delayed developmental patterns and physiological adaptations may be found in other social carnivores that must overcome similar barriers to group living.

P2.73 CARLO, M.A.*; RIDDELL, E.A.; SEARS, M.W.; Clemson University; *mcarlo@clemson.edu*

Sublethal warming of embryo temperatures affects post−hatching phenotypes in the Eastern fence lizard (Sceloporus undulatus)

Sublethal stressors will likely mediate an organism's response to climate change. Mobile animals can use behavioral thermoregulation to buffer the effects of environmental changes, but animals in sessile stages of ontogeny are vulnerable to warming. For example, lizard embryos are exposed to recurrent thermal stress as they develop in shallow nests. Previous research has shown Eastern fence lizard (*Sceloporus undulatus*) embryos will succumb to cardiac arrest under acute exposures to nesting temperatures at or above 41.5°C , which is beyond the range of temperatures experienced in contemporary climates. But how does exposure to sublethal high temperatures due to climate warming affect embryos? We reared *S. undulatus* embryos under three thermal regimes based on soil temperature data a contemporary regime with a maximum daily temperature (T_{max}) of 32.1°C, and two regimes to simulate warming scenarios in which the T_{max} was raised to 35.6°C and 39.1°C. Clutches were divided evenly among the treatments to examine impacts of the different thermal cycles on embryo physiology. Hatchlings were then raised in a common environment. To evaluate the capacity for acclimation to the embryonic thermal environment, we measured hatchling growth, metabolic rates, preferred temperatures, and sprint speeds. Results from this study will highlight important physiological constraints on embryonic lizards and the impacts of those constraints on post−hatching phenotypes. Future research should examine the long−term sublethal effects of warming as they occur throughout stages of ontogeny.

P3.171 CARR, JA*; BIEWENER, AA; Harvard Univ., Cambridge, MA; *carr.je@gmail.com*

Ontogenetic Scaling of Guineafowl Hindlimb Muscle Architecture

Although muscle architecture and musculoskeletal scaling patterns have been examined, there has been little study of ontogenetic scaling patterns of muscle architecture. How muscles with different anatomical features and muscles that produce different types of movement within the limb change in architecture during growth and what these patterns suggest for changes in limb function have received little attention. Because muscles have different mechanical roles within the limb that may be dependent on location and anatomy, we hypothesize that muscles may grow at different rates and exhibit varying architectural scaling patterns determined by their function and evolutionary constraints. To test this hypothesis, we examine the ontogenetic scaling patterns of proximal and distal muscles of the guineafowl (*N. meleagris*) hindlimb: iliotibialis lateralis pars postacetabularis (ILPO), iliofibularis (IF), iliotibialis cranialis (IC), lateral and medial gastrocnemius (LG & MG), superficial digital flexor IV (SDF−IV), tibialis cranialis (TC) and fibularis longus (FL). Muscle mass, fiber length, pennation angle, and tendon length were measured. Preliminary results demonstrate that the physiological cross−sectional area of several of the muscles studied demonstrate positive allometry as a function of body mass (exponent ranges vs $M_b^{0.67}$), with the exception of the FL (0.23 $M_b^{0.67}$), the IF ($0.11M_b^{0.56}$) and IC ($-0.08\ M_b^{0.54}$). In addition the CSA of the FL and IF tendon are isometric, the LG tendon is negatively allometric ($-0.87\ M_b^{0.46}$) and MG and SDF−IV are positively allometric ($-1.8M_b^{0.75}$ & $-2.6M_b^{0.90}$) relative to body mass. Tendon scaling patterns relative to muscle scaling patterns suggest increased strain and energy storage in the LG and IC tendons and decreased strain and energy storage in MG and SDF−IV tendons with growth and age.

P3.93 CARRIGEE, LA*; GRIFFITT, RJ; Univ. of New Orleans, Univ. of Southern Mississippi Gulf Coast Research Lab; *lcarrige@uno.edu*

Effects of Metal Nanoparticulates on the Microbiome of Zebrafish Danio rerio

Production and utilization of commercial products containing metallic nanoparticles have dramatically increased in recent years, prompting researchers to investigate their effects on environmental systems. While the primary effect of metallic nanoparticles to aquatic species has been relatively well characterized, very little attention has been paid to the potential secondary toxic effects, particularly alteration of intestinal microbial communities in the host fish. The intestinal microbiome has recently been shown to be of high importance to maintaining health status of many organisms, including aquatic species. Recent research has shown that zebrafish exposed to metallic nanoparticles accumulate these particles in tissue and display adverse effects such as altered gill ultrastructure, gene expression, and mortality. As many metallic nanoparticles are known to have strong antimicrobial properties, we hypothesized that the uptake of nanoparticles by zebrafish may disrupt the endogenous microbiota. Zebrafish were exposed to two sublethal concentrations of nanocopper and nanosilver for 48h, and the intestines removed and sent for metagenomics 16S sequencing. By comparing control and treated microbial community structures, we were able to determine the precise bacterial populations that were affected. Initial results indicate that the numbers of major populations of intestinal microbes were not significantly effected; however, numbers of lesser populations of bacteria were significantly effected when compared to control groups. The results of this research could provide important ecological information about the habitats of *D. rerio* and the projected effects of metal nanoparticulate pollution in water systems. Final statistical analysis in progress.

62.6 CARRILLO, A.*; MCHENRY, M.J.; Univ. of California, Irvine; *andresc2@uci.edu*

Zebrafish larvae learn to forage in the dark

Larval fish improve in their ability to forage in the dark as they grow, but it is unclear whether this is due to heightened prey sensing. Therefore, we performed experiments that recorded larval zebrafish (*Danio rerio*) as they fed on *Artemia* nauplii in the dark during the first month of growth. We found that larvae failed to forage when the lateral line system was compromised. However, we did not find that the morphology of the lateral line changed appreciably over growth. We therefore tested whether larvae improve in detecting prey by learning to use the lateral line system by raising groups of larvae that were prohibited from learning. One group was raised on dead *Artemia*, which offered the same nutritional content as live prey, but did not produce a hydrodynamic stimulus. The lateral line system was ablated daily in another group of larvae fed live *Artemia*. Both groups were grown for one month and were consequently naïve to flow stimuli generated by prey. After a month of growth, treated larvae were permitted to recover the lateral line and feeding experiments were conducted in the dark. We found that the capture probability of both groups was significantly lower than the control, but were indistinguishable from larvae that did not have a functioning lateral line system. This suggests that larval zebrafish learn to use the lateral line system to capture mobile prey, which permits them to forage in the dark. This ability to learn demonstrates that zebrafish larvae have flexibility in their ability to specialize to particular prey during early development.

P3.9 CARROLL, M.A.*; SKEETE, D.; CATAPANE, E,J; Medgar Evers College; *catapane@mec.cuny.edu*

Undergraduate Research − a Key to Advancing Interest in STEM

In 2006 Medgar Evers College received an NSF grant (0622197 of the DUE Program) designed to increase the number of students earning BS degrees in Biology and Environmental Science. The goals of our STEP into Science program were to: recruit new students and non−STEM students into Biology or Environmental Sciences; improve retention by providing academic, financial and mentoring support; foster integration of research and technology to better equip majors to be successful applicants to graduate/professional programs; and increase the number of students graduating with BS degrees. We use peer recruiters to attract more high school, transfer, and non−science college students into STEM majors and place emphasis on undergraduate research experiences to increase the quality and retention of science majors through their BS degree. Since the inception of the program, STEM enrollment more than doubled. Our program evaluations consistently showed that a key factor in our successful recruitment and retention was student involvement in undergraduate research activities. The number of majors actively engaged in research has risen more than 90% with a concurrent increase in student research presentations at scientific conference, and an 87% increase in the number of students receiving external research internships and travel awards to attend national conferences. STEM graduates have also increased and many of them are continuing on to Masters and Doctoral programs in STEM and hopefully will ultimately enter rewarding careers in the science enterprise.

P3.130 CARSON, R*; SALAZAR , T; PASTOR , M; YOUNG , C; PLASCENCIA , M; MORALES, S; BARTHELL, J; HRANITZ, J; GONZALEZ, V; University of Central Oklahoma, University of Chicago, San Francisco State University, Muhlenberg College, University of California Santa Cruz, University of Central Florida, Bloomsburg University , University of Kansas; *Scarson5@uco.edu*

Alteration of flower morphology influences pollinator guild composition and foraging effort

The Greek horehound, Ballota acetabulosa (Lamiaceae), is an evergreen shrub native to Southeast Greece, Crete, and West Turkey, which attracts a diverse bee community to their dense patches of inflorescences. Flowers of this plant are bilateral, with filaments and styles located on the adaxial side or top of the flower. Bee different species have morphological adaptations to passively collect pollen from this type of flowers. Flowers also feature a nectar guide, which may serve to signal reward and guide the searching behavior of pollinators. To investigate how removal of the flower's nectar guide affects bee visitors, we conducted an experiment during two days (11−June and 12−June 2014) in two adjacent plots, one control plot and one experimental plot, on the island of Lesvos, Greece. Bee visitation, handling time per bee, and nectar flow per plant were measured during 30−minute trials that were timed at two−hour intervals on each day. Nine bee species visited our plots; however, honey (Apis mellifera) and leaf cutter bees (Megachile lefebvrei) were the most frequent visitors. The relative frequencies of bees differed among trials. Handling time per bee was similar during all trials, but also displayed high variance, suggesting that individual bees might have learned or that innate differences may exist between species. However, a comparison between the two common bee species on the plot revealed that the removal of the nectar guide significantly increased handling time for honey bees but not for leaf cutter bees. Our results support the hypothesis that nectar guides reduce searching behavior of bee foragers.

P2.31.5 CARTER, A.W. *; BOWDEN, R.M.; PAITZ, R.T.; Illinois State University; *afwilso@ilstu.edu*

Does sex vary with season via maternal estrogens when temperatures fluctuate?

Understanding how organisms cope with seasonal variation in temperature may help better predict how they might respond to future climatic change. This is particularly important for thermally sensitive species like reptiles with temperature−dependent sex determination (TSD), including the red−eared slider turtle (*Trachemys scripta*). Previous work has shown that incubation temperatures and estrogens act synergistically to produce females, with less estrogen needed for feminization as temperatures increase towards the pivotal temperature (Tpiv) where a 1:1 sex ratio is produced. We also know that levels of maternally derived yolk estrogens are higher in late season clutches relative to early season clutches, but how estrogens and temperature interact under naturalistic, fluctuating conditions is unknown. Can the Tpiv be modified by hormonal shifts acting as a mechanism through which species with TSD may respond to climate change? To address this question, *T. scripta* eggs were collected throughout the nesting season to sample both early and late season clutches. Eggs were incubated at one of three ecologically relevant regimes: 26.5±4, 27.1±4, 27.7±4 ÚC. These incubation regimes were selected based upon temperatures measured at our field site and a local long−term climatic database. In addition to determining sex ratios and levels of maternally derived estrogens, this project will characterize other phenotypic traits, like behavior, that may also be influenced by seasonal thermal or hormonal shifts. This research will enhance our understanding of the concomitant influences of estrogens and temperatures on TSD, and determine if the Tpiv varies seasonally, which may enhance conservation efforts of species with TSD.

P2.161 CARTER, A.L.*; DICKSON, K.A.; California State Univ., Fullerton; *arcarter@fullerton.edu*

Compressive strength of the Chorion of the California grunion, Leuresthes tenuis: effects of fertilization and extended incubation

California grunion spawn on sandy beaches during spring high tides. Embryos develop within the sand enclosed in the chorion, which must be strong enough to protect the embryo but also allow hatching. Grunion embryos are competent to hatch at 8 days post−fertilization (dpf) at 20°C, but require an environmental trigger, agitation by waves, to hatch. If the first spring high tides after fertilization do not reach them, embryos can extend incubation and hatch during a subsequent spring tide. We hypothesized that chorions of unfertilized grunion eggs would have lower compressive strength than chorions of fertilized eggs because of hardening of the chorion at fertilization, and that chorions would have higher compressive strength during normal incubation (10 dpf) than after extended incubation (28 dpf) due to degradation over time. Gametes were collected from adult grunion in March−July 2014. Eggs were fertilized, developing embryos were incubated in the laboratory at 20°C for up to 30 dpf, and compressive strength was measured with a Kistler force transducer. Our first hypothesis was refuted because mean compressive strength (N/m^2) either did not differ significantly between unfertilized and fertilized eggs (7 of 9 collection dates), or was significantly greater in unfertilized eggs (2 of 9 dates). Mean compressive strength was greater in chorions at 10 dpf than at 28 dpf in only some clutches of eggs. The values of crushing force measured in grunion are within the range for other species, including salmonids and plaice. The strength of grunion chorions apparently does not depend on hardening as a result of the cortical granule reaction at fertilization, and instead may be determined during oogenesis.

56.2 CASASA, S.*; KIJIMOTO, T.; MOCZEK, A.P.; Indiana University, Bloomington; *ascasasa@umail.iu.edu*

The role of the Insulin Signaling Pathway in mediating nutrition−responsive growth in the polyphenic beetle Onthophagus taurus

The developmental and genetic mechanisms underlying phenotypic plasticity and their contribution to evolution are of major interests to biologists. We are investigating the role of the insulin signaling pathway, known to link nutrition to growth in a wide range of organisms, in the ontogeny and evolution of polyphenic development in the beetle *Onthophagus taurus*. In this species males exhibit a nutrition−sensitive male dimorphism in which high nutrition results in fully horned fighter males, whereas development under low nutrition conditions result in hornless sneaker males. Using RNA interference−mediated gene knockdown we are investigating the role of two cardinal components of the insulin signaling pathway, the insulin receptor (which promotes cell proliferation when activated by insulin in the presence of high nutrition), and FOXO (a growth inhibitor downstream of the insulin receptor which is activated during nutrient stress). Results to date suggest that knockdown phenotypes of either gene depend strongly on the developmental timing of knockdowns. Phenotypes range from no effect to differential − and in part substantial − alterations of appendage size, and in particular decreased as well as increased horn growth relative to body size. Taken together, our results suggest that the insulin signaling pathway plays a key role in the regulating nutrition−dependent growth and horn polyphenism in *Onthophagus taurus* and possible many other taxa.

P3.183 CASASA, S.*; MOCZEK, A.P.; Indiana University, Bloomington; *ascasasa@umail.iu.edu*

Ancestral plasticity and its role in the rapid evolution of a polyphenic threshold in horned beetles

A longstanding goal in Evo−Devo is to better understand the role of phenotypic plasticity in evolutionary diversification. The dung beetle *Onthophagus taurus* exhibits a nutrition−sensitive male dimorphism in which high nutrition results in fully horned fighter males whereas development under low nutrition conditions result in hornless sneaker males. This species was introduced around fifty years ago from the Mediterranean to the US and to Western Australia (WA). Since then, the body size−horn size threshold has diverged rapidly and heritably between these two populations to a degree normally only observed between closely related species. Previous work suggests that threshold divergences evolved in response to vastly different levels of intra− and interspecific competition for breeding opportunities in both exotic ranges. At the same time, separate work failed to find plasticity for the size threshold in descendant WA populations. Here we test the hypothesis that ancestral Mediterranean populations did harbor plasticity in the expression threshold sizes in response to high and low competition levels and that this ancestral plasticity facilitated the subsequent evolution of canalized divergences between populations, resulting in the loss of plasticity in the descendant WA populations. We test this hypothesis by exposing F1 *O. taurus* reared from a Mediterranean population to high and low population densities, respectively, and test whether competition levels experienced by mothers, father, or both alters the threshold body size expressed by their male offspring. We discuss the implications of our results for our understanding of the role of phenotypic plasticity and genetic accommodation in developmental evolution.

31.3 CASTAñEDA, LE*; REZENDE, EL; SANTOS, M; Institute of Ecology and Biodiversity, Chile, University of Roehampton, UK, Universitat Autonoma de Barcelona, Spain; *lecastane@gmail.com*

High temperature tolerance in the introduced fly Drosophila subobscura: local adaptation phenotypic plasticity and global warming.

Current debates on species' global distribution patterns and susceptibility to increasing temperatures rest on the assumption that the potentiality for adaptive changes through plasticity or evolution in upper thermal limits. This assumes that the critical thermal maximum (CTmax) is the target of selection. Based on the fundamental idea that performance at high temperatures depends on both the temperature and time of exposure we illustrate that an effective increase in high temperature tolerance may or may not alter CTmax . We studied latitudinal variation in adult heat tolerance in *Drosophila subobscura* reared at two temperatures. We used four static stressful temperatures to estimate the thermal death time curves (TDT) and two ramping assays with fast and slow heating rates. The contrasting results between protocols are compatible with expectations derived from parameters estimated from the TDT curves. We found that an increased heat tolerance to less extreme temperatures in low latitude populations carried the cost of decreasing CTmax which resulted in a counterintuitive clinal pattern in CTmax. On the other hand plastic responses did not affect CTmax but heat tolerance to lower stressful temperatures increased with increasing developmental temperature. We conclude that researchers need to estimate TDT curves if we want to understand tolerance limits and thermal adaptation.

P1.2 CASTLEBERRY, AM*; ROARK, AM; Furman University; *alissa.castleberry@furman.edu*

Genetic fingerprinting of Aiptasia pallida via amplified fragment length polymorphism analysis

Amplified fragment length polymorphism (AFLP), a standard method for genetic fingerprinting, typically involves the use of radioactive isotopes. This technique can present financial and logistical challenges, as radioactive isotopes can be expensive and dangerous, especially in an undergraduate teaching laboratory. The goal of our research was to optimize a protocol for genetic fingerprinting different clone lines of pale anemones (*Aiptasia pallida*) that did not require the use of these radioactive isotopes. DNA from individual anemones was extracted and then digested with EcoRI and MseI restriction endonucleases. Adapters were then ligated to the cut sites, and DNA was amplified via nested PCR using EcoRI− and MseI−specific primers. In the second amplification step, EcoRI primers were labeled with fluorescent tags instead of radioactive isotopes. To analyze and compare the genetic fingerprints, the DNA was electrophoresed through 8% TBE polyacrylamide gels, which were photographed using a variable mode Typhoon Trio imager. The genetic fingerprints obtained using this method allowed us to distinguish genetically distinct clone lines from one another.

96.5 CASTRO, Y.S.*; UYENO, T.A.; Valdosta State University; *yscastro@valdosta.edu*

Production of sound by the white tubercled crayfish (Procambarus spiculifer)

In this study, we describe the production of sound by the white tubercled crayfish (*Procambarus spiculifer*). Despite the fact that much is known about the white tubercled crayfish's life history, broad distribution, freshwater stream habitats, and vital role in food webs, there has been no documentation of sound production. While some studies have described sound production in the Astacoidea, they include a limited number of species. Two of those mechanisms include abdominal stridulation (Murray River crayfish, *Eustacus armatus*) and a beating motion of scaphognathites (red swamp crayfish, *Procambarus clarkii*). While the mechanism of sound production by *Procambarus spiculifer* is still unknown, we were successful in recording the sounds they produce. These sounds were recorded by a piezoelectric hydrophone modified from an acoustic stringed instrument pickup. The sounds were digitally analyzed using WaverSurfer (waveform visualization, frequency and amplitude data) and Adobe Audition software (spectral and waveform analyses). *Procambarus spiculifer* produced sounds when physically manipulated by being held by the carapace and in the presence of conspecifics. The sounds these crayfish produced were high−pitched sounds that resemble chirps ranging from 3 kHz to 10 kHz. We are currently attempting to identify a mechanism for the production of sounds by performing gross dissections, stimulations, ligations and using high speed macrovideography of the abdomen, scaphognathites and various other functional body parts.

54.2 CATES, C. D. *; WARNER, D. A. ; The University of Alabama at Birmingham; *cdcates@uab.edu*

The adaptive significance of developmental plasticity in the wild: an experimental test using the brown anole lizard (Anolis sagrei)

The environmental conditions that embryos experience during development can have profound and long−lasting effects on offspring phenotypes. The hydric conditions of the incubation substrate are particularly important for reptiles with parchment−shelled eggs. Although several studies demonstrate that moisture availability positively affects water uptake by eggs and hatchling body size, few studies have mimicked conditions in the field. In this study, we incubated eggs of the brown anole (*Anolis sagrei*) under four conditions that mimic natural variation in substrate type and moisture. At our study site (islands in a saltwater estuary), eggs have been found in two substrate types (sand/broken shell mixture and dark organic soil) and likely experience a broad range of hydric conditions. To quantify the effects of this environmental variation, we incubated eggs in a 2x2 factorial design using both substrate types at two water potentials (−30 and −600 kPa). By incubating *A. sagrei* eggs under these different combinations of substrate types and water potentials, our results reveal relatively rapid water uptake and long incubation periods for eggs experiencing moist conditions, particularly for eggs in sand/broken shell substrate. Furthermore, incubation in moist conditions results in larger hatchlings with decreased desiccation tolerance. A subsequent release−recapture study on four islands that vary in their structural and thermal environments revealed that hatchlings incubated under dry conditions perform best, but only on harsh arid islands. Overall, this work demonstrates how natural environmental variation during early life stages can have critical impacts on variation in fitness−related phenotypes and survival of offspring.

54.4 CAVES, EM*; FRANK, TM; JOHNSEN, S; Duke University, Nova Southeastern University Oceanographic Center; *eleanor.caves@duke.edu*

Colorblind colorful animals: Spectral sensitivity, temporal resolution, and spatial resolution in three species of cleaner shrimp

Visual physiologies are diverse, and an organism's ability to perceive a visual signal depends on its sensory capabilities; as a result, visual biases in receivers influence phenotypic evolution in senders. Cleaner shrimp exhibit strikingly colorful phenotypes, often with fine patterns, which might function as signals during intraspecific interactions, such as mating and agonistic encounters. However, the extent to which pressure from conspecific viewers has influenced phenotype evolution in cleaner shrimp is unknown, as their visual capabilities are unstudied. We examined the visual systems of three cleaner shrimp species that differ in size, color, and geographic range (*Lysmata amboinensis, Ancylomenes pedersoni*, and *Urocaridella antonbruunii*). In each, we quantified spectral sensitivity and temporal resolution via electroretinography (ERG), and spatial resolution using an optomotor assay. Although many coastal decapod crustaceans are dichromatic, our study species were all monochromatic with peak spectral sensitivity near 510nm. Temporal resolution was 34−39Hz (dark adapted) and 39−48Hz (light adapted); these values are lower than predicted, given that cleaner shrimp live in high light environments. Spatial resolution was between 8.2° and 11.4°, low compared to similarly−sized insect compound eyes. Our ERG and optomotor results together suggest that cleaner shrimp cannot perceive the many colors, or resolve the intricate patterns, that comprise their own phenotypes, and thus that conspecific viewers have not played a primary role in the evolution of their appearance. Cleaner shrimp engage in mutualistic cleaning interactions with reef fish, many of which possess tri− and tetra−chromatic color vision and high spatial acuity, so shrimp phenotypes may have evolved to attract client fish.

S1.7 CESPEDES, Ann M.*; LAILVAUX, Simon P.; University of New Orleans; *acespede@uno.edu*

Simulating the evolution of maximal and optimal speeds

Maximal whole−organism performance traits measured in the laboratory and expressed levels of performance in the field often exhibit a mismatch, complicating our understanding of the selection pressures influencing the evolution of performance traits. To better understand the evolution of optimal performance traits, we built an individual−based simulation, based on empirical morphology−>performance relationships derived from an integrative, multivariate model of lizard locomotor performance over a wide range of morphospace and selective contexts, to test hypotheses about selection on locomotor performance. Starting with a population of individuals with morphological attributes determining maximal performance traits, we simulate these individuals surviving and reproducing in a complex environment, presenting each individual with successive ecological challenges requiring specific performance capabilities over their lifespan. While most challenges require sub−maximal speeds, intermittent bouts requiring increased performance capacities, such as predator escape, introduce strong, but infrequent selection for maximal performance. The phenotypes of progeny are then determined via a genetic variance−covariance (i.e. G−matrix) component, and individual fitness and subsequent phenotypic distribution over time result from combinations of trait heritability and differential selection. By comparing the results of simulations run with individuals that only perform at their maximum levels versus those that adjust this effort (and thus save energy), we can test if and under what conditions there exists a selective advantage for optimal speeds below maximum capacity. Ultimately, this model allows us to simulate the evolution of optimal movement speeds over a range of selective contexts, offering insight into the factors affecting the evolutionary relationship between optimal and maximum performance.

P2.147 CHA, A*; COTA, C.D.; DAVIDSON, B.J.; Swarthmore College; *acha1@swarthmore.edu*
Filamin contributes to polarized induction of heart progenitor cells in Ciona intestinalis
Matrix adhesion is intimately linked to developmental signaling and fate induction. Precise cellular mechanisms impacting inductive signaling downstream of adhesion, such as the contribution of cytoskeletal activity, remain unclear. The cellular and genetic simplicity of our model organism, *Ciona intestinalis,* allows us to study *in vivo* cellular processes driving early heart specification events. We have shown that heart progenitor induction requires Fibroblast Growth Factor (FGF) signaling and involves polarized distribution of FGF receptors (FGFR). Polarized receptor distribution is aided by adhesion and membrane−stabilizing Caveolin−rich domains. We have also demonstrated that cytoskeletal protrusive activity coordinates a differential response to uniform FGF. However, the precise mechanism underlying localized retention of FGFRs in the heart progenitor cells remains poorly understood. Here we investigate the potential contribution of a cytoskeletal protein, Filamin (FLN). FLN modulates Caveolin trafficking downstream of matrix adhesion and may thereby stabilize FGFR. To test this hypothesis, we expressed a dominant−negative form of FLN in the heart lineage. Targeted disruption of FLN function caused increased induction, indicating that FLN destabilizes FGFR by promoting internalization and membrane turnover. We are therefore investigating the effect of FLN disruption on receptor distribution. Future studies disrupting specific binding domains of FLN may elucidate the functional interaction responsible for increased induction. Our work has the potential to unravel the role of cytoskeleton in coordinating a localized response to uniform inductive signals.

44.4 CHADWELL, B.A.*; YOUNG, J.W.; NEOMED, OH; *bchadwell@neomed.edu*
Grasping, gait and arboreal stability in squirrel monkeys (Saimiri boliviensis)
The modulation of torque about arboreal supports is a critical component of stability for tree−living animals, particularly when moving on narrow branches. Within the primate literature, the combination of grasping hands and feet and diagonal gait patterns (i.e., pairing of contralateral fore/hind feet) is argued to promote stability by facilitating production and modulation of opposing torques about the support. In our continuing investigation into the determinants of primate arboreal stability, we test this hypothesis by presenting kinematic and kinetic data from two squirrel monkeys (*Saimiri boliviensis*) crossing either broad (5cm), intermediate (2.5cm) or narrow (1.25cm) diameter supports (n = 12 strides per substrate). Kinetic data were collected using a custom−built array of 6 force poles, permitting the measurement of both substrate reaction forces and torques about the support. For each stride we quantified torque production independently from the left− and right−limb pairs. Monkeys exclusively used diagonal sequence gaits across all substrates. During these strides, left and right limbs imparted torques that were equal in magnitude (p=0.62) but opposite in direction, such that each limb pair engendered torques that tended to push the animal centrally over the pole. Within each limb pair, the animals used their grasping extremities to generate active muscular torques that were equal in magnitude (p=0.10), but opposite in direction, to the substrate reaction torques generated passively during contact with the pole, thus mitigating total limb torque. These data suggest that grasping extremities, in combination with diagonally phased gaits, provide for two levels of torque cancelation − both within limbs and between limbs − ensuring low net torque across all supports.
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P3.124 CHALLENER, R.C.*; ROBBINS, L.L.; MCCLINTOCK, J.B.; Bellarmine University, Louisville, KY, U.S.G.S., St. Petersburg Coastal and Marine Center, FL, Univ. of Alabama at Birmingham; *rchallener@bellarmine.edu*
Carbonate chemistry in a shallow, seagrass−dominated ecosystem: implications for the sea urchin Lytechinus variegatus
Open ocean observations have shown that increasing levels of anthropogenically−derived atmospheric CO_2 are causing acidification of the world's oceans. Yet little is known about the carbonate chemistry of coastal areas where many ecologically and economically important organisms occur. We characterized the carbonate chemistry of seawater within an area dominated by seagrass beds (Eagle Harbor in Saint Joseph Bay, Florida), to determine the extent of variation in pH and pCO_2 that local organisms are currently experiencing over monthly and daily timescales. Distinct diurnal fluctuations were observed at both timescales, indicating the influence of photosynthetic and respiratory processes on the local carbonate chemistry. Over the course of a year, values of pH ranged from 7.36 − 8.28 whereas when sampled on a daily basis over the course of a week, the range in pH was 7.70 − 8.06. Laboratory experiments exposing *Lytechinus variegatus* to different levels of CO_2 indicate that delayed development and reduced somatic and reproductive production may already be occurring in individuals within the Harbor. The results of this study indicate that coastal species are experiencing far greater fluctuations in carbonate chemistry than previously thought. This has significant implications for the design of ocean acidification experiments in which nearshore species are utilized.

8.2 CHAMBERLAIN, J.D.*; GIFFORD, M.E.; University of Arkansas at Little Rock, University of Central Arkansas, Conway; *jdchamberlai@ualr.edu*
Variation in fat storage and mobilization among populations of watersnakes varying in prey size
Storage of fat and its subsequent mobilization in organisms often fuels important energetically−costly life−history functions. This is particularly true when individuals are unable to feed during the periods when energy is needed, such as mating and pregnancy. The extent of fat deposition may vary among populations depending on prey size, as this trait is an important determinant of the amount of energy available for storage. Additionally, males and females should differ in the timing and extent of fat deposition/mobilization as their energetic demands differ. To examine the effect of prey size and sex on fat deposition/mobilization we examined four populations of the diamond−backed watersnake (*Nerodia rhombifer*) at fish farms with variable fish sizes. Individuals from each population (8−10 of each sex) were sacrificed monthly over the course of two fields seasons (2013 and 2014). We measured the wet mass of fat bodies, liver, and gonads and compared seasonal differences in length−corrected weights among populations and sexes. Patterns of weight changes in these tissues corresponded with important annual life−history stages and appear to vary among populations and sexes. We suggest that these differences correlate with variation seen in other life−history traits among these populations.

P3.155 CHANG, J.J.*; CRALL, J.D.; COMBES, S.A.; Swarthmore College, Concord Field Station, Harvard University; *jjchang64@gmail.com*

Touching Down Head First: Landing Strategies of Bumblebees in Variable Flow

Flying insects regularly forage in complex, three dimensional environments in a wide range of wind conditions. This behavior necessitates a robust strategy for successfully tracking and landing on targets such as flowers in variable wind conditions. While general strategies for visually guided landing have been described in honeybees, the mechanical sequence of landing in bees and particularly the effects of wind speed on landing performance have received relatively little attention. Here, we study mechanical strategies for landing in 0, 1.5, and 3.0 m/s laminar and turbulent flow conditions. Using high−speed videography, we tracked landing behavior of Bumblebees (*Bombus impatiens*) using four calibrated high−speed cameras filming at 5000 frames per second. We quantified translational and rotational kinematics of the body as well as wing and leg motions from the time of approach until wings stopped beating. In agreement with work on landing behavior in flies, we found that all bees extended legs roughly 60−70 ms before touchdown. Surprisingly, we found that in low−speed trials, all bees contacted the flower first with either their head or antennae before the legs made contact with the flower. However, in high−speed flow trials it was more common for bees to first contact the flower with their legs rather their head or antennae. This suggests that in addition to preparing for landing, leg extension in bumblebees could serve a "bet−hedging" role, allowing bees to increase the potential contact area for landing. Overall, these results show that bumblebees use a landing strategy that is robust to variable flow conditions, which has important implications for understanding how flying insects navigate and land in challenging, variable flow.

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

Crowdsourced morphometric data are as accurate as traditionally collected data in 7 ray−finned fish families

Recent advances in phylogenomics and next−generation sequencing technologies made phylogenetic inference of large radiations of organisms possible. These large phylogenies have been successfully used in conjunction with existing comprehensive datasets to answer key questions about species diversification and morphological evolution. However, collecting large amounts of new phenotypic data has typically been bottlenecked by researcher availability and effort. For geometric morphometrics in particular, a single individual often collects shape data to reduce methodological measurement errors. Here we present a method and toolkit to efficiently collect two−dimensional geometric morphometric phenotypic data at a "phenomic" scale using workers recruited through Amazon Mechanical Turk. We examine inter−and intra−observer accuracy by assigning identical image sets and digitization protocols to experienced fish morphologists, undergraduates, and Amazon workers, and compare these data to a "gold standard" set of digitizations. Our results show that the quality of Amazon workers' data are not significantly different from results collected via traditional sources and thus are a viable resource to quickly and accurately collect large amounts of phenotypic data. We also have developed a pipeline that streams crowdsourced data from the web and can iteratively analyze and update results as new data arrive. We demonstrate this workflow by examining body shape evolution of 539 species in 7 families of ray−finned fishes (Acanthurid, Apogonidae, Balistoidae, Chaetodontidae, Labridae, Pomacentridae, and Tetraodontidae) and discuss the relationship between their diversity and phenotypic disparity.

40.3 CHARTERS, J*; CLEMENTE, C; HEINIGER, J; NIEHAUS, AC; WILSON, RS; The University of Queensland; *r.wilson@uq.edu.au*

Does individual quality mask the detection of performance trade−offs? A test using Australian northern quolls (Dasyurus hallucatus)

Trade−offs are thought to constrain the evolution of performance ability, via conflicts in the morphological or physiological bases of different traits. Excellence in a particular task should be associated with poorer performance in a task requiring an opposing design (i.e. functional trade−offs), or poorer performance across all other tasks (i.e. specialist−generalist trade−offs). Though trade−offs may be evident at the physiological level, relatively few studies have successfully identified them at the whole−animal level. Previous studies on humans have shown that accounting for variation in quality (i.e. overall ability across a range of tasks) among individuals can reveal otherwise−concealed performance trade−offs within individuals. In this study, we investigated performance trade−offs in wild northern quolls (*Dasyurus hallucatus*), a semi−arboreal marsupial carnivore, across 8 different ecologically−relevant tasks, including endurance, speed, agility, motor control, acceleration, jumping, grasping strength and biting force. We expected to find evidence of functional and specialist−generalist trade−offs, but only after accounting for differences in quality among individuals. Our study is the first non−human study to examine performance trade−offs in this way, and provides insight into the evolutionary basis of performance in a keystone predator.

P1.176 CHARTERS, J*; CLEMENTE, C; HEINIGER, J; AMIR ABDUL NASIR, A; CAMERON, SF; NIEHAUS, AC; WILSON, RS; The University of Queensland; *r.wilson@uq.edu.au*

Building the best sex addict: what are the morphological and performance bases of individual quality?

Every physical activity relies on a complex assortment of anatomical, physiological, motor and behavioural traits. Identifying how such traits combine to determine success is central to the study of adaptation. The concept of individual quality is often used in studies of ecology and evolution to describe those phenotypic traits that are correlated with fitness, but such a metric of quality is usually based on only a narrow range of possible underlying traits. In our study we used the world's largest semelparous mammal − the northern quoll (*Dasyurus hallucatus*) − to explore how morphology and performance relate to an individual's overall estimated general quality, which was based on a composite measure of 8 different metrics of performance. The northern quoll is a medium−sized (approx. 1 kg) predatory marsupial previously common across the entire top−end of Australia. The mating period of this species is highly synchronous, males live for only one year, and males undergo total die−offs soon after the mating season. Such population−wide male die−offs are most likely due to the physiological stress of procuring copulations and the intense fighting among males. Given the importance of procuring mates in such a short period (approx. 2 weeks), the ability for males to win fights and cover long distances to find reproductively mature females is presumably of critical importance. We assessed the running acceleration, sprint speed, jumping power, biting force, manoeuvrability, motor control, gripping strength and endurance for 63 individual quolls. In this poster, we will discuss how morphology and performance relates to an individuals overall measure of quality.

P3.76 CHEESMAN, S.C.*; SHAHBAZI, M.; CARRUTH, L.L.; Georgia State University; *lcarruth@gsu.edu*

Early Developmental Stress Reduces Neuron Number in HVC but not RA in the Male Zebra Finch Song Control System

Exposure to early life stress can alter many aspects of physiology and behavior across all life history stages, with the brain being particularly sensitive. Stress effects are mediated by the glucocorticoid corticosterone (Cort) via intracellular or membrane−bound glucocorticoid receptors (GR). In songbirds, such as the zebra finch (*Taeniopygia guttata*), song learning and production are controlled by four interconnected song control nuclei. GR are present in two of these nuclei, HVC (proper name) and RA (nucleus robustus arcopallii). Previously we demonstrated that exposure to chronic CORT treatment for over three weeks post−hatch resulted in reduced size of HVC but not RA in brains from juvenile and adult males, as measured in Nissl stained tissue. Experimental birds received a silastic Cort implant on post−hatch day four and controls received either an empty implant or were sham−treated. To further examine the reduction in HVC volume we have quantified the number of neurons in HVC and RA in order to determine if the decrease in HVC size resulted from a decrease in HVC neuron number. We found that males chronically treated with CORT during post−hatch had significantly fewer Nissl−stained neurons in HVC than control birds. There was no difference in RA neuron number between experimental and control birds. Cort−reduction in neuron number may be a specific mechanism by which HVC size and song quality are altered in developmentally stressed birds. Taken together, this suggests a potential role for Cort in mediating adverse effects of developmental stress in adult male zebra finches and highlights the developmental plasticity of the zebra finch brain.

60.3 CHEN, C.*; NEVELN, I. D.; MACIVER, M. A.; Northwestern University; *chen.bme@u.northwestern.edu*

Dynamic gain control of force for increasing stability and maneuverability

Antagonistic forces have been shown to lead to an increase in both stability and maneuverability. For example, weakly electric knifefish, which swim by undulating an elongated fin, produce two counter−propagating waves along the fin when swimming at low velocities. Changes in the location where these waves meet (called the nodal point) along the fin allow the fish to rapidly maneuver forward and backward. These fish are able to follow oscillations of a moving enclosure to remain hidden. We observe that the fish can track enclosure movements up to two hertz by rapidly shifting the nodal point, often at even higher frequencies. Experiments on a robotic ribbon fin show that as the frequency of the nodal point shift increases, the force amplitude also increases. In other words, the force gain can be increased through dynamic movements of the nodal point and could be useful when heightened maneuverability is needed. Also, the increased counteracting forces are able to better reject perturbations, leading to increased stability.

49.2 CHEN, C.W.; Auburn University; *czc0056@gmail.com*

The impact of maternal protein intake on offspring organ development in the house mouse (Mus musculus).

Based on studies in humans and lab rodents, it has been suggested that a mother's diet plays a central role in programming offspring organ development. As a result, offspring typically display improved health and performance when their adult diet matches the quality of the diet their mother consumed as they developed. Although this effect has important implications for the ability of wild populations to respond to changing environmental conditions, the relative importance of maternal programming in free−ranging animals is poorly understood. With this investigation, we evaluate plasticity of organ mass in the house mice (*Mus musculus*). Mice were maintained in enclosures designed to mimic the home range and group sizes of mice living in a barn or similar building. The parental generation of mice was maintained on 10% or 20% protein diet. A subset of young was euthanized at weaning and all additional young were kept on the same diet as their parents or switched to the alternate diet. Two additional sets of offspring were euthanized just before the onset of reproduction (56 d) and at 1 year of age. At each time period, body mass and masses of the liver, spleen, kidneys and abdominal fat pads were recorded for each individual. Our results suggest that maternal diet did not have a significant impact on organ mass at weaning. Just before onset of reproduction, the mass of the kidneys were greater in young in the high−high and low−high treatment than in the other two groups but no other effects were seen. At one year of age, we found no significant effects of treatment group on organ mass. These results suggest a mothers diet may have little impact on offspring organ development in wild populations, although this does not preclude the possibility that organ physiology differed between groups.

21.3 CHENEY, J A*; KONOW, N; MIDDLETON, K M; BREUER, K S; ROBERTS, T J; GIBLIN, E L; SWARTZ, S M; Brown University, Providence, RI, University of Missouri, Columbia; *Jorn_Cheney@Brown.edu*

Shaping the wings of bats: Muscle and wing skin interactions in flight

Bat wing membranes are extremely thin. Because of the structural slenderness of the membrane and its composition of compliant skin, it has little bending stiffness, which results in the wing membrane supporting aerodynamic load primarily through tension. To bear aerodynamic load through tension, the wing membrane deflects and its three−dimensional configuration changes, forming an aeroelastic coupling between membrane stiffness and aerodynamic force. This coupling can confer many potential benefits, but has the notable consequence that there is a limited range of aerodynamic conditions in which the membrane performs optimally. Bats possess an array of muscles that both originate and insert into the wing membrane that have been hypothesized to extend this range of optimal flight mechanics by modulating wing membrane stiffness. We measured the electromyogram of the plagiopatagiales proprii in flight in Jamaican fruit bats, *Artibeus jamaicensis*, at two flight speeds. We found that the muscles contract synchronously during downstroke, which is likely to maximize force production. Our results indicate that the coordinated function of the plagiopatagiales proprii may act to modulate wing stiffness in flight and therefore also three−dimensional wing form.

91.4 CHENG, B*; TOBALSKE, BW; WANG, Y; HEDRICK, TL; POWERS, DR; WETHINGTON, SM; DENG, X; Penn State Univ., Univ. of Montana, Purdue Univ., Univ. of N. Carolina, George Fox Univ., Hummingbird Monitoring Network, Purdue Univ,; *buc10@psu.edu*

Force Production and Flight Control of Hummingbird Escape Maneuvers

Hummingbirds are capable of a repertoire of aerobatic maneuvers that are unmatchable in both natural and man−made fliers. Within this repertoire, escape maneuvers are arguably the most unique in that they are characterized by rapid and large−angle rotations about all three body axes. This poses challenging flight control and stabilization problems that interest both biologists and engineers. Kinematic analyses show that hummingbirds are able to rapidly change the three degree−of−freedom wing motion on stroke−by−stroke basis, therefore equipped with extraordinary control authorities for flight control. In addition, hummingbirds also flare their tails to the maximum degree through the entire course of the escape maneuver. In this study, we investigate the force production from both wings and tails of hummingbirds from four different species and evaluate their flight stability and performance. It was found that, similar to insect flight, hummingbird flight is inherently unstable; however, a flared tail enhances the flight stability by producing counter torques, especially in hummingbird species with relatively large tails (e.g. magnificent hummingbird). Estimation of mass−specific power suggests that hummingbirds need to at least double their muscle power output in order to accomplish the escape maneuver. The results also suggest potential scaling effect in hummingbird flight, which can only be understood by integrating flight dynamics, muscle performance and neural control.

31.6 CHEVIRON, ZA*; ELOGIO, TS; LUI, MA; STORZ, JF; MCCLELLAND, GB; SCOTT, GR; University of Illinois, Urbana−Champaign, McMaster University, University of Nebraska, Lincoln; *cheviron@illinois.edu*

Functional genomics of adaptation to hypoxic cold stress in highland deer mice

In species that are distributed across steep elevational gradients, adaptive variation in physiological performance may be attributable to both transcriptional plasticity and canalization in underlying regulatory networks. We performed a series of common−garden experiments that were designed to elucidate the role of regulatory plasticity in evolutionary adaptation to hypoxic cold−stress in deer mice (*Peromyscus maniculatus*). Using a system−biology approach, we integrated genomic transcriptional profiles with assays of metabolic enzyme activities, tissue−level phenotypes, and measures of whole−animal thermogenic performance under hypoxia in highland (4350m) and lowland (430m) mice from three experimental groups: (1) wild−caught mice that were sampled at their native elevations; (2) wild−caught/lab−reared mice that were deacclimated to low−elevation conditions in a common−garden lab environment; and (3) the F1 progeny of deacclimated mice that were maintained under low−elevation common−garden conditions. Highland mice exhibited consistently greater thermogenic capacities than lowland mice, which was associated with enhanced oxidative fiber density and capillarity in skeletal muscle. Performance differences were also associated with greater activities of oxidative enzymes and both constitutive and plastic changes in the expression of transcriptional modules that influence hierarchical steps in the O_2 cascade, including tissue O_2 diffusion (angiogenesis) and tissue O_2 utilization (muscle fiber composition, metabolic fuel use, and cellular oxidative capacity). These results suggest that both regulatory plasticity and canalization make important contributions to physiological performance, but their relative contributions vary among steps in the O_2 transport cascade.

115.5 CHICOLI, A*; PALEY, D.A.; Univ. of Maryland, College Park; *achicoli@umd.edu*

Modeling the effect of group size on rheotactic behaviors

Many fish exhibit (positive) rheotaxis, a behavior in which fish orient upstream with respect to the flow. Rheotaxis may confer many potential benefits, including energetic cost savings and improved interception of downstream drifting prey. Despite the fact that many species school during at least some portion of their life, little is known about the importance of rheotactic behavior to schooling fish and how the presence of nearby conspecifics affects rheotactic behavior. Understanding how these behaviors are modified by social factors is thus of ecological importance. Here we present an all−to−all consensus framework over the space (the N−torus) of fish headings to model group rheotactic behavior in which individuals receive noisy information about the relative headings of their neighbors and the flow direction − in inverse proportion to the flow speed. Using tools from control theory, we study the effect of flow speed and group size on rheotactic performance and generate testable predictions of fish behavior. The anticipated contributions of this work are (1) the extension of an existing consensus model to include a reference direction and unbounded (Von mises) noise; (2) the comparison of a biological metric of consensus with one used in control theory; and (3) investigation of the influence of noise values, the number of agents and flow speed one achieving consensus to a reference (upstream) direction. In ongoing work, we are conducting laboratory experiments to test the effect of social information on rheotactic behavior. The results of this study may have implications for fish ecology, collective behavior and flow sensing.

P2.30 CHINTAMEN, S.H*; CALISI, R.M; KRIEGSFELD, L.J; ROSENBLUM, E.B; Univ. of California, Berkeley, Barnard College, Columbia University, Univ. of California, Berkeley, Univ. of California, Berkeley; *sana.chintamen@gmail.com*

Use it or Lose it: Neuroanatomical evolution in response to a changing environment

Our world is changing rapidly, and with it, so are its inhabitants. How do these rapid changes affect the brain's ability to help organisms navigate through new environments? We evaluated the effects of rapid environmental change on the brain using the Lesser Earless Lizard (*H. maculata*) as a model. We compared the medial cortex− a structure important for spatial navigation and spatial memory− of two populations living in adjacent yet physically distinct environments. Specifically, we asked whether differences in habitat complexity were associated with changes in corresponding neural structures. The first environment, the White Sands formation in southern New Mexico, exhibits markedly reduced physical and biological complexity relative to the surrounding dark soil habitat of the Chihuahuan desert. We found neuroanatomical differences between the two populations. Specifically, lizards in the less complex environment had smaller medial cortices in relation to overall brain size than those in the more complex environment, consistent with our expectation that reduction in medial cortex area is related to a reduced need for spatial navigation and spatial memory. In the more complex environment, males had larger medial cortices than females, also consistent with the fact that male lizards are often exposed to more habitat complexity than females. By integrating the fields of neurobiology, ecology and evolutionary biology, we have uncovered a mode of neuroanatomical selection in which organisms with less need for use of their medial cortex "lose it", or experience a reduction in the area it encompasses within the brain. Overall, our work demonstrates that environmental change can affect brain structure and these changes in neuroanatomy can occur rapidly.

P3.194 CHIONO, A.J.*; HOPKINS, S.S.B; PRICE, S.A.; Univ. of California, Davis, Univ. of Oregon; *ajchiono@ucdavis.edu*

Phylogeny and the Inference of Diet from Carnassial Shape across Carnivora

Traditionally, to infer diet from tooth morphology across Carnivora, three linear measurements on the lower carnassial are used. Unfortunately, these measurements lose much of their explanatory power when phylogeny is taken into account, which may generate problems when applied to distantly related fossils. We therefore investigate an alternative method for inferring diet using Geometric morphometrics. We examined 232 specimens from 125 extant terrestrial carnivorans and identified 4 homologous landmarks on the occlusal view of the lower carnassial. Landmarks were aligned using Generalized Procrustes Analysis and the mean shape calculated for each species. The main axes of shape variation represent two ways to achieve elongation, one found in feliforms and the other in caniforms. We estimated the multivariate phylogenetic signal within shape and used it to parameterize discriminant function analyses (DFA) to estimate how well shape predicts diet. The strength of the phylogenetic signal differs between sub−orders: feliforms exhibit a strong signal (K=0.9, p−value=0.001) while caniforms have a much weaker but still significant signal (K=0.3, p−value=0.001) compared to the null Brownian motion expectation (K=1). Using DFA to identify carnivores from omnivores we get 30−40% misclassification, but it drops significantly if the phylogeny is ignored for feliforms. We conclude that the inference of diet using landmark geometric morphometrics is influenced by phylogeny but the strength of the effect differs between the suborders: feliforms exhibit a very tight correlation between phylogeny, tooth shape and diet. We are therefore investigating whether the upper carnassial or tooth outlines will provide more reliable, phylogenetically−independent, estimates of diet across carnivorans.

70.5 CHIPMAN, AD*; STAHI, R; The Hebrew University; *ariel.chipman@huji.ac.il*

Blastodermal segmentation in the milkweed bug Oncopeltus fasciatus

The insect segmented body plan is conserved and stereotypical, but the embryonic processes leading to this body plan are variable. In long germ segmentation, best known from *Drosophila melanogaster*, a hierarchy of gene interactions results in the generation of all segments in the blastoderm. This derived mechanism is found in most holometabolous insects. Short germ (sequential) segmentation involves clock−like oscillations that produce most trunk segments post gastrulation. Sequential segmentation is ancestral, and is the predominant process in hemimetabolous insects. However, the segmentation process in most insects actually uses a mix of both mechanisms. The anterior−most segments are formed in the blastoderm, while the remaining segments appear sequentially from a growth zone, during the germ−band stage. In order to understand how long germ development evolved from the ancestral short germ pattern, we study the hemipteran *Oncopeltus fasciatus*, a species that displays intermediate germ segmentation, including a blastoderm stage similar to that of *Drosophila*, and a growth zone with sequential segmentation. We ask whether blastoderm segmentation in *Oncopeltus* is more similar to the sequential segmentation in its growth zone or to the simultaneous segmentation seen in *Drosophila*. Analysis of four segmentation genes: *engrailed*, *wingless*, *even−skipped* and *delta* during blastoderm stages of *Oncopeltus* show that blastoderm segments appear almost simultaneously. In addition, knocking down gap genes leads to loss of specific segments in the blastoderm. These results point to the fact that blastodermal segmentation in *Oncopeltus* is similar to the segmentation process in *Drosophila*, raising the possibility that *Drosophila* maintains the vestiges of an ancient process originally used only for anterior segments. This provides insights into the evolution of long−germ development.

P3.94 CHITTESTER, EB*; NEUMEYER, CH; COVI, JA; Univ. of North Carolina at Wilmington; *tebyn97@hotmail.com*

Effects of the fungicide, fenarimol, and insecticide, tebufenozide, on early development and hatching in the brine shrimp, Artemia franciscana.

Lipophilic insecticides and fungicides are carried in runoff from sites of application to aquatic environments where they come into contact with non−target invertebrates like zooplankton. Unfortunately, few studies assess the impact of these chemicals on early zooplankton development, and almost nothing is known about the effect of exposures during or immediately following periods of obligate dormancy. Because the life−cycles of most inland and estuarine zooplankton involve a dormant stage, it is important that management authorities understand the effect of anthropogenic chemicals on those life−stages. We used post−diapause cysts of the brine shrimp, *Artemia franciscana*, as a zooplankton model with which to test the effect of the common agricultural fungicide, fenarimol, and insecticide tebufenozide. Brine shrimp cysts were dechorionated and preincubated with fenarimol or tebufenozide for 24 h on ice prior to hatching at room temperature in the continued presence of the chemical. Tebufenozide had no effect on development, emergence from the first embryonic cuticle, or hatching of the nauplius larva. However, exposure to 1ug/ml fenarimol significantly slowed development, and delayed both emergence and hatching. Development was also delayed by preincubation with 1ug/ml fenarimol even if the embryos were subsequently washed and allowed to develop in a fenarimol free medium. This indicates that the embryonic cuticle of *A. franciscana* is permeable to the fungicide. It is important to note that an ecologically relevant concentration of fenarimol had no effect, and that this model is limited to assessing susceptibility when an embryonic cuticle is the only permeability barrier present.

9.3 CHMURA, HE*; KRAUSE, JS; PEREZ, JH; SWEET, SK; ASMUS, A; HUNT, KE; MEDDLE, SL; MCGUIGAN, MA; BOELMAN, NT; GOUGH, L; WINGFIELD, JC; UC Davis, Columbia U, UT Arlington, New England Aquarium, U Edinburgh; *hechmura@ucdavis.edu*

Reproductive success in the White−crowned sparrow (Zonotrichia leucophrys gambelii) and Lapland longspur (Calcarius lapponicus): Reproductive Timing and Implications for Global Change.

Birds breeding in the Arctic face a short window of time in which conditions favor reproduction. With a limited growing season and harsh weather restricting when nesting habitat and food resources are available, appropriate timing of nesting is thought to be important for reproductive success. The optimal timing of reproduction, however, may vary across years. Additionally, given the rapid pace of climate change in the Arctic, the optimal breeding season may shift dramatically across future decades. Understanding the connection between reproductive timing and reproductive success is critical to evaluating how arctic breeding species will fare as climate change continues to progress. To examine the relationship between spring phenology and reproductive success, we monitored nests in the shrub breeding White−crowned sparrow *(Z.l. gambelii)* and the open tundra breeding Lapland longspur *(Calcarius lapponicus)* near Toolik Lake Research Station, Alaska. Data were collected across three breeding seasons with divergent spring phenology from 2012 to 2014. Using a Bayesian statistical approach, we model daily survival rate and examine how nest microhabitat, phenology of food resources, and other factors relate to mortality from different sources including predation and starvation. We evaluate our findings in light of the future changes projected for arctic ecosystems.

P2.135 CHOW, MI*; LEMA, SC; Cal Poly, San Luis Obispo; *slema@calpoly.edu*

Iodothyronine deiodinase and thyroid hormone receptor gene expression in peripheral tissues varies among wild populations of a Death Valley pupfish

Environmental variation can impact patterns of gene expression and contribute to phenotypic differentiation among populations. Pupfishes (genus *Cyprinodon*) inhabiting the Death Valley region of California and Nevada, USA, occupy a collection of remote aquatic habitats that vary widely in ecological conditions. Previous work on these taxa has shown that exposure of pupfish to elevated temperatures (e.g., greater than ~30°C) during early life leads to altered body shape and a developmental loss of the paired pelvic fins, and pointed to such morphological changes as being related to altered thyroid hormone signaling. We therefore hypothesized that pupfish living in extreme thermal environments would exhibit altered patterns of thyroid hormone production, metabolism or tissue sensitivity. For this study, we collected Amargosa pupfish *Cyprinodon nevadensis amargosae* from two geographically isolated habitats in the Death Valley region: the Amargosa River, a thermally variable habitat, and Tecopa Bore, a hot spring and associated marsh where pupfish occupy waters exceeding 37°C. Gene expression related to thyroid hormone signaling was quantified in collected fish using quantitative real−time RT−PCR. Our data indicate that the relative abundance of gene transcripts encoding iodothyronine deiodinase enzymes type 1 (*dio1*), type 2 (*dio2*), and type 3 (*dio3*) in the gill epithelium are consistently elevated in both male and female pupfish from the hot spring habitat. Transcript encoding thyroid hormone receptor ±B (*tr±B*) was also found to be at higher relative levels in the gill of pupfish from the hot spring. These findings suggest that populations of pupfish occupying habitats with distinct thermal profiles may show divergent gene expression patterns for deiodinase enzymes and thyroid hormone receptors.

P2.181 CHRISTIANSON, K.M.*; DITSCHE, P.; Univ. of Washington; *kel.christianson@gmail.com*

Super Suckers: The Role of Suction in Chiton Attachment

In a marine environment, attachment to substrate is vital to the success of many invertebrates, particularly those in the intertidal. Wave action, tidal flow, and predation are challenges that these organisms combat through a variety of mechanisms. Among these are attachment mechanisms, which help the animals stay in place. Chitons belong to the phylum Mollusca, which often use a mixture of suction and glue to attach to a substrate. In 1911 and 1916, G.H. Parker laid the groundwork for the study of chiton attachment forces. He made the assumption that chiton attachment "depends almost exclusively upon suction". However, his observations did not involve formal testing, which left the questions of how and with how much force chitons attach to a substrate virtually unexplored. In this study we measured the attachment forces of the chiton species *Mopalia muscosa*. In order to investigate the contribution of suction specimens were allowed to attach to substrates with and without perforation. Perforation in the substrate inhibited the chiton's use of suction. We were also interested in the impact of surface roughness on chiton attachment. Therefore, we performed the same experiment using substrates of three different grades of roughness: smooth, grain size of 0.267mm, and grain size of 1−2mm. On solid smooth substrates and substrates with a grain size of 0.267mm, *M. muscosa* attached with tenacities of 21 and 22 kPa, respectively, while tenacity upon the roughest surface was much lower (10kPa). On the perforated substrates, we found a significant decrease in tenacity, with only 30% and 50% of the tenacity depending on roughness. Our results show that suction plays a significant role in chiton attachment. Furthermore, the surface roughness of the substrate has a significant effect on total attachment force in chitons. Beside suction, other attachment mechanisms such as glue seem to play an important role.

P3.2 CIERI, R.L.*; HUTTENLOCKER, A.K.; FARMER, C.G.; University of Utah; *bob.cieri@gmail.com*

Traveling tactile toolboxes for teaching evolutionary biology to blind students

Blind and visually impaired K−12 children are an underserved group in terms of science education. Although they are often enrolled in traditional education systems, lack of teacher training and resources often limit the opportunities these children have to experience the wonder and joy of science. To help create opportunities for blind students to appreciate the diversity of structure and function in the natural world, we are generating traveling toolboxes focused around different themes, containing 3−D, tactile materials paired with relief graphs and tables, as well as printed braille and sound−recorded discussions that expose students to biological designs. The first two boxes, refined from feedback by blind students at multiple stages of design, will be housed at the Natural History Museum of Utah and distributed to Utah public schools in the spring of 2015. One toolbox, designed for students in high school, includes models of Galapagos fauna and relates to natural selection and conservation biology, and another, designed for middle school, includes model primate skeletal material relevant to human evolution. Discussions reflect current best pedagogical practice, and question the students to come up with their own ideas instead of simply hearing the "right" answer. Discussions can be modified to be applicable to multiple grand bands. Testing shows that students were enthusiastic to have teaching elements that they could touch, and generated insightful questions from the discussion and tactile observations of the materials. The scope of this project may be increased with more tactile kits, kits that focus on other non−visual senses, or by creation of an online database where scientists and educators can generate teaching materials for the blind relevant to their expertise, interests, and needs.

P3.200 CLARDY, T; Virginia Institute of Marine Science; *tclardy@vims.edu*

Lateral line canals of the pricklebacks (Cottiformes: Zoarcoidei: Stichaeidae)

The mechanosensory lateral line system is a unique sensory system in fishes and some aquatic amphibians used for the detection of water flow. The anatomy and complexity of lateral line canals on the head (cephalic canals) and body (trunk canals) varies greatly across teleostean fishes. Multiple lateral line canals on the trunk are uncommon in teleostean fishes and are found in representatives of only fifteen families. The family Stichaeidae, commonly known as pricklebacks, is the second most species−rich family of the Cottiformes suborder Zoarcoidei, comprising 38 genera and 80 species of intertidal and nearshore marine fishes distributed in the North Pacific, Arctic, and North Atlantic Oceans. Cephalic and trunk lateral line canal patterns vary greatly within the family. Some stichaeid genera lack trunk lateral line canals, others have a single canal in a form that is typical of most teleostean fishes, and other genera feature well developed cephalic canals and multiple, highly complex trunk canals. In some genera, canals are supported by small, dermal, ring−like ossifications. In this study, I illustrate and compare the mechanosensory systems of twelve stichaeid genera, spanning the range of lateral line patterns within the family. Fractal dimension (D) is used to quantify the complexity of canal patterns within the family. The complexity of lateral line canals ranges from a D of 0.98 in *Dictyosoma burgeri*, which has a reduced canal network, to D of 1.57 in *Phytichthys chirus*, which has a complex cephalic network and four highly branched trunk canals. Finally, lateral line patterns are mapped onto a cladogram of Zoarcoidei to discuss the evolution of the mechanosensory system within the group. Multiple lateral line systems appear to have evolved at least twice within Zoarcoidei.

92.5 CLARK, CJ*; KIRSCHEL, A; HADJIOANNOU, L; PRUM, R; UC Riverside, University of Cyprus, Yale University; *cclark@ucr.edu*

Cryptic flutter produces klaxon−like wing song in Smithornis broadbills

Broadbills in the genus *Smithornis* produce a loud breeet, a klaxon−like song that has been hypothesized to be non−vocal. The sound is only produced during a distinctive flight display, in which the male flies in a tight circle, returning to his point of origin. Although most birds that produce non−vocal communication sounds also have feathers distinctively modified for sound production, *Smithornis* broadbills do not. We investigated the mechanism of sound production of Rufous−sided Broadbill (S. rufolateralis) and African Broadbill (S. capensis). Synchronized high−speed video and sound recordings of displays demonstrated that pulses of sound were produced during the downstroke, that the wingtip speed reached approximately 15.7 m s−1, and that during downstroke, subtle gaps sometimes appear between the outer primaries feathers P6−P10 (P10 is outermost). Tests of a whole spread wing in a wind tunnel at speeds above 15.8 m s−1 demonstrated that at specific orientations, P6 and P7 both may flutter and produce sound. Tests on individual feathers P5 − P10 from males each species reveal that all of these feathers may produce sound via aeroelastic flutter, but that P6 and P7 produce the loudest sounds most similar to the wing song, and at the lowest airspeeds. Field manipulations of P6 and P7 provided consistent results with changes in the timbre of the sound, and specifically a reduction in the tonal quality. Altogether these results demonstrate that P6 and P7 are the sound source. *Smithornis* have evolved reduced syringeal complexity as the primitive vocal song was replaced by a functionally equivalent wing song.

P2.202 CLARK, S. M.*; ROBERTSON, J.; Westminster College, PA; *clarsm22@westminster.edu*

The Effect of a Sub−Lethal Concentration of Rotenone on Neuromast Density in Mexican Blind Cave Fish, Astyanax mexicanus

The sensory unit of the lateral line system of fishes is the neuromast, an organ containing hair cells that detect mechanical stimuli in the environment. This mechanosensory system contributes significantly to food acquisition, predator avoidance, navigation and social interactions in different fish species. Lacking functional eyes, Mexican cave fish (Astyanax mexicanus) have a particularly well−developed lateral line system. The superficial disposition of neuromasts affords ready exposure to water borne chemical agents. For example, homology between lateral line hair cells and mammalian inner ear hair cells has led to use of cave fish as a model system in chemical ototoxicity studies. Rotenone is a plant−derived insecticide and piscicide that acts as a mitochondrial electron transport inhibitor; it is widely used in insect control and fish population management. In mammals, directed oxidative damage to dopaminergic neurons suggests a link between low levels of rotenone exposure and Parkinson's disease. This study examines the effects of sub−lethal rotenone treatment on the neuromasts of the cave fish. Treatment groups were exposed to either low volumes of vehicle ethanol (controls) or 0.1 mg/L rotenone for up to 18 hours. Fish were then stained with the fluorescent mitochondrial marker DASPEI and neuromasts were imaged using fluorescence microscopy. Analysis of results focuses on comparisons of location−specific counts of neuromasts and assessment of hair cell integrity. I predict that increased time of rotenone treatment will be associated with a decrease in the number of viable neuromasts. Results of this work may contribute to a better appreciation of the physiological and cellular consequences associated with exposure to low levels of rotenone in an aquatic vertebrate.

79.1 CLARK, AJ*; CRAWFORD, CH; KING, BD; DEMAS, AM; UYENO, TA; College of Charleston, Valdosta State University ; *clarkaj@cofc.edu*

Material properties of hagfish skin with insights into knotting behaviors

Hagfish use coordinated head and body knotting movements to dismember large carcasses into ingestible items. When feeding, keratinous teeth protrude from the mouth and contact the food surface while a body knot, formed at the tail, slides towards the head and pushes against the food surface surrounding the area in contact with the dentition. In these situations, the body knot creates a stable platform and an ad hoc lever for tooth movements. We propose that knotting in hagfishes might be facilitated by the absence of vertebrae, a complex arrangement of axial musculature, and loose skin. Between the axial muscles and the hagfish skin is a large blood−filled subdermal sinus devoid of the intricate myoseptal tendon networks characteristic to the taut−fitting skins of other fishes. This morphology raises the assumption that hagfish skin is ineffective at transmitting forces generated by axial muscles to the surrounding water, rendering hagfish skin a poor external tendon. Results from quasi−static uniaxial tensile tests to failure on fresh skin samples from specimens of Pacific hagfish, sea lamprey, and penpoint gunnel show that hagfish skin is as strong and stiff as the taught skins of more evolutionarily derived fishes, and is 60% stiffer and 20% stronger in the axial orientation relative to the hoop orientation. These anisotropic properties violate Laplace's law (by which hoop stress should be twice that of axial stress) suggesting that the body of a hagfish is not a thin−walled pressurized cylinder, and thus does not function like an external tendon. Instead, the subdermal sinus encased between loose skin and axial musculature could be functionally important during knotting when large associated axial strains could impose damaging levels of tension in the skin.

96.4 CLARK, BJ; HUCKANS, JH*; IBRAHIM, GT; HRANITZ, JM; Bloomsburg University of Pennsylvania; *jhranitz@bloomu.edu*

Intensity modulation in toad calls scales inversely with body size: are large males ending on a good note?

The ability to distinguish fundamental frequency from resonant frequency in vertebrates with tubular vocal tracts essentially eliminated dominant frequency as a proxy for resonant frequency in birds and mammals. Many studies have since shown that fundamental frequency and resonant frequency convey important different information to signal receivers. Anurans lack a tubular vocal tract, making this differentiation difficult. Thus, anuran call analysis still relies on dominant frequency. Interestingly, intensity modulation of dominant frequency in anurans is common, for example, in Fowler's Toads (*Anaxyrus fowerli*). While physiological hypotheses abound, we propose a biomechanical association with small body size as another explanation of intensity modulation. We analyzed male advertisement calls to disambiguate fundamental and resonance frequencies of *A. fowleri*. The observed shift in fundamental frequency helped to identify resonant frequency. Since the fundamental frequency was also heavily amplitude−modulated, intensity changes of the upper and lower sidebands were used to completely scan the entire resonance. Using a Helmholtz model, the resonant frequency and quality factor were extracted. *A. fowleri* exhibited distinct fundamental and resonant frequencies whose close proximity contributed to low spectral flatness. A comparison of mainland versus dwarf island toads suggest that resonant frequency is inversely correlated with head width and that fundamental frequency is inversely correlated with snout−vent length. These previously undetected characteristics of advertisement calls impact the interpretation of intensity modulation in anurans as static versus dynamic call trait.

6.4 CLAY, T.C.*; PETERMAN, W.E.; GIFFORD, M.E.; University of Arkansas at Little Rock, Illinois Natural History Survey, Champaign, University of Central Arkansas, Conway; *taclay@ualr.edu*

Physiological and fitness consequences of embryonic rearing environment among populations of post−metamorphic wood frogs, Lithobates sylvatica

Early ontogenetic stages can have lasting effects on future stages. It is important to quantify the magnitude and nature of carry−over effects within a species before making broad generalizations among species. We examined how experimental pond drying affected post−metamorphic morphology, physiology, and performance in wood frogs, *Lithobates sylvatica*. In addition, we tested if populations differed in their response to pond drying. Initial mass, limb−length, snout−vent length, and resting metabolic rate were measured on newly metamorphed frogs. Juveniles were then reared with ad−libitum food for 7 weeks to measure growth rate. Larval treatment induced differences in limb length with individuals in the drying treatment having longer limbs upon completion of metamorphosis. Postmetamorphic frogs differed by population in initial mass, snout−vent length, jumping performance, swimming performance, resting metabolic rate, and growth rate. Our study suggests that population, and not larval conditions, has a greater influence on the post−metamorphic phenotype and performance. Furthermore, despite population level differences, our study suggests that populations respond similarly to larval rearing conditions.

P1.167 CLEMENTE, C*; WILSON, RS; The University of Queensland; *r.wilson@uq.edu.au*

Using dynamic computer games to explore the evolution of prey escape speeds

The interaction between predators and their prey represents the classic evolutionary arms race − any improvements in predator performance that make prey capture more likely should be countered by improvements in prey escape abilities. In this study, we tested the prediction that the evolution of prey speed depends on the energetic costs associated with their capture by a predator. We developed a dynamic computer game to quantify the rate and direction of evolutionary change in prey escape speeds. We asked humans (i.e. predators; N=150) to capture as many uniformly sized dots (i.e. prey; N=100) as possible as they moved singly across a computer screen. Prey speed varied up to four−fold among individuals and they were captured by clicking on them with a mouse. Surviving prey then reproduced (3 clonal offspring each), and a new generation of 100 individuals was sourced at random from these offspring. This was repeated for six generations. Human subjects were randomly assigned into one of 3 treatments, representing low, moderate and high costs associated with prey capture. Subjects were asked to maximize energetic gains, taking into account that each successfully captured prey earned 10 energy units, while each attempt to capture prey (successful or not) cost 1, 2 or 5 energy units, depending on treatment group. We expected that if the costs of prey capture were low, then prey would be captured across all speeds and the evolution of prey speeds would slower and less directional. However, if the costs of prey capture were high, then only the slowest prey within a population would be captured, promoting directional and rapid selection of prey speed. After six generations , we were able to determine how the average and frequency distribution of prey speed within a population evolved in response to the costs of prey capture.

S1.4 CLEMENTE, C J *; WYNN, M L; AMIR ABDUL NASIR, A F; HUDSON, M G; WILSON, R S; University of Queensland; *c.clemente@uq.edu.au*

Balancing biomechanical constraints when selecting movement speeds in natural environments.

Even during extreme fitness−defining behaviours like running away from predators, an animal should select a speed that balances the benefits of high speeds against the probability of mistakes. In my talk I will explore this theme by quantifying trade−offs between speed, maneuverability and motor control in two groups of animals; wild northern quolls (*Dasyurus hallucatus*) and Australian water dragons (*Intellagama lesueurii*). Across both animals with different locomotor styles, we found that the faster an individual approached a turn the higher the probability that they would crash and these risks were greater when negotiating tighter turns. To avoid crashes, animals modulated their running speed when they moved through turns of varying angles. Average speed for quolls when sprinting along a straight path was around 4.5 m/s but this decreased around tighter corners to speeds of around 1.5 m/s when running through 135 degree turns. I will also discuss how bipedal vs quadrupedal locomotion affects the turning ability of lizards that transition between these two locomotor forms. As the selection of an optimal movement speed must balance the relative cost and benefit of speed and maneuverability, it is also crucial that we have an understanding of how these two performance traits independently translate to fitness. During the third part of my talk, I will present data from a simple tablet−based game using human subjects, that provides a quantitative description for the relationship between speed and maneuverability with fitness. Taken together, our work reveals that animals must balance the competing demands of speed, maneuverability and control when selecting running speeds, and that the optimal choice will also depend on the relative importance of these performance traits with fitness.

45.2 CLEMENTS, LAJ*; STALKER, JC; WENK, L; Jacksonville University, Jacksonville, FL; *lclemen@ju.edu*

Ocean Acidification and Arm Regeneration in the Burrowing Brittle Star Ophiophragmus filograneus

Environmental perturbations, both natural and man−made have consequences on the growth, behavior and ecology of marine organisms. Ocean acidification is a consequence of elevated atmospheric CO_2 and may impact the calcification and growth of shallow sub−tidal benthic invertebrates. This experiment shows the effect of two levels of increased CO_2 on the regeneration of brittle star limbs. Three CO_2 levels (control, elevated and high) resulted in pH differences in aquaria−based treatments: control CO_2 pH ~8, elevated CO_2 pH ~7.5, and high CO_2 pH ~7. These pH levels reflect those reported by IPCC estimates. Ten brittle stars, each with one arm surgically removed, were placed in each of nine aquaria in a Latin square design. Temperature, salinity, pH levels, dissolved oxygen, and CO_2 pressure were monitored daily and animals were fed every third day. After one month, the dry weight and ash free dry weight of regenerated and non−regenerated portions of each individual were determined. Increased acidity and CO_2 levels resulted in increased in arm regeneration and a decrease in overall body mass. *Ophiophragmus filograneus* are able to utilize the additional CO_2 despite the decrease in pH, but there appears to be a metabolic cost which decreases overall body mass.

95.4 CLEMMENSEN, S.F.*; HULSEY, C.D.; University of Tennessee; *sclemmen@vols.utk.edu*
Morphological convergence in durophagous Heroine cichlids
Trophic divergence in cichlid fish is linked to shifts in pharyngeal jaw morphology. For instance, in the Heroine cichlids of Central America, the ability to crush hard−shelled mollusks is a convergent phenotype with multiple evolutionary origins. These durophagous species often have very similar pharyngeal jaw morphologies associated with the pharyngeal jaw apparatus and some of these similarities could be due to phenotypically plastic responses to mechanical stress. We examined both bone and soft tissue differences between durophagous and non−durophagous Heroine cichlids and compared them to phenotypically plasticity morphologies induced through diet manipulations to determine the degree to which convergent morphologies in durophagous cichlids were likely due to phenotypic plasticity.

P3.187 CLIFTON, GT*; CARR, JA; Concord Field Station, Harvard U., Bedford, MA, CFS, Harvard U., Bedford, MA; *glenna.clifton@gmail.com*
Hindlimb muscle anatomy of foot−propelled swimming birds
Within the great diversity of birds, numerous lineages have colonized aquatic environments. Birds that swim using their feet face opposing constraints for locomotion on land versus through water. On land, birds require powerful muscles to produce large ground reaction forces and must position their feet for body stability. On the surface or underwater, the production of hydrodynamic forces does not solely rely on muscle power, but also on foot shape and velocity. A swimming animal's limb orientation is not constrained by terrestrial stability, but contributes to body drag. Due to these differing conditions, we expect hindlimb musculoskeletal morphology to vary with the degree of aquatic specialization. To examine this, we have dissected the hindlimbs of birds ranging from completely terrestrial to highly aquatic: Helmeted guinea fowl (*Numida meleagris*), Mallard (*Anas platyrhychos*), Canada goose (*Branta canadensis*), Mute Swan (*Cygnus olor*), Double−crested cormorant (*Phalacrocorax auritus*), Western grebe (*Aechmophorus occidentalis*), Red−throated loon (*Gavia stellata*), and Common loon (*Gavia immer*). We find that specialized swimming and running birds have equally muscular hindlimbs compared to surface swimming waterfowl (7% vs. 4% body mass). The distribution of hindlimb muscle mass shifts distally with increased swimming ability: from 40% distal in guinea fowl and mallards to 70% in grebes and loons. Most specialized swimmers have exceptionally large gastrocnemius muscles and digital flexors, with long fibers and a low degree of pennation. Cormorants, however, do not show the same trend. Since, many of these groups have evolved foot−propelled swimming independently, these observed trends in hindlimb morphology might represent different anatomical strategies for swimming in foot−propelled birds.

P1.194 CLIFTON, IT*; GIFFORD, ME; University of Central Arkansas, Conway; *iclifton1@uca.edu*
Genetic variation in head shape within and among populations of Nerodia rhombifer
Organisms occurring in different areas are exposed to different environmental pressures often causing variation in some trait or suite of traits. Throughout Arkansas diamondback watersnakes (*Nerodia rhombifer*) occur in natural areas and at fish farms. These snakes are frequently found in large densities on fish farms because of the high food abundance. Fish farms provide an ideal system for the study of morphological variation because the size of fish available as prey varies from farm to farm. Because snakes are gape−limited predators they can only consume prey items that are small enough to be swallowed whole. Therefore, snakes with large heads should be able to swallow larger prey than snakes with smaller heads. Given enough time it is possible that different populations would diverge in morphological traits in such a way that head size is best suited to the prey that is available to them. However, for this to happen the variation must be heritable. To determine the degree to which head shape is heritable we measured three cranial traits on offspring from more than 100 litters (~30 from each population). We estimated quantitative genetic parameters using a full sib design. All cranial measurements are significantly heritable although some variation exists among cranial elements and among popualtions.

34.3 COCKREM, J.F.; Massey University, Palmerston North; *j.f.cockrem@massey.ac.nz*
Individual variation in corticosterone responses and adaptability to environmental change in birds
Birds, like other animals, live in complex environments that can change at any time. When stimuli from the external environment are perceived to be a threat or potential threat then a stress response is initiated and corticosterone is secreted. There is considerable individual variation in corticosterone responses, and a stimulus that initiates a large response in one bird may initiate a small response in another bird. For example, peak corticosterone responses to capture and handling were 15 times higher in some birds than others in a study of little penguins (Eudyptula minor) in New Zealand. Corticosterone responses and behavioural responses to environmental stimuli are together determined by individual characteristics called personality. Birds with low corticosterone responses and proactive personalities are likely to be more successful (have greater fitness) in constant or predictable conditions, whilst birds with reactive personalities and high corticosterone responses will be more successful in changing or unpredictable conditions. It is proposed that birds with reactive personalities and high corticosterone responses will be better able to cope with environmental changes due to climate change than birds with proactive personalities and relatively low corticosterone responses. Phenotypic plasticity in corticosterone responses can be quantified using a reaction norm approach, and reaction norms can be used to determine the degree of plasticity in corticosterone responses of individual birds, and mean levels of plasticity in responses of species of birds. Reaction norms for corticosterone responses can in future be used to help predict the ability of birds to cope with environmental changes due to climate change.

P2.62 COGLEY, T.R.*; TEETS, N.M.; MORGAN, T.J.; HAHN, D.A.; Univ. of Florida, Kansas State Univ.; *trcogley@ufl.edu*
Survival of the Coldest: Developing methods to quantify autophagy during cold hardening in Drosophila melanogaster
Rapid cold hardening (RCH) is a form of adaptive plasticity that allows insects to improve their cold tolerance in a short period of time (i.e. minutes to hours). RCH allows an organism to cope with sudden cold snaps and diurnal thermal cycles, which is especially important as thermal variability is projected to increase with climate change. Recent genetic evidence suggests that autophagy, a cell recycling process that breaks down damaged organelles and macromolecules, is involved in RCH. However, the physiological role of autophagy during RCH has not been examined. The objective of our study is to develop methods for quantifying autophagy during RCH in the common fruit fly, *Drosophila melanogaster*. Activation of cellular autophagy can be visualized with LysoTracker Red DND−99, a fluorescent dye that stains acidic lysosomic and autophagic vesicles. While this dye is commonly used as a qualitative marker of on/off autophagic processes in *D. melanogaster*, a reliable method to quantify autophagy across tissue types has not been developed. Here we optimize protocols to measure levels of autophagy in response to RCH and other stressors. Preliminary results indicate a significant increase in LysoTracker staining in the adult midgut in response to RCH followed by a brief cold shock, and current experiments are underway to expand these results to additional tissues and treatment conditions. Combining these protocols with genetic tools for studying autophagy in *D. melanogaster*, we will be able to further our understanding of the physiological processes that govern rapid adaptive plasticity to cold and other extreme conditions.

44.5 COLE, K.*; MCGOWAN, C.P.; Univ. of Idaho; *cole2839@vandals.uidaho.edu*
How Kangaroo Rats Achieve Speed Increases over Uneven Terrain
The natural terrain of kangaroo rats is mainly comprised of sparse scrub across uneven desert hills. It is thought that these animals hop from scrub to scrub, requiring the ability to quickly accelerate while moving across uneven ground. Preliminary studies have suggested that kangaroo rats mainly increase speed via an increase in force production (decreased contact time) with relatively little change in contact length or hop frequency. Additionally, it appears that this pattern is maintained when hopping on an inclined plane. This increase in force production that results in an increase of speed has also been seen in humans, and could provide insightful correlations between human running and kangaroo rat hopping. Kangaroo rats were recorded while hopping on a treadmill at four set speed increments ranging from 1.64 m/s to 2.01 m/s over level, ten, and twenty degree incline. Their gait was then analyzed to determine the methods used to achieve speed increases on level and inclined terrain. Our results show that there is a significant difference between speed for contact time and peak ground reaction force, indicating that the kangaroo rats do alter the amount of force produced during a step cycle in order to increase their speed. Level hopping also resulted in a much higher stride frequency than the other inclines. Based on these results, it appears that kangaroo rat hopping mechanics are similar to those of human running.

P2.153 COLELLA, G.E.*; ROBERTSON, J.C.; Westminster College; *gcolella729@gmail.com*
Neuromast density and eye degeneration in developing blind cave tetra, Astyanax mexicanus
The "eyeless" or " blind" cave fish *Astyanax mexicanus* is a species of teleost adapted to the low−light conditions of their native cave environments in Mexico. One sensory adaptation of these fish is an extensive and well−defined lateral line system, thought to enhance sensitivity to water−borne mechanical stimuli. In early ontogeny, cave fish do possess rudimentary eyes, but over the course of development, eye degeneration occurs in parallel with maturation of the lateral line mechanosensory organs. This study explores the developmental intersection of these two different adaptive sensory programs. My goal was to correlate the developmental loss of visual status by looking to identify critical points in time where the logistic degeneration of cave tetra eyes and advancing logistic growth of neuromasts correlate with one another over developmental time. To correlate eye degeneration versus mechanosensory capacity in post−hatch cave fish, DASPI−labeled superficial lateral line neuromasts at discrete opercular and orbital locations were imaged using fluorescent microscopy. Neuromast densities were then compared to measures of eye size in the same fish. Logistic analysis of results showed that cave tetras express inverse exponential rates of eye degeneration and neuromast formation as fish became larger in length. Neuromasts appeared to be in initial stages of reaching maximum densities in the size classes of fish used in this study, suggesting that when eye degeneration was complete, neuromast densities cease advancement in response. It is thought that this pattern could be due to biological processes such as genetic pleiotropy. Quadratic polynomial analysis also suggests that orbital neuromasts develop earlier in developmental time than operculum neuromasts, suggesting that separate developmental processes may code each neuromast collection.

7.3 COLLAR, DC*; WARD, AB; MEHTA, RS; Univ. of Massachusetts, Boston, Adelphi University, Univ. of California, Santa Cruz; *dccollar@gmail.com*
Anatomical basis of body shape diversification in labyrinth fishes
Body elongation is one of the most prominent axes of morphological diversity in vertebrates, especially bony fishes. Elongation is known to occur by reducing the secondary body axis (depth or width), increasing the length of the precaudal or caudal vertebral regions, or increasing the relative length of the head. However, it is not known whether some body regions change more often than others or what suites of anatomical changes underlie major shifts in elongation. In this study, we quantify the contribution of four anatomical components to diversification of body shape in 23 species of labyrinth fishes (Anabantoidei), a clade of Old World freshwater teleosts that range from deep−bodied to torpedo−like forms. We found that two major subclades Anabantidae and Osphronemidae overlap broadly in overall body shape and that this variation is a consequence of similar anatomical changes, even though these clades have been largely geographically separated during their evolution. Phylogenetically controlled multiple regression revealed that in both clades head shape independently explains the most variation in elongation, while lengthening of the abdominal and caudal vertebral regions are secondarily important. Moreover, the torpedo−shaped bodies of *Luciocephalus pulcher* (pikehead) and *Luciocephalus aura*, which represent the most elongate forms in the clade by far, result from exaggerated changes in the same anatomical features that drive shape variability across all labyrinth fishes. Altogether our results reveal a common anatomical basis for body shape diversity that is taken to the extreme in *Luciocephalus*. Our study also showcases an approach for identifying general mechanisms underlying elongation when looking across other teleost clades.

47.7 COLLIN, R*; CHAN, KYK; Smithsonian Trop. Res. Inst., Panama, Hong Kong Univ. Sci. Tech., Hong Kong; *collinr@si.edu*
Living On The Edge: Small Thermal Safety Factors For Fertilization And Development In The Tropical Sea Urchin Lytechinus variegates
Thermal tolerance is particularly relevant to understanding and predicting organisms' responses to changing environmental conditions because it influences organisms' performance and in turn limits their biogeographic ranges. Tropical terrestrial organisms are thought to live near their thermal tolerance limits, and small thermal safety factors put them at risk from global warming. However, little is known about the thermal tolerance of tropical marine invertebrates, and how this limit relates to the ambient temperatures they may experience. We used embryos and larvae of the tropical sea urchin *Lytechinus variegatus* from Bocas del Toro, Panama to document the effects of chronic elevated temperatures and acute heat stress on development of this common shallow−water species. Both fertilization success and short−term larval survival after 2−hour exposure to elevated temperatures were high between 28−32°C, with a rapid drop in survival and a median lethal temperature (LT_{50}) of ~34.5°C. Long−term rearing showed good (over 50%) survival to metamorphosis from 23−33.5°C, with a small percentage of larvae surviving slightly higher temperatures. Larvae grown at the highest temperatures were smaller, metamorphosed slightly later and at smaller sizes than those reared at 26−30°C. Environmental data show that larval *L. variegatus* do not currently experience temperatures over their thermal limit in Bocas del Toro. Published predictive models suggest they will be begin to experience negative impacts at shallow sites by 2054 and throughout much of the Bahia Almirante by 2084. Our results highlight that tropical marine invertebrates could have small thermal safety factors during some stages in their life cycles, and they may be vulnerable to climate change in the near future.

40.4 COLLINS, CE*; HIGHAM, TE; University of California, Riverside; *clint.collins@email.ucr.edu*
The interplay between locomotion and adhesion on inclines in the Namib Day Gecko
Terrestrial animals must effectively navigate structurally complex environments. For geckos, non−level substrata are important because the adhesive system engages during uphill locomotion, limiting sprint speed due to the increased time that is required to deploy and disengage the adhesive toe pads. Our previous research indicates that *Rhoptropus afer*, relying on fast sprints to escape, avoid the steepest available inclines and declines during predator evasion. Additionally, one population predominantly avoids inclines in its habitat, and exhibits reduced adhesive toe pad size. To understand the interplay between habitat use, escape behavior, and morphology, we quantified the 3D kinematics of *R. afer* on level and uphill surfaces. We recorded 45 individuals on a 1.5 m trackway angled at 0° and 30°. Corroborating previous studies, speed decreased during uphill locomotion, driven by decreased stride frequency and increased stance time, but not stride length. The timing and use (on/off) of digital hyperextension was variable within and among treatments, yet was employed more often during uphill locomotion. Furthermore, curvature of the longest hind−limb digit was also affected by incline. The coefficient of variation was calculated to determine relative stereotypy among distal and proximal kinematics, incline, and populations. Specifically, we test the hypotheses that kinematics are more stereotyped on 30° due to the increased reliance on the adhesive system, and that distal limb elements are generally more stereotyped than proximal elements due to the highly integrated adhesive system. We dissect individual variation and the effects of incline on locomotion, and how these features relate to predator evasion and habitat use in the field. Supported by NSF IOS−1147043.

P1.40 COLLINS, EE*; HALANYCH, KM; MAHON, AR; Central Michigan University, Auburn University; *eecollin1@gmail.com*
Species diversity of adult and larval spionids (Spionidae; Polychaeta) in the Southern Ocean
While commonly found in the plankton, our current understanding of spionid biodiversity in Antarctica is limited by the difficulties of sampling the region and a lack of taxonomic expertise in the identification of spionid species, particularly for larval life history stages. With difficulties utilizing morphological characters to determine species diversity within the Spionidae, we chose to use DNA barcoding as a tool for taxonomic identification. Samples from throughout the Western Antarctic, including the Peninsula, Bellingshausen, Amundsen, and Ross Seas were collected, DNA was extracted, and standard genetic barcoding methods were applied. A fragment of the mitochondrial cytochrome c oxidase subunit I (COI) was used as our barcode marker to connect our knowledge of larval populations to adults collected from throughout the region. Additionally, the genetic barcodes generated in this study will also help determine if any of the collected organisms are cryptic species of spionids or potentially previously unrecorded species from the regions sampled. Future directions will include expanded sampling for both adults and larvae from other regions of the Southern Ocean and also to potentially utilize genetic and morphological characters to describe new species of spionids from the region.

S1.10 COMBES, S.A.*; SALCEDO, M.K.; GAGLIARDI, S.F.; CRALL, J.D.; IWASAKI, J.M.; RUNDLE, D.E.; Harvard University; *scombes@oeb.harvard.edu*
Optimal flight speeds during dragonfly predator−prey encounters
Theories of pursuit and evasion suggest that predators can maximize their chances of success by adopting an intermediate speed − one that is fast enough to rapidly gain on prey, but not so fast that they will vastly overshoot their target if it performs a sharp maneuver. Similarly, despite the fact that evasion is a matter of life or death for the prey, moving at maximum velocity may reduce the prey's ability to maneuver and increase the risk of errors or injuries. Despite some elegant theoretical work on these topics, few studies have directly measured the movement velocities of freely behaving predators and prey. We performed predation trials to quantify the flight speeds and behavioral strategies of wild−caught dragonflies pursuing a variety of prey, including fruit flies, mosquitoes, and house flies. We filmed >150 predation attempts with high−speed cameras, and found that dragonflies typically reach peak accelerations of 15−20 m/s^2 within 1−2 wing beats of take−off, and attain maximum velocities shortly before prey capture. Dragonfly velocity was strongly correlated with prey velocity: more than 60% of variability in dragonfly peak velocity during successful captures was explained by prey velocity, following the simple relationship of dragonfly velocity = prey velocity + 1 m/s. Failed pursuits were more often characterized by peak dragonfly velocities that fell below (or occasionally above) this relationship. Prey were more likely to escape if they flew at high speeds while performing erratic, unpredictable turns. Our data thus support the idea that predators and prey adopt movement speeds aimed at rapidly minimizing (or maximizing) the distance between one another, without compromising their ability to perform sudden maneuvers.

P3.196 CONCANNON, M.R.*; ALBERTSON, R.C.; UMass Amherst; *mrconcan@cns.umass.edu*

The evolution of a unique trait in East African cichlid fishes

The evolution of unique morphologies can change the way an organism interacts with its environment and lead to the exploitation of new niches. However, it is often difficult to study questions about the evolutionary history of such traits because comparative analyses are limited due to the narrow distribution of such traits. In the expansive adaptive radiation of cichlid fishes in East Africa's rift valley lakes, a rare facial morphology has evolved in at least two lineages, once in Lake Malawi and once in Lake Tanganyika. The trait is characterized by a dramatically hypertrophied snout that folds in on itself to form a flexible flap that rests on the premaxilla, the tooth−bearing upper jaw bone. Flap variation differs between these two lineages. In Lake Malawi, the trait is binary such that only two species within the genus *Labeotropheus* possess conspicuous flaps. Alternatively, within the Ectodini tribe of Lake Tanganyika the trait appears to vary continuously among its approximately 40 species. While it is speculated that flaps are used during foraging, little is known about how this unique trait might increase evolutionary and/or ecological success within a lineage. To address this question, we analyze the evolutionary history of flap size within the Ectodini along with other functionally salient trophic morphologies, and compare the ecologies of species with and without flaps. Our goal is to elucidate how and why rare traits evolve and how they can impact niche breadth.

112.6 CONNOR, KC*; GERMAN, DP; Univ. of California, Irvine; *kwasiconnor@hotmail.com*

Digestive Performance of the Mussel Mytilus californianus in Response to Varying Food Availability

The sessile intertidal mussel *Mytilus californianus* is a sentinel of Global climate change because its distribution, abundance and growth are ultimately set by environmental constraints on resource acquisition, allocation and thermal stress. Mussels residing highest (vertically) on the shore live at the fringes of their bioenergetic capacity because of limited access to food and subjection to higher temperatures. While thermal stress has been studied comprehensively in these organisms, investigations of resource acquisition and digestive physiology are lacking. To assess digestive physiology in mussels, we measured the activity of several digestive enzymes that digest proteins and carbohydrates, metabolic rate, clearance rate, and digestive efficiency in individuals subjected to low, medium and high food rations under controlled conditions. We used these parameters to estimate scope for growth for each feeding condition. The stress imposed by feeding level was further expanded upon from environmental and biological data collected in the field. As expected, digestive enzyme activity and scope for growth increased with rising food ration under controlled conditions. Furthermore, field measurements revealed that populations in wave−protected, high−intertidal areas where temperatures are high and food availability low are bioenergetically challenged more than those in other spatially separated microhabitats (including wave−exposed, high−intertidal areas). This investigation will help to identify, more precisely, populations under environmental stress within a shore and predict their vulnerability to the negative impacts of Global Climate Change.

98.5 CONRAD, J.L.; NYIT College of Osteopathic Medicine; *jack.conrad@gmail.com*

The problems of questionable holotypes and referred specimens as exemplified by Coniophis precedens (Reptilia, Squamata)

The Cretaceous squamate *Coniophis precedens* has been put forth as a transitional form between lizards' and snakes because of an apparent mosaic of derived (snakelike) and plesiomorphic (lizardlike) characteristics. The holotype of *Coniophis precedens* is a dorsal vertebra. Referred specimens include vertebrae, maxillae, and a dentary; these referrals were based on relative size and stratigraphic occurrence. The referred dentary is snakelike, but the maxillae show no clear snake synapomorphies, leading to the suggestion that snakelike' characters appeared in the mandible and vertebrae before the maxilla. Because there are no overlapping parts or associated specimens to confirm skull fragment referrals, the original study presented a phylogenetic analysis demonstrating that the individual elements occupy a similar phylogenetic position within Squamata, as basal snakes. Unfortunately, taxon selection from that analysis constrained these specimens to be snakes. When non−snake taxa (including a clupeid fish) were put into that analysis, they also were recovered as basal snakes. I re−examined the specimens and my own broad−scale morphological cladistic analysis of squamates found that the holotype *Coniophis precedens* vertebra is a basal snake. The dentary was volatile within the tree topology, but may represent a basal snake. The maxillae belong to a necrosaur−grade' platynotan lizard. Squamate paleontology has a long and continuing history of designating extremely fragmentary holotype specimens. Complete fossil skeletons or body fossils are extremely rare, especially for terrestrial taxa, so designation of incomplete holotypes is a necessity. Even so, there must be a limit to what is acceptable based on the utility of a given specimen as a name holder. I propose a basic conditional system for assessing specimen usefulness as a holotype.

P3.169 CONRADES, A. D.*; FINLEY, N. L.; GIDMARK, N. J.; Truman State University, Whitman College, University of Washington, Friday Harbor Laboratories; *adc8288@truman.edu*

Bigger, Stronger but Not Faster: jaw biomechanics through ontogeny of the great sculpin, Myoxocephalus polyacanthocephalus

Bigger, Stronger but Not Faster: jaw biomechanics through ontogeny of the great sculpin, *Myoxocephalus polyacanthocephalus* Suction feeding is the most common vertebrate feeding mode. Fishes suction feed by rapidly expanding the buccal cavity, creating a subambient pressure inside the mouth that causes water (and, ideally, a prey item) to rush in. The predator's ability to close the mouth around evasive prey determines feeding success. As a fish grows, the volume it engulfs should scale with length to the third power (volume length^3). This becomes a burden on larger fishes, as muscle force (which drives mouth closing) should scale with length squared (force muscle cross−sectional area length^2). Since suction volume increases faster with size than muscle force, a force deficit results as fish grow larger. Two ways to counteract this deficit are to increase muscle mass or increase skeletal leverage within the jaw. In this study, we examined musculoskeletal variation in anatomy and kinematics across an ontogenetic series in the suction−feeding great sculpin, *Myoxocephalus polyacanthocephalus*. Our results show that great sculpin mandibles change shape as they grow, increasing jaw−closing muscle leverage, which counters the force deficit (N = 6, p = 0.0456). Kinematic results agree: a given amount of muscle strain produces less jaw displacement in larger fish (N = 6, p > 0.00015). We did not find disproportionate changes in muscle mass with size (N = 7, p=.514). Smaller fish, therefore, rely on high−velocity jaw closing whereas larger fish rely more on high forces to close the jaw. We hypothesize that a smaller fish needs high speed to reduce the risk of prey escape from a small suction volume, whereas a large fish needs high forces to move the disproportionately large volume of water.

P1.3 CONTES−DE JESUS, M.M.*; BLACKBURN, D.C.; University of Puerto Rico, Rio Piedras, California Academy of Sciences, San Francisco; *maytee.cdj@gmail.com*

A new species of skink (Scincidae: Eugongylus) from the Republic of Palau in the western Pacific

A new species of scincid lizard in the genus *Eugongylus* is described from the islands of Palau in the western Pacific Ocean. It was first discovered in the late 1960s and initially identified as *Eugongylus mentovarius*, though more recent studies have recognized it as an undescribed species. The new species described here appears restricted to the Palauan archipelago. Using DNA sequence data from two mitochondrial genes, NADH dehydrogenase subunit 2 (ND2; 443 bp) and Cytochrome b (CYTB; 361 bp), we evaluate both intraspecific variation of the new species within the archipelago and its relationship to other *Eugongylus* species for which data is available (*E. albofasciolatus*, and *E. rufescens*). We also used morphological data to distinguish the new species from the five recognized species of *Eugongylus*: *E. albofasciolatus*, *E. mentovarius*, *E. rufescens*, *E. sulaensis*, and *E. unilineatus*. Using maximum parsimony, maximum likelihood, and Bayesian methods, we found two distinct but closely related mitochondrial lineages within Palau and also that the new species is more closely related to *E. rufescens* than to *E. albofasciolatus*. While the six species are morphologically similar, the new species can be diagnosed by a combination of its medium body size, dorsal coloration with small dark spots but lacking a distinct pattern of transverse bars, and tail length similar to snout−vent length. The description of this new species provides insight into genetic variation across the islands of Palau, as well as additional information on variation among other species in the genus *Eugongylus*.

P3.61 COOK, M*; ANDERSON, C; MARSON, K; EARLEY, RL; Univeristy of Alabama; *mollycook93@gmail.com*

Female power' trumps color as a predictor of pair−bonding success in convict cichlids

Sexual dimorphism, phenotypic differences between males and females, plays an important role in mate selection. In rare cases such as in convict cichlid fish the sexual dimorphism is reversed; females, not males, display ornate carotenoid−based coloration. The adaptive function of female coloration, however, is poorly understood. One hypothesis is that color is a quality indicator in females and that males discriminate among females with varying amount of color. We examined whether male mate choice is influenced by variations in female coloration and whether females' behavior determines pairbonding success. We hypothesized that males would choose more colorful females, that the latency to pairbond would be significantly lower if female orange patch sizes differ greatly, and that female−female and female−male behavioral dynamics would be important determinants of pairbonding success. We used four different treatments to test these hypotheses, where males were allowed to interact for 10 days with a pair of females: mismatched for orange patch size; matched for small orange patch size; matched for large orange patch sizes; or mismatched for orange patch size under a green−filtered light that limits perception of orange color. Our results reject the hypothesis that males choose mates on the basis of color. Our results also reject the hypothesis that pairbonding latency would change as a function of the color asymmetry between females. However, females that were highly aggressive towards other females, and that did not submit to the male had the highest probability of successfully pairbonding. While the adaptive function of female color remains somewhat of a mystery, it seems that behavioral elements outside of courtship are important predictors of pairbonding success.

S2.2 COOKE, S.J.*; DONALDSON, M.R.; RABY, G.D.; PATTERSON, D.A.; FARRELL, A.P.; GALE, M.; ROBINSON, K.; NGUYEN, V.; JEFFRIES, K.; ELIASON, E.; MARTINS, E.; HINCH, S.G.; Carleton Univ, Ottawa, Univ of British Columbia, Vancouver, Fisheries and Oceans Canada, Vancouver; *steven_cooke@carleton.ca*

Fishing for effective conservation: context and biotic variation key to understanding post−release survival of Pacific salmon

Resource managers require accurate estimates of mortality while fishers desire guidance on strategies for reducing mortality and maintaining the welfare status of fish that are to be released. In partnership with stakeholders our team has studied as a model fish group adult Pacific salmon intercepted by all three fishing sectors in both marine and freshwater environments while they were en route to natal spawning grounds. What emerged from our field, laboratory and modeling studies across multiple species, gear types, and environmental conditions are a number of themes. First, context, particularly as it relates to environmental conditions (e.g., water temperature, location relative to freshwater−saltwater transition) and the behaviour of fishers, dramatically influence outcomes for fish. Second, there is immense biotic variation among individuals, populations and species. These finding create immense challenges for managers. How does one develop generalized management responses given limited time and resources to study all possible combinations of species, populations, and contexts, particularly for multi−sector mixed−species fisheries? We present a framework to guide research on release mortality to ensure that credible and cost−effective science advice is available to support management and conservation actions.

51.1 COOPER, R.L.*; DE CASTRO, C.; TITLOW, J.; MAJEED, Z.R.; MALLOY, C.; VAUGHN, M.; KING, K.; Dept. Biology, Univ. KY. , Sayre School, Lexington, KY., Dept. Biochem, Univ. of Oxford, Oxford, UK, Univ. Salahaddin, Erbil, Iraq; *RLCOOP1@uky.edu*

Maintaining the Drosophila larval heart in situ: Modulators and stretch activated channels

The Drosophila heart is of interest as a genetic and physiologic model for developmental studies, pharmacological screening, investigating the ionic bases for pacemaker activity as well as understanding the modulation of pacemaker activity. To study cardiac physiology in vivo a suitable saline is necessary to maintain heart activity. Recently a modified HL3 saline has shown some promise in maintaining the heart rate (HR) (de Castro et al., 2014). However, this minimal saline, which is pH stable, does not maintain the HR for long periods of time for electrophysiological or imaging studies. A cocktail of OA, DA, Ach and 5−HT was shown to be beneficial to maintaining a stable heart rate for longer periods of time. Each of the modulators separately was shown to prolong and increase frequency of the HR. Even without the common hemolymph sugars trehalose and sucrose, the heart was still able to beat for long periods of time. With the cocktail of OA, DA, and 5−HT the heart rate would stay stable for about 2 hours without stopping. Recently it was demonstrated that the larval heart is sensitive to stretch and that this is likely due in part to a TRPA family of stretch activated channels. We developed an apparatus to simulate body wall contraction and relaxation on the heart tube to test the effect on maintaining the beating cycle of the heart for prolonged times. We are also examining the effect of inhibiting stretch activated ion channels in the intact larvae by RNAi knockdown.

110.8 COOPER, R.L.*; MAJEED, Z.R. ; MALLOY, C; ZEIDLER−WATTERS, K.; KRALL, R.M.; JOHNSON, D.; MAYO, S.; COLGAN, W.; CHUNG, W.−Y.; MEGIGHIAN, A.; DUPONT−VERSTEEGDEN, E.E.; Dept. Biol., Univ. KY, Dept. Ed, Univ. KY, Dept. STEM, Univ. KY, ADInstruments Inc, Co., Korea Military Acad., Korea, Univ. of Padova, Italy, Rehabil. Sci. & Ctr. for Muscle Biol., Univ. KY; *RLCOOP1@uky.edu*

Citizen science with high school students and adults from around the world participating in analysis of synaptic transmission

The goal in this project is to have people of the world participate in data analysis of synaptic transmission and contribute to authentic scientific processes in the interpretation and make meaning of the findings. High school aged students in Kentucky, USA beta tested the protocols and then we engaged world citizens in participation. Ideas for novel methodological approaches in analysis were encouraged in the discussion. The learning objective is to be able observe and measure quantal synaptic vesicular events and examine perturbations in the responses due to various experimental manipulations. One project is to examine if CO_2 may cause blocking of glutamate receptors, another is the influence of factors present in the spillage of cytoplasm from injured cells on glutamatergic receptors, modulation of GABAergic transmission and mutational effects of synaptically relevant proteins. The preparations are crayfish and Drosophila larval NMJs. Assessment of learning in the area of synaptic transmission and enthusiasm of engagement in this citizen science project by the participants are underway.

P3.47 COOPER, R.L.*; MAJEED, Z.R.; MALLOY , C.; BLüMICH, S.L.E.; CHUNG, W.−Y.; PUTNAM, R.W.; Univ of KY, Univ. Salahaddin, Erbil, Iraq, V.M.F., Univ. Leipzig, Leipzig, Germany , Korea Military Academy, Seoul, Korea, Dept. of Physiology & Biophysics, Wright State University, Dayton, OH.; *RLCOOP1@uky.edu*

Effects of intracellular pH on synaptic transmission: Differences in evoked and spontaneous release

We are addressing two issues: (1) the influence of pHi on vesicular packaging of neurotransmitter; (2) response of glutamate receptors on postsynaptic targets with altering extracellular and intracellular pH. These investigations are being addressed at the model crayfish and Drosophila neuromuscular junctions (NMJs). These two projects are interrelated as transmission at glutamatergic synapses is retarded in the presence of CO_2 which cannot be fully accounted for by a reduced pHi within the presynaptic nerve terminal or within the postsynaptic muscle fiber since the EPSPs increase in amplitude with rebound acidification after a pulse of NH_4Cl. High (40 mM) proprionic acid acidifies both the pre− and post−synaptic cells. When used the frequency and amplitude of mini's increases despite a slight membrane depolarization. However, evoked transmission is blocked. The use of high [CO_2] containing saline blocks evoked and mini's as well as the sensitivity of glutamate receptors. These NMJs are glutamatergic and the evoked (non−spiking) synaptic potentials and spontaneous (quantal) events are readily measured. Addressing the mechanisms underlying these observed phenomena may help in understanding synaptic depression after high frequency stimulation and feedback process in synaptic transmission. These studies tackle fundamental principles which are likely present in glutamatergic neurons for all animals.

16.2 COOPER, W J*; SMITH, A; PARSONS, K; ALBERTSON, RC; WESTNEAT, MW; Washington State University, University of Massachusetts, Amherst , University of Glasgow, University of Chicago; *jim.cooper@wsu.edu*

Evolution of Trophic Morphology in Perciform Fish Skulls

The functional morphology of perciform fish skulls is complex and evolutionarily flexible. Their adaptive potential has contributed to the generation of thousands of species that utilize most aquatic food sources. The manner in which lineages diversify can be shaped by both environmental and intrinsic factors. Recent work has suggested that environmental forces may dominate in shaping adaptive radiations. Here we suggest that intrinsic patterns of skull integration have strongly affected perciform skull diversification. The functional requirements of successful feeding impose patterns of integration on fish skulls. These patterns manifest themselves as developmental, evolutionary and population level phenomena. Here we present the results of a comparative study that examined the macroevolutionary consequences of specific integration patterns. Our data suggest that particular patterns and degrees of integration have important evolutionary consequences for both the speed and direction of adaptive divergence. Specific integration patterns may predispose certain groups toward certain ecological niches or sets of niches. We discuss potential tradeoffs between different types of adaptive potential that are conferred by different patterns of skull integration. Directional shifts in the evolution of integration patterns and their consequences for evolutionary diversification invite further study. The mechanisms by which integration patterns are altered through shifts in skull morphogenesis are largely unknown, but may offer significant insights into how skull integration itself evolves.

37.5 COPLEY, S*; WILLIS, MA; Case Western Reserve University; *sxc764@case.edu*

Behavioral context modulates use of wide−field motion input in Manduca sexta flight.

For most animals in flight, wide−field motion input is vital for maintaining control of movement. Males of the crepuscular hawkmoth, *Manduca sexta* use this information, along with olfactory and mechanosensory input to track odor plumes to food and mates. While both involve tracking a plume of odor, it is assumed that wide−field motion will be used in the same way to stabilize flight during plume tracking. To asses this, *M. sexta* males were challenged to track wind−borne plumes of flower scent or female pheromone with a single compound eye painted, either right or left. Loss of input from one of the compound eyes did not significantly impact the moths' ability to maintain controlled flight before orienting to the odor, and compared to intact controls, these individuals (n=23 for both groups) did not perform in a significantly different manner while tracking a plume of female sex pheromone. However, while tracking a tobacco flower, the ability for these individuals (n=28 for both groups) to track the plume of floral scent (14% for experimental animals and 71% for controls), then feed from the flower was greatly reduced. The results suggest that the motivation towards a particular stimulus also impacts if the animal will or can use wide−field motion to orient towards it. In the context of searching for mates, the motivation to orient to an attractive odor is high, so if the animal is able to perform the behavior, it will as long as it has enough visual input to control flight. Whereas if the animal is presented with a less−compelling stimulus, such as food, it will be less likely to attempt orientation towards it when its wide−field motion input is reduced. We kindly thank Jennifer Milligan for her assistance. These experiments, SC, and MAW were supported by AFOSR grant FA9550−12−1−023-7

P3.181 CORBET, MB*; MEYER, NP; Clark University, Worcester MA; *mcorbet@clarku.edu*

BMP signaling during early development of the annelid Capitella teleta

Bone morphogenic proteins (BMPs) are a family of signaling molecules that specify cell fate in a concentration−dependent manner. BMPs and their antagonists function in dorsal−ventral (D−V) axis specification and neural fate specification in vertebrates and *Drosophila*. In hemichordates application of exogenous BMPs during development dorsalizes the animals, but does not repress neural fate specification, suggesting that BMP signaling may have played an ancestral role in D−V axis specification. There is little data on D−V axis and neural fate specification from spiralians (one of two major protostome clades). However, in the spiralian annelid *Helobdella*, short−range BMP5−8 and the antagonist Gremlin pattern the D−V axis in the prospective segmented ectoderm. BMPs also pattern the D−V axis in the annelid *Platynereis dumerilii* but do not appear to repress central nervous system development. The annelid *Capitella teleta* has a clear D−V axis, with an anterior brain and a ventral nerve cord. Brain development begins during gastrulation with the ingression of single cells from localized areas of anterior ectoderm. Ventral nerve cord development is less well characterized, but begins shortly after gastrulation. We assessed the role of BMPs at early cleavage stages and during gastrulation in *C. teleta*. After applying exogenous recombinant BMP4 protein at multiple time windows, we did not see clear evidence of abnormal D−V patterning. However, recombinant BMP4 clearly affected neural development, including formation of the brain and eyes. These findings contrast what has been observed in other spiralians, and raise questions about the ancestral function of BMP signaling.

P1.177 CORCORAN, J.P.*; MERZ, R.A.; Swarthmore College; *jpcor4@gmail.com*

Burying efficiency and sediment preferences reveal complexities in habitat choice for Dungeness (Metacarcinus magister) and red rock (Cancer productus) crabs

Particle size distribution is a key physical factor in determining where organisms live in sedimentary marine habitats because it strongly influences the mechanical properties of the medium and thus the energy required to move through it. We examined burying efficiency in and preference among five natural sediments for Dungeness (habitat specialists) and red rock (habitat generalists) crabs. Crab burial speeds and sediment stiffnesses were measured at five field sites. Dungeness crabs buried equally well in less stiff, well−sorted sands and more stiff, poorly−sorted mud/cobble mixtures. At all sites they buried more quickly than red rock crabs whose performance decreased with increasing heterogeneity of the sediment. These results are contrary to expectations based on reported habitat specificity of the two species. Burial speed decreased with increasing carapace size especially for red rock crabs. The burial success and speed of Dungeness crabs is associated with the relatively larger surface area of their propoduses and the sharper angle formed by the posterior border of the carapace and abdomen. In replicate mesocosms, crabs explored five substrates and then buried in one. Dungeness crabs tended to select well−sorted sediments similar to where we found them in the field. In contrast, red rock crabs were least likely to bury in the mud/cobble sediment in which they had the most difficulty burying although this sediment was typical of the field site where they were most common. The discrepancies among burial performance, sediment preference, and natural distribution reveal the complexity of habitat use between these co−occurring species and are in contrast to the pattern shown by burying fish and some other crab species.

P2.196 CORN, K*; BRASH, J; FARINA, S; SUMMERS, A; Cornell University, Valley Steel and Stone, University of Washington; *kac372@cornell.edu*

Jawzall: Effects of Shark Tooth Morphology and Repeated Use on Cutting

Shark teeth both pierce and cut their prey, which is viscoelastic and structurally and materially heterogeneous. We propose a device for testing the function of shark teeth in a biologically relevant context with respect to their movement relative to the prey. We used this device to test whether tooth shape has an effect on cutting efficiency on a large actinopterygian prey item (salmon) and how quickly teeth dull. Teeth from four sharks, tiger (*Galeocerdo cuvier*), sandbar (*Carcharhinus plumbeus*), silky (*C. falciformis*), and sixgill (*Hexanchus griseus*), were attached to 30.5cm straight saw blades with epoxy. Each blade was mounted in a reciprocating saw and applied to a chum salmon with constant force. Published data report that *Carcharodon carcharias* shakes its head at 0.5Hz (~15cm/s). Our saw moved the teeth 35 cm/s. Our bite force' was substantially below that reported for sharks, due to of limitations of our system. There was not a significant effect of tooth shape on the area of prey cut per linear distance traveled. The mean area cut per cm traveled across all tooth shapes was 69 cm^2/cm. There was a significant effect of repeated use on cutting speed. After 12 reciprocations, a tooth cut only 7% of the tissue it cut on the first 6 reciprocations (at 5.7cm/reciprocation). This rapid dulling is enhanced by the high speeds at which we are cutting, as the fish tissues appear much stiffer at high strain rates. Sharks have very rapid tooth replacement and we propose this is driven by the speed of dulling from use.

P3.36 CORNWELL, F.J.*; KRAJNIAK, K.G.; Southern Illinois University Edwardsville; *fcornwe@siue.edu*

The Effects of FMRFamide−related Peptides on the Isolated Crop−Gizzard of the Earthworm Lumbricus terrestris.

The smooth muscle contractility of *L. terrestris* can be regulated by a variety of neurotransmitters, including the family of FMRFamide−related peptides (FaRPs). Previously we used the recently identified earthworm FaRP, APKQYVRFamide, to explore the effects of FaRPs on the crop−gizzard of *L. terrestris*. The goal of this project is to determine the effects of other FaRPs on the contractile activity of the crop−gizzard of *L. terrestris* by exploring the importance of amino acid substitutions and sequence extensions to the tetrapeptide core. The crop−gizzard was isolated and suspended inside of a tissue bath composed of worm saline. Contractions were recorded using a Grass force transducer, and the data was displayed utilizing Iworx Labscribe 2. Increasing concentrations of each peptide were applied and allowed to take effect. The changes in activity were used to create log−dose response curves. FMRFamide and APKQYVRFamide both caused concentration−dependent decreases in contraction amplitude, with FMRFamide having a threshold of 10^{-8} and APKQYVRFamide having a threshold of 10^{-6}. YMRFamide also caused a concentration−dependent decrease in amplitude equipotent to APKQYVRFamide. FVRFamide and YVRFamide both caused a decrease in amplitude with a threshold of 10^{-8} followed by an increase in activity at higher concentrations. This indicates the presence of phenylalanine in the fourth position from the C−terminus is more important than the valine substitution. PAKHYVRFamide caused a concentration−dependent decrease in contraction amplitude with a threshold of 10^{-8}. AGAYVRFamide caused a decrease in amplitude with a threshold of 10^{-8} followed by an increase in activity at higher concentrations. This indicates that lysine and glycine might play a role in determining peptide activity, while proline may determine potency.

66.3 CORUSH, JB; University of Tennessee, Knoxville;
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Diadromy and Diversification
Many fishes are limited to marine or freshwater environments, however, roughly 250 of the nearly 30,000 teleost fishes are diadromous, or migrate between marine and freshwater during a particular stage of their life. Evolutionarily, diadromy is of interest due to its rare, yet widespread occurrence in nearly 40 families of fishes, not to mention this behavior is also found in various invertebrate families. Using a tree consisting of 7822 species of fishes with the implementation of MUSSE model in R, rates of transition in and out of diadromy to and from marine and freshwater lifestyles was tested to understand the role diadromy plays in transition between different phases. Additionally rate of diversification as a function of speciation and extinctions were examined in all three character states. Results indicate that transitions to diadromy are rare from both marine and freshwater clades, yet once acquired, diversification rates tend to be high when compared to marine fishes and equivalent or higher compared to freshwater fishes, depending on the model choice. Additionally transition out the diadromous character state occurred at a rate that was two orders of magnitude higher than transitions out of marine or freshwater to any other state. This information does not support the hypothesis that diadromy is simply an intermediate state while transitioning between freshwater and marine systems.

P1.180 COSTA, A.C.*; MEHTA, R.S.; WARD, A.B.; Adelphi University, University of California, Santa Cruz;
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Elongation Enables Aquatic and Terrestrial Locomotion
Extreme body elongation has evolved multiple times within actinopterygian and sarcopterygian fishes. While this specialized body plan has been associated with living in highly structured habitats, many elongate fishes are also known to make terrestrial excursions. Here, we investigated how two elongate species, ropefish (*Erpetoichthys calabaricus*) and eel catfish (*Gymnallabes typus*), with different types of axial elongation move aquatically and terrestrially. Specifically, we examined how these species use vertical substrate in their environment by conducting aquatic and terrestrial locomotor trials where fish traveled through an array of cylindrical pegs spaced at different intervals. We predicted that ropefish, which have an elongate precaudal region, would spend more time contacting pegs than eel catfish, which have an elongated caudal region. Individuals completed both aquatic and terrestrial trials at two different peg−spacings. In general, both fish were found to move through the peg array similarly to limbless tetrapods. At the smaller spacing, individuals spent more time, on average, contacting a peg during a terrestrial trial than during an aquatic trial. Additionally, more of the body contacted the peg when the animal was moving terrestrially. Despite differences in their axial patterning, ropefish and eel catfish exhibited similar changes in locomotory patterns when traversing the terrestrial environment. However, these species did differ in speed and contact time; ropefish moved more slowly and contacted pegs for longer durations than eel catfish. This study provides further understanding of how elongate fishes can use axial undulation to move on land. In on−going studies, we are examining how these fishes move between environments.

P2.107 COSTELLO, R.A.*; SYMES, L.B.; University of Virginia, University of Wisconsin, Madison; *rac2zb@virginia.edu*
Effects of anthropogenic noise on male signaling behavior and female phonotaxis in Oecanthus tree crickets
Communication is vital to the survival and reproductive success of organisms. There is growing evidence that anthropogenic noise interferes with acoustic communication. While recent studies have tested whether signalers behaviorally modify their signals to prevent masking from noise, studies have only recently begun to test whether noise in fact interferes with the perception of acoustic signals. In this study, we investigated how road noise affects both male signaling and female phonotaxis in *Oecanthus* tree crickets. To determine whether males alter their calls in the presence of road noise, we assessed how a playback of road noise changed four male calling characteristics: dominant frequency, call amplitude, total time spent calling and latency to begin calling. We used response trials to test the ability of females to localize and respond to male calls in the presence of road noise. Unlike studies in other organisms, which detected quantifiable differences in signals, male tree crickets were less likely to call but did not change signal characteristics. Surprisingly, female response to male signals was not affected by the presence of road noise, despite the potential masking effects of road noise. Because tree crickets often communicate in environments with many species of calling insects, tree crickets may be adapted to tolerate novel sources of acoustic interference. This study presents a case where male signals and female responses are not affected by road noise. Since species are differentially affected by noise, detailed understanding of behavior and sensory systems may be necessary for predicting the effect of acoustic interference on trophic interactions and population dynamics. (www.sciencedirect.com/science/article/pii/S0003347214002292)

90.1 COTA, C. D.; DAVIDSON, B. J.*; Swarthmore College;
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Mitotic membrane turnover coordinates differential induction of the heart progenitor lineage
Embryonic cells use adhesion to interpret microenvironmental cues, forming signaling compartments along adherent membranes that influence cell survival and developmental patterning. While it is known that dividing cells detach from the surrounding extracellular matrix and initiate extensive membrane remodeling, the in vivo impact of mitosis on adhesion−dependent signaling remains poorly characterized Here we show that mitotic membrane dynamics orchestrate adhesion−dependent signal polarization. We investigate in vivo signaling dynamics using the invertebrate chordate, Ciona intestinalis. In Ciona, matrix adhesion polarizes Fibroblast Growth Factor (FGF)−dependent induction of the heart progenitor lineage. Through targeted disruption and selective rescue of matrix adhesion in the heart progenitor lineage, we show that adhesion promotes localized enrichment of FGF receptors by inhibiting mitotic internalization and degradation. We have experimentally defined the integrin motif responsible for adhesion dependent retention of FGF receptors. Furthermore, our results indicate that adhesion polarizes receptor retention by influencing mitotic distribution of Caveolin−rich membrane domains. These results fundamentally re−define the relationship between cell division and adhesive signaling, revealing how mitotic membrane turnover resets historic, pre−mitotic receptor distribution according to contemporaneous adhesive cues.

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Living in a turbulent world − Impacts on fish habitat choices and swimming

The natural habitats of fishes are characterized by water movements driven by a multitude of physical processes of either natural or human origin. The resultant unsteadiness is exacerbated when flow interacts with surfaces, such as the bottom and banks, and protruding objects, such as corals, boulders, and woody debris. There is growing interest in the impacts on performance and behavior of fishes swimming in "turbulent flows". The ability of fishes to stabilize body postures and their swimming trajectories is thought to be important in determining species distributions and densities, and hence resultant assemblages in various habitats. Furthermore, water flow, structure and vorticity are related to the shape of the body and fins of fishes swimming largely in relatively steady flows. Adaptations to minimize energy losses would be anticipated. A theoretical framework is proposed to quantify fish−eddy interactions. Dimensionless parameters are derived based on a common element: eddy circulation. A set of variables defines the flow field whereas a second set quantifies fish characteristics as an embedded body in the flow. By comparing both sets of variables, different regimes are predicted describing fish responses to a wide range of physical perturbations. Understanding impacts of turbulence and vorticity on fishes is important as human practices modify water movements, and as turbulence−generating structures ranging from hardening shorelines to control erosion, through designing fish deterrents, to the design of fish passageways become common.

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Muscle function in rainbow smelt, Osmerus mordax, during winter

Rainbow smelt (*Osmerus mordax*) display an impressive ability to acclimate to very cold water temperatures. These fish express both anti−freeze proteins and glycerol in their plasma, liver, muscle and other tissues to avoid freezing at sub−zero temperatures. Further, these fish must feed actively in this cold water to maintain osmolyte levels. We explored smelt muscle function in winter through: (1) thermal acclimation studies on smelt swimming performance, muscle contractile properties and muscle protein expression; and (2) muscle mechanics experiments that evaluated the influence of osmolytes on muscle function. The thermal acclimation studies demonstrated a strong influence of cold acclimation on swimming performance, with cold acclimated fish able to swim at higher sustained swimming speeds but at perhaps higher energetic costs than warm acclimated fish. These cold−acclimated fish had faster contractile properties in both their fast− and slow−twitch myotomal muscle and corresponding shifts in myosin content in both muscle types. The mix of osmolytes in the myotomal muscle of cold−acclimated fish influenced muscle contractile properties. One of the osmolytes that is elevated in winter smelt, trimethylamine oxide, appears to lead to increased force and power production by fast−twitch muscle. Other osmolytes elevated in these fish in winter, such as urea and glycerol, negatively influence muscle function. The thermal acclimation response of smelt in winter must overcome both the effects of cold temperatures as well as the negative effects of increased osmolyte levels on muscle function.

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Running with certainty on uncertain terrain requires little to no neural feedback

Rapid legged locomotion is of critical importance for many animal species. In most natural environments, animals cannot rely on the ground being predictably flat. We present a result from nonlinear control showing that under most circumstances animals should be able to select a feed−forward strategy that would eliminate the uncertainty in movement generated by non−flat terrain. Since this strategy requires no sensory feedback, it may be implemented morphologically in the shape of the body and the mechanical structure of the limbs. We demonstrate such a strategy for the Spring Loaded Inverted Pendulum model of running. We hypothesize that such controllers appear in some rapidly running organisms. In such systems, no investigation of neural feedback could reveal the dominant mechanism of control, and analysis of neuronal responses would at best be misleading.

P3.63 COUNTRYMAN, C.E.*; CHADWICK, N.E.; Northern Michigan University, Auburn University; *ccountry@nmu.edu*

Reproductive Patterns in the Pederson Cleaner Shrimp Anclyomenes pedersoni

Life history strategies of organisms impact their abilities to recover from disturbances, and provide important information for species management plans. Most aspects of life history remain unknown for *Ancylomenes pedersoni* (Pederson cleaner shrimp) which is a major remover of fish ectoparasites on Caribbean coral reefs. Pederson cleaner shrimp occur on giant sea anemones as obligate symbionts. This project investigated major reproductive traits of this important shrimp species, including minimum size at reproduction and duration of egg incubation. A. pedersoni were cultured in the laboratory in closed−system aquaria. We found that the smallest reproductive female had a carapace length of 2.9mm and that development of the eggs in the ovaries lasted an average of 13.13 (+/−6.28) days and incubation of eggs (eggs being held in the abdomen) lasted an average of 3.25 (+/− 1.73) days before being released. This project also examined their reproductive strategies, to assess whether isolated females can produce eggs and thus whether sperm storage, simultaneous hermaphroditism or parthenogenesis occurs in this species. Three individual females, three juveniles and three pairs of females also were placed in separate tanks and egg production was observed daily over the course of eight weeks. While many individuals produced eggs, cleavage of the eggs did not occur after the first week, except in two shrimp during the last two weeks of observations which were with another shrimp classified as a juvenile/male. None of the paired females or isolated females showed cleavage in their eggs throughout the experiment and the isolated juveniles did not produce eggs at all suggesting that parthenogenesis did not occur in this study. In conclusion, we have demonstrated a three day incubation of eggs without fertilization in this species and our data suggest that parthenogenesis is unlikely.

P1.47 COWLES, JM*; COWLES, DL; Walla Walla University; *joanna.cowles@wallawalla.edu*

Photosynthesis and the green isopod Pentidotea resecata

The isopod *Pentidotea resecata* can be found living on the eelgrass *Zostera marina* and *Macrocystis spp* along the western coast of the United States. Two separate color morphs can be found, a brown morph which lives on *Macrocystis* and a green color morph on *Zostera marina*. Diet consists mainly of their primary substrate along with epiphytes such as diatoms which often grow on the substrate surface. In this study respirometry was done on individuals of the green color morph to determine whether chloroplasts consumed in their diet maintained functionality. Light and dark respirometry was conducted on living specimens with as many diatoms and other epiphytes removed from their body surface as possible. Each isopod was then sacrificed and its gut removed before repeating both light and dark respirometry to determine the contribution to photosynthesis from the epiphytes. Most individuals used for respirometry were between 4.5 and 5 cm to eliminate variation in metabolic rate due to body mass. These sizes are all greater than the size range reported in the literature. Little size−dependent variation in metabolic rate was seen within the range used. All respirometry was conducted with partial pressures of oxygen above 100 mm Hg and no oxyconformity was observed. During live respirometry the mean respiration rate was consistently higher during the dark than during the light, indicating photosynthesis. Comparison of whole−animal respiration with that of animals with their guts removed showed that although epiphytes do contribute to both respiration and photosynthesis, the material within the gut is likely contributing as well. Over a three week experimental period the level of respiration increased in the dark, possibly due to increased diatom load. Trends in metabolism over time as measured during the light were not as clear.

61.5 COWLISHAW, RJ; Southwestern College; *richard.cowlishaw@sckans.edu*

Bringing the Ocean to Kansas: The Marine Biology Degree Program at Southwestern College

Southwestern College (SC) is a small liberal arts institution in Winfield, KS. Founded in 1885, the college has a long academic history in the biological sciences but it is unique among landlocked states in offering a marine biology degree program since 1985. The idea of such a major was seeded in a long history of SC biology faculty leading Jan−term road trips out to the West Coast and the attendance of SC students in summer courses at the University of Oregon's Institute of Marine Biology (OIMB). The affiliation of OIMB with the East−West Three Seas Program inspired SC faculty to develop a marine biology degree in Kansas; a program that would provide a track for high school graduates with a genuine passion for marine biology to pursue it academically without relocating out of the region. Majors must spend at least one summer, ideally between their second and third years, at a marine field station taking field courses to acquire at least 10 credit hours in marine science. On main campus, majors take a lab−based marine biology course and a 1 credit hour marine biology seminar course. In addition, majors take five additional lab−based courses from among the following: ecology, animal behavior, animal physiology, biochemistry, freshwater biology, developmental biology, and microbiology. Recognizing that marine biology is largely a graduate field, majors are strongly encouraged to apply for research internships at marine field stations for the summer between their third and fourth years in order to prepare for graduate school application. Of the 29 graduates in the program since 2003, ten of them went on to graduate school in the aquatic sciences. Although recent changes in the academic calendar eliminated the opportunity for Jan−Term trips, efforts are underway to develop May−term road trips to coastal locations to enhance the SC marine biology program.

1.7 COX, R.M.; University of Virginia; *rmc3u@virginia.edu*

Integrating costs of reproduction between the sexes: a synthesis of sexual selection and life history perspectives

Costs of reproduction structure important evolutionary tradeoffs in males and females, but we lack a general framework for comparing these sex−specific costs and integrating them into a holistic view of life−history evolution. Conceptually, this is due to the historical separation of research on life−history evolution, which has focused primarily on females, versus sexual selection, which has focused primarily on males. Empirically, this is because the primary costs of reproduction are often measured in different currencies, occur at different times, and encompass different regulatory processes in each sex. A first step towards integration between sexes is the measurement of reproductive costs in common currencies, particularly energy and fitness. Recasting the immunocompetence handicap hypothesis in an energy−based perspective illustrates the potential limitations of viewing costs of reproduction through mechanisms that are sex−specific, especially when the tradeoffs that structure such costs are generalizable to either sex. Likewise, sexual conflict theory shows how genetic correlations between the sexes can constrain the evolution of optimal solutions to reproductive tradeoffs within each sex, emphasizing the importance of integration in units of fitness. In these and other cases, a more informative framework could be established by focusing on downstream regulatory axes that are shared between the sexes, and through experiments that abolish the sex−specific aspects of reproductive investment. This approach is illustrated by a series of experiments exploring the mechanistic underpinnings and fitness consequences of reproductive costs in the brown anole (*Anolis sagrei*). Taken together, these ideas form the basis of a more general framework for integrating theory on life−history evolution and sexual selection by focusing explicitly on the interaction of reproductive tradeoffs in both sexes.

56.4 COX, C. L,*; CARD, D.; ANDREW, A.; CASTOE, T. A.; COX, R. M.; The University of Virginia, The University of Texas at Arlington; *clcox@virginia.edu*

Sexual concordance in phenotypic and transcriptomic responses to testosterone in brown anoles

Understanding how different phenotypes develop from the same underlying genome is an important goal of integrative biology. Males and females share an autosomal genome, which may constrain the development of sexual dimorphism. Developmental modifiers such as sex steroids, which are secreted in sex−specific fashion, can facilitate the development of sexual dimorphism by differentially regulating the expression of shared autosomal loci. However, it is generally unknown whether the evolution of endocrine−mediated sexual dimorphism is achieved primarily through sex differences in circulating hormones, or also through sex−specific tissue sensitivity to these hormones. We tested the effect of the sex steroid testosterone (T) on whole−organism growth and tissue−specific gene expression of the liver (a major integrator of energetics and growth) in males and females of a lizard (*Anolis sagrei*) with pronounced male−biased sexual size dimorphism. We administered either testosterone or placebo implants to intact males and females at the age (5−6 mo) when sexual dimorphism first becomes pronounced. T shifted both sexes toward a male−specific pattern of development by stimulating growth, bone elongation, resting metabolic rate, and utilization of fat reserves. The transcriptome of the liver was similarly impacted by T, which shifted both sexes towards a male−specific pattern of gene expression that included altered regulation of genes in the insulin−like growth factor (IGF−1) pathway. Our results suggest that the evolution of endrocrine−mediated sexual dimorphism in growth and body size is achieved primarily through sex differences in circulating androgen levels, rather than through a reduction in sensitivity of females to androgens.

P1.171 CRALL, JD*; CHANG, JJ; MISTICK, EA; COMBES, SA; Concord Field Station, Harvard University, Swarthmore College; *jcrall@oeb.harvard.edu*

Free flight through tough turbulence: Bumblebee flight stability across body size, speed, and flow regime

Flying animals regularly traverse complex landscapes characterized by dynamic, turbulent airflows. Despite longstanding interest in the mechanics of insect flight, recent studies have just begun to shed light on the effects of flow variation on flight performance. Most of these studies have focused on discrete flow perturbations or unsteady, structured flow such as Von Karman vortex streets. Wind in natural environments, however, is often characterized by isotropic turbulence containing flow variation across a range of spatial and temporal scales. Here, we present results from free flight experiments in bumblebees (*Bombus impatiens*) ranging from 95−200 mg flying in a wind tunnel across flow conditions. Body and wing dynamics were quantified for bees flying through each of five flow regimes: still air, low (1.5 m/s), and high (3.0 m/s) speed flow in both turbulent and laminar conditions. Turbulence was created with a square grid placed upstream of the wind tunnel working section, which created near−isotropic turbulence with an intensity (SD/mean) of ~15%, while laminar flow had a turbulence intensity of less than 1%. Variance in both body and wing kinematics increased in turbulent flows. In addition, wingbeat frequency in turbulence appears to increase relative to laminar flow at high (but not low) wind speeds, supporting previous findings in structured, unsteady flow. Finally, we examine the effect of body size on flight stability, as well as kinematic strategies for controlling body orientation and position in response to variable flow. Overall, these results demonstrate the challenges that face insects flying through variable flow and reveal the robust flight strategies necessary for successful navigation in natural aerial environments.

115.4 CRALL, JD*; GRAVISH, N; MOUNTCASTLE, AM; COMBES, SA; Concord Field Station, Harvard University; *jcrall@oeb.harvard.edu*

Portrait of a hive: Linking division of labor, foraging ecology, and flight performance using automated tracking in bumblebees

The origins and ecological consequences of division of labor in insect colonies are of great importance to understanding the evolution of social insects. Direct observation of individual behavioral patterns within the hive and their connections to ecologically relevant traits outside the hive (i.e. foraging capacity and flight performance) presents difficulties in insects, however, because of their size and the labor−intensive nature of manually tracking individuals. In this study, we explore the connections between in−hive behavior, temporal foraging pattern, and flight performance in bumblebees (*Bombus impatiens*) using beeTracker, a new, freely available tracking program. Inspired by similar programs that use optical tags to identify individuals (such as ARTag), this program tracks the position of unique tags from video frames or still images. Here, we use this program to track dozens to hundreds of individual bumblebees per colony, both within the hive and as they enter and exit the hive to forage in the natural environment. In combination with an automated motion capture system adjacent to the hive, this system also allows us to quantify individual−level maneuvering flight performance over the course of several weeks. Finally, an automated scale system provides data on individual masses of bees as they exit and enter the hive, allowing quantification of individual resource intake rates. Our results provide support for strong and stable inter−individual differences in both foraging behavior and brood−care in the hive. Interestingly, behavioral performance in these tasks appears largely unrelated to body size, which has been hypothesized to drive behavioral specialization in bumblebees.

44.1 CRANDELL, KE*; SMITH, AF; TOBALSKE, BW; University of Montana; *kristen.crandell@umontana.edu*

Coping with compliance during take−off and landing in the Diamond dove (Geopelia cuneata)

Birds appear to transition smoothly from aerial to terrestrial environments via take−off and landing. These transitions are presumably under high selective pressures, including events such as predation evasion, hunting, and avoiding wing damage. Take−off and landing occur on substrates with often−unpredictably varying levels of compliance. Previous work describes avian leg and wing modules as functionally distinct, with slight overlap during these critical transition phases. We conducted experiments to test the effects of perch compliance upon module coordination. We predicted varying compliance would require modulation of both wing and leg activity. Surprisingly, the birds did not modulate leg activity in response to compliance during takeoff, whereas they did during landing. During take−off on compliant perches, smaller leg peak forces and application times cause lower initial flight velocity. Birds partially compensate for this deficit using their wings after leaving the perch. In contrast, birds have the same flight velocity at touchdown regardless of known perch compliance. Unlike during take−off, birds vary peak leg force inversely with time of force application, indicating work absorption by the legs is modulated. Therefore we suggest that legs and wings operate as functionally distinct modules during transitions to and from flight. These experiments provide new insight into how control strategies differ between take−off and landing.

P2.134 CRANDELL, KE*; CRINO, OL; KLAASSEN VAN OORSCHOT, B; BREUNER, CW; TOBALSKE, BW; University of Montana, Macquarie University; *kristen.crandell@gmail.com*

The developmental environment has sustained effects on flight performance in zebra finch

The developmental environment can have pervasive and sustained effects on phenotype and performance. Environmental cues during development can induce phenotypic responses that transmit information about the post−natal environment, and are sustained across life−history stages (i.e. developing programming). *Glucocorticoids* are stress hormones that can act as mediators between the developmental environment and the post−natal phenotype. While many phenotypic effects of glucocorticoid exposure during development are negative, there is increasing evidence for an adaptive role in shaping the postnatal phenotype. To test this hypothesis, we examined the effect of glucocorticoids on flight performance across life−history stages in the zebra finch. Flight performance can directly influence individual fitness via avoiding bodily damage, escaping predation, mating, and foraging success. We administered the glucocorticoid corticosterone (CORT) and quantified flight performance at four life stages. We find that flight velocities during take−off were not affected by treatment for birds at 15, 28, and 60 days post−hatch (dph). However, at 100 dph CORT−fed birds had significantly higher flight velocities compared to controls. Surprisingly, we found in younger birds (15, 30 dph) that clutch size affected flight velocity; birds from smaller clutches exhibit higher take−off velocities. These data indicate an adaptive role of CORT on the postnatal phenotype, suggesting that early environment can have sustained effects on performance measures. Further, some developmental factors have stronger effects than others (e.g. brood size versus CORT treatment).

P2.185 CRANE, R.L.*; PATEK, S.N.; Duke University, Durham, NC; *rcrane140@gmail.com*

Where to strike a snail: smashing strategy of mantis shrimp

Animals use a variety of behavioral and mechanical methods to access hard−shelled prey. Strategic application of force to fracture snail shells is observed in crushing and peeling predators, and these slow, high impulse strategies form the foundation of our current understanding of snail shell evolution. In contrast, mantis shrimp (Stomatopoda) impact and break snail shells with an ultrafast hammer. Here we test whether mantis shrimp select specific impact locations or randomly strike snail shells. We collected *Neogonodactylus bredini* and their size−matched molluscan prey (genus *Cerithium*) in Panama. Using video recordings of mantis shrimp feeding on snails, we noted the timing and location of every strike until the mantis shrimp began eating. The mantis shrimp followed a stereotyped behavioral sequence of rotating the snail, placing it on the substrate, tapping it with the antennules, often repeating these three behaviors, and then striking. Although individual mantis shrimp used a variety of strike location strategies, trends emerged across all individuals. Mantis shrimp rarely struck the body whorl and the middle third of the shell, yet frequently struck the apex and aperture. Mantis shrimp tended to strike near the aperture at the start of a trial and near the apex at the end. No sex or size differences were found in strike location, although larger mantis shrimp struck at a slower rate than smaller mantis shrimp. In conclusion, mantis shrimp follow a consistent pattern of strike locations when processing size−matched snails. Mantis shrimp impacts and behavior offer new windows into the role of fracture mechanics, force application, and behavioral strategies in the coevolution of snails and predators.

P3.168 CRANE, N.R.*; LEONARD, J.B.K.; Northern Michigan University; *nacrane@nmu.edu*

Effects of Rearing Habitat on Growth and Morphology of Brook Trout (Salvelinus fontinalis)

Stocked fish species are typically raised in high density, homogeneous environments with little to no cover or habitat variation. The effects of these conditions on the growth and morphology of these organisms are not often examined or compared to the effects of more naturalized conditions. I reared individually tagged young−of−the−year brook trout (*Salvelinus fontinalis*) (n=143) in 1135L round tanks or in an artificial stream for 90 days on a diet of 1.5g of 1mm trout pellets per day. Preliminary results indicate that the mean total length (overall x=87.3mm), standard length (overall x=78.4mm), and mean weight (overall x=6.106g) did not differ between the two habitats. Daily weight−based growth (overall x=0.0604 g/day) did not differ between the two habitats. In the next stage of this project, we will evaluate morphological differences based on thin plate spline morphometric analysis of standardized landmarks on tagged individuals to evaluate changes in shape related to rearing habitat.

P3.188 CRAWFORD, C.H.*; NAYLOR, G.J.P.; College of Charleston; *crawford.callie@gmail.com*

Skeletal Anatomy in the Chondrichthyan Tree of Life

Current understanding of the Chondrichthyan phylogeny lags behind that of many other vertebrate classes. Many of the studies conducted to date have produced conflicting topologies. In an effort to address the lack of consensus on Chondrichthyan phylogeny, the Chondrichthyan Tree of Life project was developed. One component of the Tree of Life examines the morphological variation across Chondrichthyans through the use of Computed Tomography (CT). CT is a nondestructive method for viewing internal structures of extant and fossilized specimens. Reconstruction programs can be used to manually segment the data into separate skeletal structures, creating 3−Dimensional representations of the structures which can then be viewed digitally or printed in 3D. The quality and ease of segmentation is tightly tied to the visible contrast between study structures and other tissues in the organism. In most groups of vertebrate organisms, skeletal structures are made of calcified bone which has high radiopacity, leading to greater contrast between the skeleton and soft tissues. Chondrichthyans, by comparison, have skeletons composed of cartilage which is much less radiopaque than bone, resulting in lower contrast with surrounding tissues. We will describe the basis of the anatomical component of the Chondrichthyan Tree of Life and the processes which go into creating interactive digital representations of the CT scan data. Additionally, some of the unique skeletal structures we have encountered will be presented.

S2.9 CRESPI, Erica J*; RISSLER, Leslie J; Washington State University, University of Alabama; *erica.crespi@wsu.edu*

Geophysiology of the wood frog: Integrative assessment of population health at different spatial scales and life stages

While correlations among risk of extinction, genetic variability, and physiological stress are widely assumed, few studies have directly measured the relationships among these indices of population fitness. Working within a theoretical framework of species range dynamics, we aim to test whether independent assessments of habitat quality, generated from spatially−explicit ecological niche models (ENM), correlate with neuroendocrine and genetic indicators of population−level health within the eastern range of the wood frog (Lithobates sylvaticus). During the 2011 breeding season, we sampled males from 20 populations, which spanned the latitudinal range of the eastern clade of wood frogs and were located within a range of habitat qualities as predicted by a climate−based ENM. We also sampled males from roadside and woodland breeding sites within select climatic regions to resolve the impact of local habitat conditions stress responsiveness of populations. For each population, we measured baseline plasma corticosterone (CORT) and testosterone concentrations and CORT responsiveness to a standard dose of ACTH. Based on findings from laboratory experiments, we predicted that baseline CORT will be higher and ACTH−responsiveness lower in areas of lower habitat quality. We also recorded body measurements, reproductive deformities, and assayed for chytrid, ranavirus, and trematode infections. We also measured individual and population−level genetic variability using microsatellite markers. Ultimately, we will integrate these broad and fine−scaled measures of population fitness to understand the geography of population health, how species are distributed in space, and how these distributions will be altered by environmental change.

102.6 CRINO, O.L.*; HURLEY, L.L; MAINWARING, M.C.; DUVALL, C.; BUCHANAN, K.L.; GRIFFITH, S.C.; Macquarie University, Lancaster University, Deakin University; *ondicrino@gmail.com*

Divorce in a socially monogamous bird: hormonal mechanisms and reproductive consequences

Zebra finches (*Taeniopygia guttata*) form long term pairs, within which both sexes contribute to parental care and paired birds raise iterative broods together. In free−living birds, pairs can be disrupted if one member is lost (e.g. to predation). The remaining bird will often pair with a new mate. Pair disruption is known to increase physiological stress as demonstrated by elevated levels of the steroid stress hormone corticosterone (CORT). CORT is an important hormone for maintaining homeostasis, but can negatively impact reproduction by decreasing levels of hormones such as prolactin, which modulate parental behaviors. Although it is known that pair disruption increases CORT in zebra finches, it is currently unknown how this affects prolactin levels and reproductive success. Using a paired design, we examined the effects of pair disruption on parental behavior and reproductive success in zebra finches. Additionally, we examined the specific hormonal mechanisms (prolactin and CORT) that may explain changes in physiology and behavior following pair disruption. Finally, we examined the impact of pair disruption on nestlings by measuring nestling body size and stress (CORT) responses. Taken together, these data provide an integrated examination of how pair bonds in socially monogamous birds affect individual reproductive success, with possible transgenerational consequences.

P2.109 CRISP, E. M.*; CHADWICK, N. E.; Auburn University; *emc0020@auburn.edu*

Effects on anemonefish behavior of visual and chemical signals from conspecifics

The types of signals that animals use to communicate with conspecifics may strongly influence their behavior and ecology. Anemonefish use both chemical and visual cues to locate host sea anemones, but the relative importance of signal types for communication with other anemonefish remains unknown, and may be important for detection of individuals especially at night. Our preliminary studies revealed that anemonefish secrete substantial amounts of estrogen into the surrounding water, which may serve as a chemical signal to conspecifics, among other potential functions. We examined behavioral responses in 2 species of anemonefishes (*Amphiprion bicinctus* and *A. ocellaris*) to stimuli from conspecifics, by presenting receivers with cues from senders that were either: both visual and chemical, visual only, chemical only, or lacking (no stimulus). Responses depended on the body size and social status of the receiver fish. Large, dominant females did not respond to any cues, while smaller, subordinate males responded more to visual than to chemical cues. This variation in response will be discussed in the context of gender and size roles in anemonefish social groups, as well as how nocturnal signals from conspecifics may influence both behavioral and physiological processes.

12.4 CRISWELL, K.E.*; COATES, M.I.; University of Chicago; *kcriswell@uchicago.edu*

Vertebral column evolution and development: homoplasy in the vertebrate centrum

Although the vertebral column is a defining feature of vertebrates, little is known about the evolution and development of this fundamental structure. The vertebrate axial column consists of several components, including a notochord, centrum, neural arches, hemal arches, various processes, and ribs. The presence and condition of many of these structures in different vertebrate groups is not well documented. To analyze variation and morphological diversity of axial columns across major groups of gnathostomes, we examined extant and extinct species of chondrichthyans, osteichthyans, and stem gnathostomes. We performed parsimony−based ancestral state reconstructions on a supertree of gnathostomes that was assembled from recent phylogenies. Our results indicate that centra have evolved independently as many as nine times. Other instances of convergence include polyspondyly and fused anterior vertebrae (synarcuals and the Weberian apparatus). Centrum development is known to be diverse: teleost centra can form the notochord, somites, or both, while tetrapod centra form exclusively from the somite. To investigate what appears to be multiple origins of centra, and to add a necessary comparison with data from other gnathostome models, we treated a range little skate embryos (*Leucoraja erinacea*) with Lugol's iodine and obtained microCT scans of the axial column. The scans reveal a complex construction: an inner calcification constricts the notochord and an outer calcification surrounds both the notochord and the inner structure. Such homoplasy and diversity among vertebrate centra indicate novel developmental patterns that have yet to be explored throughout major vertebrate lineages.

P2.123 CROCKER−BUTA, S.P.*; LEARY, C.J.; University of Mississippi; *scrocker@go.olemiss.edu*

Variation in the responses of male green treefrogs to vocal playbacks: Does relative attractiveness or endocrine state predict mating tactic expression?

Males of many anuran amphibians alternate between calling and an alternative non−calling "satellite" mating tactic. Satellite males remain in close proximity to calling conspecific males and attempt to intercept females attracted to the calling male's vocalizations. Most studies on alternative mating tactics in anurans have focused on how the social−acoustic environment influences tactic decisions. The underlying hypothesis is that males assess the relative attractiveness of other males and adopt a satellite tactic when they are unable to effectively compete with conspecifics. However, vocal playback studies that are commonly used to address this hypothesis report considerable variation in the probability of satellite tactic expression and no such studies have shown that variation in the responses of individuals is attributable to differences in vocal attractiveness. We examined whether variation in the responses of calling male green treefrogs (*Hyla cinerea*) to close−range broadcast advertisement calls (simulating the approach of another male) was related to vocal attractiveness or circulating levels of corticosterone (CORT) and androgens − hormones known to affect the probability of calling behavior in anurans. Calling male *H. cinerea* exposed to broadcast calls either: 1) continued to produce advertisement calls, 2) stopped calling (and adopted a satellite tactic), or 3) responded with aggressive vocalizations. We predicted that males that stopped calling in response to broadcast calls would be as attractive as males that continued to call but that males that stopped calling would have significantly higher CORT levels and lower androgen levels; males that responded aggressively were expected to have the highest androgen levels. We present results from field−based experiments that test these hypotheses.

2.1 CROFTS, S.B.*; NEENAN, J.N.; SCHEYER, T.M.; Univ. of WA, Seattle, Univ of New England, Armindale, Australia, Palaeontological Inst. and Museum, Univ of Zurich, Switzerland; *croftss@uw.edu*

Changes in placodont tooth morphology and replacement

Most placodonts, an extinct clade of Triassic marine reptiles, were durophagous and had highly modified crushing teeth, but evolved from an ancestor that did not consume hard−prey. Over time this group evolved a dental battery that could both effectively break hard shells, and persist as a functional unit despite wear. We used laser scan and CT data to examine changes in tooth shape and replacement rate across placodont phylogeny. More basal species have overall convex maxillary and palatal teeth, with many replacement teeth at various stages of development, but show no replacement pattern. The more derived armored placodonts can be separated into two groups: the Cyamodontidae and the Placochelyidae. Maxillary and palatal teeth of the cyamodontids are moderately convex, and the caudal−most palatal teeth are functionally flat. The cyamodontids have reduced the number of replacement teeth, and replace teeth in functional units. All placochelyid teeth have concave occlusal surfaces, and the caudal−most teeth feature a cusp along the medial edge of the concavity. These organisms have one or two replacement teeth at a time, with at least one replacement tooth growing under the most posterior palatine tooth. These changes in tooth morphology and tooth replacement indicate increased specialization for prey crushing in the cyamodontoid radiation relative to more basal species and support the hypothesis that placochelyid species had a different dietary specialization.

P3.199 CROGHAN, J.A.*; CALDWELL, M.W.; Ohio University, University of Alberta; *jasmine.croghan@gmail.com*

Digital preparation and 3D visualization of small and delicate fossils: Unprecedented detail from Oligocene snakes

Micro−CT scanning has ushered in a new era of visualization for investigators of small vertebrate fossils. Previously, the study of small, fragile fossils, especially those embedded in matrix, required the time consumptive and often deleterious process of micro−preparation to reveal their structures, followed by light microscopy for analysis. These techniques can be damaging to delicate structures such as those found in a snake skull. They also can fail to reveal internal morphology that can be vital for systematic assignments and morphological analysis. Additionally, physical preparation may not even be possible or advisable when a specimen is composed of many articulated bones, as in the many cranial and vertebral elements of an ophidian. The benefits of this technique are demonstrated here, with the full preparation and 3D visualization of a new genus and species of snake from exposures of the Oligocene White River Formation in Wyoming, USA. Features of the internal braincase, the shape of fragile elements like the septomaxilla, and the tracts of the cranial nerves are revealed with this technique for the first time in an extinct ophidian. The 3D models also provide a much greater capacity for future studies, providing broad access to prepared specimens by serving as a digital replica for a specimen that cannot be seen in person or that is too small to cast.

93.3 CROMBIE, TA*; JULIAN, D; Univ. of Florida, Gainesville; *tcrombie@ufl.edu*

Heat and oxidative stress synergize to reduce survival and inhibit expression of stress response genes in the nematode Caenorhabditis elegans

Maintenance of homeostasis may be especially challenging in habitats characterized by large variations in external environmental parameters, such as fluctuations in temperature and redox potential. Deviations in such parameters can temporarily disrupt homeostasis or "stress" an organism, potentially leading to reduced energy, fitness, and survival, depending on the intensity and duration of the stress. We recently showed that heat and oxidative stress interact synergistically to reduce survival in the nematode *C. elegans*. Whereas animals grown at 20 °C and then exposed to heat stress (35 °C for 4 h) had 0 % mortality, and animals exposed to oxidative stress via the redox cycling compound juglone (100 ¼M for 4 h) had 30 % mortality, animals exposed to the combination of heat and oxidative stress (35 °C and 100 ¼M juglone for 4 h) had 91 % mortality, which is 61 % greater than expected assuming an additive model. Here we tested whether impaired expression of stress response genes plays a role in the observed synergistic interaction between heat and oxidative stress. In the case of juglone−induced oxidative stress, glutathione S−transferases (gsts) are expressed to detoxify juglone. Using a reporter strain containing GFP fused to the promoter fragment upstream of gst−4, we found that induction of gst−4 by juglone was inhibited at temperatures greater than 30 °C. We validated this result with qPCR, which showed an 18.7−fold increase in expression of gst−4 in response to 20 ¼M juglone at 20 °C, but only a 5.9−fold increase in gst−4 expression at 33 °C. We found similar, heat−dependent inhibition for other isoforms of gst. These findings suggest that a heat−dependent inhibition of gst induction is at least one mechanism by which heat and oxidative stress synergize to reduce nematode survival.

S2.8 CROSSIN, G.T.; Dalhousie University; *gtc@dal.ca*

Applying the Concepts of Conservation Physiology to the Problem of Seabird−Fisheries Interactions.

High levels of fisheries bycatch remains a problem for marine conservation efforts, and many populations of turtles, sharks and seabirds continue to show decreases as a direct result of incidental mortality. Among seabirds, 19 of 21 albatross species (Diomedeidae, the most globally threatened bird family) are impacted by fisheries, as are many related petrels (Procellariidae) and even penguins (Spheniscidae). Studies examining the frequency and extent of seabird bycatch or overlap with fisheries have benefited from electronic tracking technologies, which provide a useful means for identifying the times and locations where potential risks are greatest. Such studies have been useful for guiding management efforts and minimizing bycatch. I will review the relevant studies, and will also make an argument that physiological tools can further increase our understanding of seabird−fisheries interactions. I will draw from examples in albatrosses and penguins that my colleagues and I are conducting, wherein electronic tracking and physiological techniques are used in tandem. What our preliminary studies show is that individual variation in breeding investment patterns can influence how and when seabirds disperse from breeding colonies, which may contradict assumptions about the breeding biology of seabirds that are often used to guide fisheries regulations. This makes the already complicated job of fisheries management more complex. I will aim to provide examples of future studies that could be useful to conservation and management.

27.3 CROVO, JA*; JOHNSTON , CE; Auburn University, Auburn University ; *jac0058@auburn.edu*

A little less noise there: The effect of traffic on stress and hearing in the blacktail shiner, Cyprinella venusta

Noise pollution from anthropogenic sources is an increasingly problematic challenge faced by many taxa, including fishes. Noise generated from boat engines induces both a significant elevation in cortisol secretion and a shift in auditory thresholds in exposed fishes. Recent studies also confirm that vehicular traffic noise propagates effectively from bridge crossings into surrounding freshwater ecosystems; however, its effect on the stress response and hearing capacities of freshwater fishes has not been examined. The Blacktail Shiner (Cyprinella venusta) is a soniferous hearing specialist found throughout the Southeastern United States and was used as a model to investigate the degree to which traffic noise impacts stress and hearing. Fish exposed to an underwater recording of interstate traffic exhibited a significant elevation in cortisol levels. Hearing threshold shifts for this species occurred at the frequencies of 300 and 400 Hz, where their hearing is most sensitive. Future work aims to elucidate the relationship between cortisol and hearing threshold integrity.

87.2 CROWDER, CM*; MEYER, E; FAN, T−Y; WEIS, VM; Oregon State University, Corvallis Oregon, National Museum of Marine Biology and Aquarium, Checheng Taiwan; *crowderc@onid.oregonstate.edu*

Impacts of temperature on the reproductive physiology of the brooding coral Pocillopora damicornis during different phases of the lunar cycle: Insights from transcriptomics

The timing of reproduction in corals is associated with interrelated environmental variables, including temperature, lunar periodicity, and seasonality. Given the environmental crisis currently facing corals, it is essential to examine the effects that changing environmental variables have on coral reproductive physiology. To evaluate these effects, replicate *Pocillopora damicornis* corals were collected from Nanwan Bay, southern Taiwan and placed in seawater tanks exposed to natural light and subjected to a high (28°C) and a low (23°C) temperature treatment during a monthly reproductive cycle. The timing of reproduction, measured as the number of planulae released per lunar day, was compared for the two temperature treatments. There was a significant shift in the timing of planulae release, with earlier release occurring in corals exposed to higher temperature. Furthermore, to evaluate the effects of temperature on the transcriptomic profiles associated with monthly reproductive cycles, high throughput RNA−Seq analysis was conducted on replicate colonies. Tissue samples were collected at four different lunar phases (new moon, 1st quarter, full moon, and 3rd quarter) and analyzed for global changes in gene expression profiles. This work contributes an unbiased functional genomics approach to expression profiling during reproductive cycles to identify genes in cnidarian reproductive pathways.

P1.190 CULLEN, JA*; MARSHALL, CD; Texas A&M University, Galveston; *jcullen@tamu.edu*

A Preliminary Analysis of Ontogenetic Scaling of Bite Performance Within Three Species of Texas Sharks

Although renowned for consuming large prey, sharks often undergo a series of profound dietary and habitat changes during their ontogeny that may constrain how certain species effectively capture and handle different prey types and sizes. Bite force production in some shark species has been observed to increase significantly from parturition through juvenile stages due to positive allometry of the jaw adducting mechanism. However, our knowledge regarding these patterns is limited to a few species and size classes. Bull (*Carcharhinus lecuas*), blacktip (*Carcharhinus limbatus*), and bonnethead (*Sphyrna tiburo*) sharks are common along the Texas coast, and recent data demonstrates that coastal habitats in Texas function as nurseries for these species. The goal of this study is to compare the biomechanics of bite performance and its constraints on the trophic ecology of these three species over their ontogenetic stages. Maximum gape, gape angle, and bite performance was measured in each species at several ontogenetic stages. In addition, body length and five girth measurements were collected to investigate scaling relationships with jaw morphology and bite performance. Theoretical bite force was calculated to discern relative changes in force production over time. Comparisons among all three species will begin to allow us to characterize the relative performance of their feeding apparatuses from a morphological and biomechanical perspective, as well as its effect on trophic ecology.

79.6 CUNDALL, D*; IRISH, F; Lehigh University, Moravian College; *dlc0@lehigh.edu*

Evolutionary implications of feeding mechanics in two enigmatic snakes, Xenopeltis unicolor and Calabaria reinhardtii.

Xenopeltis unicolor and *Calabaria reinhardtii* are unusual semifossorial snakes, the former hypothesized as a sister taxon of pythons, the latter hypothesized to be a sister taxon of boas. They feed on a variety of small vertebrates, including small and nestling mammals. Both have strange and different skulls but share akinetic properties of the upper jaws. *Xenopeltis* has many small, hinged teeth whereas *Calabaria* lacks teeth on medial upper jaw bones and has fewer fixed and larger teeth on lateral jaw elements. Video records of feeding in 19 *Xenopeltis* and five *Calabaria* revealed no detectable independent movements of the right and left upper jaws and limited (*Xenopeltis*) to moderate (*Calabaria*) independence of the mandibles. Both species initiate intraoral prey transport by pushing the head over the prey and independently advancing right and left mandibles. Snakes used constricting coils or burrow walls or floor to anchor prey. Later phases of intraoral transport recruited the anterior trunk to hold prey while the jaws of both sides worked synchronously in a type of pharyngeal packing. The structure and behavior of the feeding systems of these two enigmatic species show that neither are functionally macrostomate and they share few of the derived traits of their sister taxa. Although both appear to be relics of alethinophidian feeding experiments that apparently left no other descendents, *Xenopeltis* demonstrates that rapid intraoral prey transport of small to moderately−sized prey by snakes does not necessarily require independence of left and right palatomaxillary arches.

P3.74 CUPP, JR., P/V; Eastern Kentucky University; *paul.cupp@eku.edu*

Territorial Defense by Male−Female Pairs in Green Salamanders, Aneides aeneus

Previous studies of green salamanders, *Aneides aeneus*, have shown that resident males exclude intruding males from territories and resident females exclude intruding females (Cupp 1980, Cupp unpubl. data). This study addresses the question, will male−female pairs cooperate in defending against intruding males, or will resident males play a more significant role in territorial defense. Territorial and aggressive behavior of male−female pairs of green salamanders, *A. aeneus*, from southeastern Kentucky were studied during late spring, summer, and fall. When male *A. aeneus* were placed into lab chambers or rock crevices containing resident male−female pairs, resident males responded aggressively while females did not. In 18 trials, resident males won 16 encounters, usually exhibiting overt aggression in chasing intruders from the chamber or crevice. Aggressive behaviors used during these encounters, primarily by resident males, included snapping, snout−pressing, biting, and bite−holds. In five cases, intruding males attempted to initiate courtship behavior with resident females. Females showed little or no aggression, usually remaining off to the side away from the aggressive activity. The lack of aggression of females toward males may be related to the stronger jaw musculature and elongated premaxillary teeth of males that could potentially damage eggs of gravid females. Resident males are the aggressors and defenders against intruding males.

P3.17 CYPHER, A.D.*; ICKES, J.R.; BAGATTO, B.; The University of Akron; *adc51@zips.uakron.edu*

Bisphenol A exposure compromises the cardiovascular response to hypoxia in Danio rerio.

Bisphenol A is an estrogen mimic that also disrupts the hypoxia−inducible factor (HIF−1±) which mediates the cardiovascular system's response to hypoxia via angiogenesis and erythropoiesis. The purpose of this study was to determine if BPA compromises the typical cardiovascular response to hypoxia in zebrafish (*Danio rerio*). Cardiovascular response was assessed by measuring cardiac and vascular parameters including caudal vessel diameter, cardiac output (Q), peak arterial and venous RBC velocity, and vascular branching in hypoxia and BPA treatments. With hypoxia exposure alone, arterial and venous vessel diameters decreased by 23% and 29%, respectively while RBC velocity decreased by 35% and 28%. Arterial and venous diameter decreased with BPA exposure alone, but simultaneous exposure to BPA and hypoxia compounded to further decrease diameter and red blood cell velocity. Heart rate (’H), which was unaffected by hypoxia, had a 17% decrease with BPA alone at the highest concentration. BPA and hypoxia synergized to decrease ’H by 51 and 87% in the 1 mg/L and 5 mg/L BPA treatments, respectively. Q, a product of ’H and stroke volume (SV) was also unaffected by hypoxia alone, but decreased by 54 and 74% in the highest BPA concentrations with co−exposure. Co−exposed embryos at the highest concentration of BPA took 146% times longer to reach 50% hatching compared to 86% longer with hypoxia alone. BPA alone did not delay development. Mortality rates were highest in the 5 mg/L BPA and hypoxia exposure. Our results indicate that simultaneous exposure to BPA and hypoxia synergistically compromises the cardiovascular system's response to hypoxia, slows development, and increases mortality.

S5.11 DABE, E.C.*; SANFORD, R.S.; BOSTWICK, C.J.; WILLIAMS, P.L.; RIVA, A.; KOHN, A.B.; MOROZ, L.L.; University of Florida; *emily.dabe@gmail.com*

Epigenomics of Neuroplasticity in Invertebrates: Part 1. Cell Identity

Establishing and maintenance of neuronal identity are key epigenetic processes where expression of several thousand genes is tightly co−regulated in each cell within neural circuits. These processes are mainly elusive due to the lack of data available to probe epigenetic mechanisms at the single−cell level. Here we evaluate the role of DNA methylation in regulating neuronal identity by combining the power of single−cell transcriptome and methylome data from unambiguously identified single neurons within feeding, defensive and memory circuits. To our knowledge, this is the first time transcriptome and methylome data from the same identifiable single neurons has been compared. Specifically, we applied this integrative approach for examining the role of epigenetic modifications in the patterning of transmitter phenotypes and identified a set of both evolutionary conserved and lineage−specific genes in control of neuronal identity across species.

P1.25 DABE, E.C.*; KOHN, A.B.; WILLIAMS, P.L.; MOROZ, L.L.; University of Florida; *emily.dabe@gmail.com*

Epigenomic Signatures in Basal Metazoans: Histones and modifying enzymes

The presence or absence of histone modifying enzymes in a species can allow for different 3D genomic organizations. This might in turn allow for different body plan development. Here I examined the evolution of histone and histone modifying enzymes across more than nine representative ctenophore species and several molluscs including the classic neuroscience model *Aplysia californica*. Though ctenophores had fewer overall recognizable histone modifying enzymes than molluscs, the lineages showed similar patterns of arginine methyltransferase enzyme (the PRMT gene family) expression during early development. A previously undescribed ctenophore specific histone H3 variant was identified as a candidate providing a novel substrate for epigenetic modifications. Within the ctenophore phylum, the histone mark H3K9me3 associated with transcriptional silencing is exclusively controlled by different classes of enzymes in pelagic versus benthic ctenophores which might contribute to the body plan differences seen in these ctenophore sub−classes.

P2.69 DAGG, JN*; MENDONCA, MT; Auburn University; *jnd0008@auburn.edu*

Thermal minimum sensitivity of the invasive cane toad, Rhinella marina, along latitudinal gradient in Florida.

The invasive cane toad, *Rhinella marina*, originated in South and Central America, but was intentionally introduced into several countries including South Florida around the 1930s for biocontrol purposes (Lever 2001). In comparison to Australia where they travel east to west, the Florida peninsula provides limited longitudinal movement, and they are required to travel along more latitudinal isothermal gradients in order to increase their geographic spread. Invasive tropical poikilothermic species are generally restricted in their northern range expansion due to thermal minimum sensitivity. Our lab has recently revealed established cane toad populations in three novel locations that are located north of the expected geographical range in Florida (Holcombe et al 2007). As part of my research into physiological limitations, tradeoffs, and phenotypic variation allowing for this northern establishment, we measured field critical thermal minimum (CTmin) across an isothermal gradient as an extrapolation of potential thermal sensitivity to colder winter conditions. We hypothesized that colder regions invasion front will have lower thermal minimums than warmer regions origin. CTmin was measured within 12 hours of collection from four separate populations ranging from south to north: Miami, Lake Placid, New Port Richey, and Deland, FL. Toads were placed within a controlled incubator, measured for body temperature every 10 minutes, and failure to elicit a righting response was used for the endpoint. Preliminary results indicate a trend towards lower thermal minimums at higher latitudes. Deland, the northernmost population had individuals that had significantly lower CTmin than individuals from Miami (p=0.039).

P2.133 DAGGETT, A. A.; Trinity University; *adaggett@trinity.edu*

Fall Calving Effects on Weight Gain and Fiber Quality in Ovibos moschatus (Musk Oxen) Calves

Musk ox (*Ovibos moschatus*) tend to give birth in the spring (April−June), which provides adequate time for the provision of resources for growth and maturity before the following winter. However, occasionally birth takes place in the fall (September−November). In this study, I compared weight and fiber quality between spring and fall musk ox calves. I predicted that spring calves would be heavier, grow slower after weaning, and have courser fiber than fall calves. The calves were weighed weekly for eight weeks after being separated from their mothers. Fiber samples were collected in the spring proceeding their calving year and analyzed for fiber quality. There was only one fall calf that showed a smaller starting weight but a faster rate of gain over eight weeks. This calf also had a smaller mean fiber diameter and standard deviation. Finally, the spring calves displayed a slightly higher mean fiber curvature. These results indicate the challenges that fall calves face as they approach winter, and the need for adjustments in their energy allocation.

26.3 DAKIN, R; LENDVAI, AZ*; OUYANG, JQ; MOORE, IT; BONIER, F; University of British Columbia, Virginia Tech, Netherlands Institute of Ecology , Queen's University; *lendvai@vt.edu*

Reciprocal allocation of parental care benefits tree swallows with more female−like plumage color

Females often increase reproductive allocation when paired with attractive mates, consistent with the idea that sexually selected traits influence brood value. Similarly, males are predicted to respond to female traits that signal offspring genetic quality or the female's capacity to contribute parental care. Here, we test the relative influence of a bird's own and its partner's traits on parental care in tree swallows (Tachycineta bicolor), a mutually−ornamented species in which plumage color is related to male and female reproductive performance. Using models of avian color vision, we show that both sexes feed offspring at a higher rate when paired with a partner with greener−hued, more female−like plumage. Partner coloration is a better predictor of an individual's parental behavior than that individual's own color. Results of a path analysis reveal that offspring of females with greener−hued plumage attain greater mass as a result of additional care provided by their fathers. We suggest that both sexes may benefit by investing more care when paired with a highly invested mate, and that this pattern of differential allocation could contribute to the maintenance of trait variation under selection for bluer−hued, more male−like plumage.

P1.32 DALIS, M.*; YANG, H.; FULLER, T.; SANBORN, A.; RESH, C.; BLAKESLEE, A.M.; SANTAGATA, S.; Long Island University−Post, San Francisco State University; *scott.santagata@liu.edu*

Preliminary phylogeographic patterns and species delimitation of phoronid worms

The known species diversity of phoronid worms is low (two genera and 11 accepted species) when compared to brachiopods and many other marine invertebrate groups. As such, our goals were to better estimate phoronid species diversity, detect cryptic species, and discern phylogeographic patterns in select lineages using mitochondrial, ribosomal, and nuclear genes. Overall, molecular data support a closer relationship among *Phoronopsis* spp. and infaunal *Phoronis* spp. that brood embryos in the lophophore. Results from mitochondrial genes suggest that these markers have been subjected to purifying selection among phoronid species. However, specific lineages (e.g., *Phoronis pallida*) exhibit divergent cytochrome c oxidase subunit I (COI) haplotypes that include several (inferred) novel amino acid differences. It is plausible that these differences are the result of adaptive selection from a commensal relationship with thalassinid mud shrimps. Populations of *P. pallida* from sites in Puget Sound, WA and Hatfield, OR, USA contain two distinct and largely concordant genetic parsimony networks. Members of the smaller network exhibit an intermediate level of genetic divergence (~6−7%) from all other *P. pallida* haplotypes. When considering intraspecific genetic distances estimated from other phoronid species, the divergent clade of *P. pallida* may suggest sympatric incipient speciation or possibly a cryptic species. Although further sampling is needed, and AMOVA analyses do not support significant differences among sites, geographic differences in haplotype subclade frequencies are evident.

107.2 DALLMANN, CJ*; SCHMITZ, J; Bielefeld University; *cdallmann@uni−bielefeld.de*

Joint moments in the limbs of a freely walking insect: multifunctional and flexible contributions to propulsion and support

Coordinating forces in a multi−jointed limb challenges biological and artificial walking systems alike. Joints of a limb have to act together to propel the body, stabilize it against gravity, and adjust locomotion to changes in the environment. Studies on insects have provided many insights into the neuromechanics underlying joint control, but little is known about how insect leg joints actually contribute to locomotion when movements are unrestrained and under body load. To further our understanding, we analyzed joint moments in intact, freely walking stick insects. Joint moments were derived from rigid link models of all limbs by combining three−dimensional high−speed motion capture with single leg force recordings. Unexpectedly, we found that the coxa−trochanter joint (part of the "hip"), primarily responsible for providing support, was generally also responsible for modulating propulsion. Large supporting moments at this joint concurrently reduced propulsion at the beginning of stance and increased it toward the end. In the other leg joints, stabilizing forces dominated propulsive forces. Notably, these moments did not necessarily follow fixed patterns. They were particularly variable at the middle leg's femur−tibia ("knee") joint, with a high sensitivity to the leg's extension−presumably to counteract deviations from an orthogonal leg posture. This motor flexibility may arise from strict feedback control involving dedicated force sensors (campaniform sensilla) for each joint. Future studies with manipulated sensory input may help us unravel their importance for walking control and inspire control algorithms for multi−jointed robotic legs.

S7.9 DANIEL, TL*; EBERLE, AL; Univ. Washington; *danielt@uw.edu*

Unsteady forces form in flapping foils and depend on fluid−solid coupling in water but not in air.

Flapping flexing foils and fins face fluid forces that contain significant unsteady terms. To explore how structural mechanics and unsteady flow forces interact to determine lift and thrust performance on heaving and pitching elastic foils we coupled a computationally efficient two−dimensional unsteady vortex method with a finite element method to compute locomotor forces over a wide range of kinematics (frequency as well as heave and pitch amplitude and phase) and structural mechanics (size and stiffness) for flapping foils. We show that the coefficients of thrust and lift in airfoils rarely depend on the coupling of unsteady fluid forces whereas, because of increased fluid density, flow forces are an important determinant of the instantaneous deformation of foils. Thus fluid−structure coupling is crucial in aquatic systems and less so in aerial systems. In airfoils, even in regions of structural resonance, fluid loading never contributes more than 20% to the development of locomotor forces. In contrast, and depending on foil stiffness, that fraction is far greater in water. In both systems, the emergent bending dynamics and foil forcing can be tuned to produce maximum forces.

99.7 DANOS, N*; HOLT, N; AZIZI, E; Univ. of California Irvine; *nikoletta.d@gmail.com*

Age−related changes in the material properties of muscle−tendon units.

Senescence in animals decreases locomotor ability. It is well known that there is an increased amount of collagen held together by stronger covalent bonds within the skeletal muscles that power locomotion. Changes in intramuscular collagen content are also accompanied by changes in the mechanical properties of tendons and aponeuroses acting in series with muscles. However, it is unclear how such changes affect the performance of the muscle−tendon unit (MTU). To understand how changes in mechanical properties of isolated components affect an integrated MTU, we compared the Young's modulus and resilience of all the component tissues that make up the medial gastrocnemius MTU in mature (4 mos) and aged (33 mos) rats. We find a 1.4−2 fold increase in the Young's modulus of all the tissues examined: whole muscles, muscle fiber bundles, tendons and aponeuroses. No significant effect of aging was observed on tissue resilience. Aponeuroses, given their sheet−like structure were tested biaxially. With aging, the stiffness of the aponeurosis along the line of action of the muscle increases significantly with increasing orthogonal strain. The same was not true for young animals or for tissues tested along the transverse direction. Additionally, we show significant architectural differences in old MTUs: muscles become smaller, longer and thinner, with lower pennation angles, while tendon cross sectional area remains unchanged. Our results indicate that due to both biochemical and architectural changes aged muscles became stiffer and had decreased capacity for force production while operating in series with elastic elements that had increased stiffness. These results suggest that age−related structural changes may limit the capacity of muscles to utilize elastic energy storage and change where muscles operate on the force−length curve *in vivo*. Supported by NIH AR055295.

38.1 DANTZER, B*; BENNETT, N; CLUTTON−BROCK, T; University of Michigan, University of Pretoria, University of Cambridge; *dantzer@umich.edu*

Identifying the proximate causes of inter−individual variation pro−social behavior in wild Kalahari meerkats using an experimental approach

In cooperative breeders, socially subordinate individuals generally do not breed and instead contribute to several pro−social (or "helping") behaviors that benefit the offspring produce by the dominant breeding pair. Some subordinates consistently do more helping behavior than others regardless of their age, body condition, or other factors. The proximate causes of this variation in pro−social behavior are relatively unknown. We are investigating the developmental and physiological causes of such inter−individual variation in helping behavior in Kalahari meerkats (*Suricata suricatta*). Meerkats are a cooperatively breeding species and both female and male subordinates exhibit several helping behaviors. Subordinate meerkats will take care of and feed the offspring produced by the dominant breeding pair even though they may not even be related to them. Previous studies in both social and non−social species suggest that elevated glucocorticoid levels may promote self−investment over investment in reproduction, whether it be their own reproduction or investment in the offspring produced by dominants. We performed short−term experimental manipulations of the glucocorticoid levels of female and male subordinate meerkats to determine how they impacted the expression of several cooperative behaviors. We present the results from these experimental manipulations, which emphasize the importance that glucocorticoids play in mediating pro−social behavior.

S11.10 DAS, S.; Colorado State University; *sdas@mail.colostate.edu*
Genetic and hormonal basis of limb regeneration across the Pancrustacea
Regeneration is a developmental process that allows an organism to re−grow a lost body part. Historically, the most studied aspect of limb regeneration across Pancrustacea is its morphological basis and its dependence on successful molting. Although there are distinct morphological differences between Insect and Crustacean regeneration processes, in both cases the phenomenon is initiated via formation of a blastema, followed by proliferation, dedifferentiation, and redifferentiation of blastemal cells to generate a functional limb. In recent years, with the availability of sequence data and tools to manipulate gene expression, the emphasis of this field has shifted towards the genetic basis of limb regeneration. Among insects this focus is on genes that are known to be required during embryonic leg development. RNAi mediated functional studies conducted during regeneration of imaginal discs of *Drosophila melanogaster*, larval legs of *Tribolium castaneum*, and nymphal legs of *Gryllus bimaculatus* reveal that several conserved pathways and transcription factors (Dachshund, Distal−less, Decapentaplegic, Hedgehog) are required for successful leg regeneration. In contrast to insect limb regeneration studies, work by the crustacean biologists has focused on the hormonal basis of limb re−growth. Regeneration in decapods, like *Uca pugilator* and *Gecarcinus lateralis*, occurs in discrete growth phases in tandem with the molt cycle stages. Recent studies have shown that ecdysteroid hormone signaling is necessary for blastemal proliferation. Although the current research emphases of Insect and Crustacean limb regeneration are fairly distinct, the results generated by functional studies of a wide array of regeneration genes will be beneficial to the entire Pancrustacean scientific community for generating testable regeneration models.

1.1 DAVIDOWITZ, G.*; FAVELA, A.; ALLEN, N.O.; GRONENBERG, W.; MOORE, A.F.; University of Arizona; *goggy@email.arizona.edu*
Male and female allocation strategies to head function is mediated by resource limitation
Head functions such as vision, olfaction and feeding are critical to an organism's survival. Here we show how males and females of the Carolina sphinx moth *Manduca sexta* allocate resources to the head differently under different resource constraints (high versus low quality diet and starved versus unstarved larvae). We found that on high quality diet males and females allocated resources (measured as calories per gram) similarly to the head but on poor quality diet, larger females decreased allocation to the head whereas larger males increased their allocation of resources to the head. When starved, larger males and females allocated more resources to the head although males starved after feeding high quality diet did not change allocation. To better understand these patterns, we further investigated whether the sexes differ in how resources are allocated to functions of the head (vision, olfaction and feeding) and whether this changes with resource limitation due to diet quality or starvation. Preliminary data suggests that in general, males allocated more resources to vision (eye size) relative to females under resource limitation. Preliminary results further suggest that males allocate more resources to feeding (proboscis mass) and olfaction (antenna mass) relative to females. We further investigated how these differences in head function translate into allocation to brain volume (optic lobe, olfactory lobe and mushroom body as well as the muscles involved in nectar feeding). Overall, these results suggest that the two sexes of *Manduca sexta* have different resource allocation strategies to head functions and these strategies are dependent on the amount and quality of resources available.

79.7 DAVIS, JS*; WILLIAMS, SH; High Point University, Ohio University Heritage College of Osteopathic Medicine; *jdavis0@highpoint.edu*
Jaw Adductor Motor Pattern During Rhythmic Mastication in Two Carnivoran Species with Divergent Dietary Specializations
Carnivorans share an evolutionary history specializing on a diet of vertebrate prey. As such, they are characterized by a suite of morphological and behavioral specializations that aid in capturing and feeding on animal tissues. However, a few carnivoran species have secondarily specialized on alternative, plant−based diets. In spite of the dietary specialization and diversity among carnivorans, very few studies have investigated their mastication in vivo. The goal of our study was to compare and contrast the masticatory motor pattern of two species of musteloid carnivoran with divergent dietary specializations: a carnivorous mustelid, the ferret (*Mustela putorius furo*) and a frugivorous procyonid, the kinkajou (*Potos flavus*). Electromyography was recorded bilaterally from anterior and posterior temporalis, medial pterygoid, and superficial and deep masseter during rhythmic mastication. Pairwise comparisons were used to determine whether timing of peak muscle activity differed between the jaw adductors. Both species exhibited near−simultaneous peak activity of all jaw adductors. This motor pattern is likely to facilitate concentration of muscle force for rapid vertical jaw movements used for slicing animal tissues. However, interspecific differences suggest specializations in the kinkajou motor pattern may be associated with transversely−oriented grinding jaw movements, which may assist them in processing fruit.

P1.49 DAVIS, LM*; ROBINSON, CD; ANDRE, BM; JOHNSON, MA; Trinity University; *ldavis1@trinity.edu*
What makes a lizard invasive? Behavioral and neural correlates of invasion success
To understand what makes an invasive species successful, we must understand the behavioral mechanisms these invaders employ. In this study, we examined traits associated with the "boldness" behavioral syndrome (i.e., aggression, general activity levels, and behavioral flexibility), and the morphology of brain regions associated with those traits. We assessed boldness by conducting a series of four behavioral tests designed to measure aggression towards prey, aggression towards a conspecific, overall activity in an open field test, and flexibility in completing a novel task. We compared these measures in two species pairs: the native green anole (*Anolis carolinensis*; n = 12) and the invasive Cuban brown anole (*Anolis sagrei*; n = 15), and the native Texas banded gecko (*Coleonyx brevis*; n = 4) and the invasive Mediterranean house gecko (*Hemidactylus turcicus*; n = 8). We found that the brown anole was "bolder" than the green anole in two of the four behavioral tests conducted, but there was no difference between the two gecko species for any of the behavioral tests conducted. In contrast to our predictions, the native green anole had a larger brain−to−body mass ratio (a general indicator of behavioral flexibility) and a larger brain diameter than the invasive brown anole. However, the Mediterranean house gecko had a larger brain−to−body mass ratio than the native Texas banded gecko, consistent with the predicted pattern. Our current work examines cellular morphology in regions of the brain involved in aggression (the amygdala) and exploratory behavior (the hippocampus and hypothalamus) by measuring the neuron size and density in these regions. Together, these results will provide one of the first studies of the relationships between brain and behavior in invasion biology.

P3.156 DAVIS, J.L.*; MCCLOUD, E.S.; FIELD, B.S.; University of Southern Indiana; *jldavis2@usi.edu*

Non−uniform Material Properties Observed in Lycaenidae Wing Veins

Insect wing flexural stiffness has already been shown to behave non−linearly along the wing span in other insect wings. We have shown that flexural stiffness of butterfly wings peak at approximately the 40−60th percentile of the total wing span. However, little work has been done to understand how each component of the wing (Veins and Membrane) contributes to the total stiffness of the wing. Separating the key components of the butterfly wing allows not only for the study of the contribution of flexural stiffness of each component, but allows for study of the material properties through finite element modeling. Here we use finite element models to show that material properties are not uniform throughout the *Lycaenidae* wing veins. These results have direct implications on flight; they could play a roll in the passive "clap and fling" mechanism observed in these butterflies.

61.3 DAVIS−BERG, E.C.*; MINBIOLE, J.E.; LABARBERA, M.; Columbia College Chicago, University of Chicago; *edavisberg@colum.edu*

Care and Use of Invertebrates in the classroom (on the cheap)

Invertebrates are an excellent addition to undergraduate classrooms, providing learning opportunities in behavior, ecology, genetics, and many other areas of life science. Many of these benefits are best realized from extended cultures of organisms, but scientists and teachers often do not know how to keep invertebrate animals alive, healthy and exhibiting normal behavior for an extended period. Extended culture lowers costs so that instructors do not need to collect or order new animals every term and permits longer experiments and activities in the classroom. We explain basic husbandry techniques for a variety of invertebrates including marine, freshwater, and terrestrial animals and provide instructions for proper disposal or preservation of cultures. Additionally, we outline helpful tips such as keeping slugs from turning into mush; fruit fly food recipes; feeding jellyfish; exploring local ponds, vacant lots, supermarkets, and more. We give simple lesson plans for invertebrate activities that go beyond supplier's information sheets. Examples include: keeping jellyfish alive without a special tank, examining the radula from a marine snail, observing courtship behaviors and learning in fruit flies, trail following in a variety of invertebrates, tube ventilation in marine worms, and more. Our advice is drawn from a combined fifty years of trial and error. Instructors without previous experience in extended cultures can keep invertebrates in their classrooms and teaching labs with these effective protocols. We encourage others to add to this store of practical advice.

S12.1 DAY, Steven W; Rochester Institute of Technology; *Steven.Day@RIT.edu*

Mechanical Models of Suction Feeding

Suction feeders generate a flow of water into their mouth with a rapid and highly coordinated movement of multiple muscle and skeletal elements in the jaw. Successful prey capture is dependent on the fluid flow and the predator is able to control and modulate aspects of the fluid flow through skeletal mechanics. Hydrodynamic forces primarily cause the forces resisting skeletal movement and associated mouth opening. A model of the skeletal mechanics and their relation to fluid mechanics is key to a full understanding of suction feeding performance. Despite this obvious relationship between the musculoskeletal movement and generated fluid flow, functional models of the feeding within the fish are relatively simple and not generally not complete or predictive of suction performance. This talk summarizes the recent history, current state, and potential future of mechanical models of suction feeding. This includes: 1) Heuristic explanations of musculoskeletal mechanics, 2) Application of mechanical advantage from levers and four bar linkages to predict jaw opening speed, 3) Suction Index as a model to predict pressure based on musculoskeletal morphology, 4) Numerical modeling of multiple skeletal and muscle models, and 5) the potential utility of physical models of suction feeding.

73.4 DAYAN, D I*; CRAWFORD, D L; OLEKSIAK, M F; University of Miami − Rosenstiel School of Marine and Atmospheric Science; *ddayan@rsmas.miami.edu*

Population genomics of rapid adaptation in Fundulus heteroclitus exposed to power station thermal effluents

Temperature is one of the most important environmental parameters affecting an organism's physiology, yet our understanding of evolutionary adaptation to rapidly changing environmental temperature is still incomplete. This study utilizes genotyping−by−sequencing derived genetic markers to examine genetic structure and adaptation among natural fish populations exposed to thermal effluents near power generating stations. Thermal effluents impact nearby estuaries and can raise mean water temperature by 1−3°C. Using a combination of outlier scan and population genetic structure clustering approaches, this study reveals substantial population structure among exposed and unexposed populations of the estuarine fish, *Fundulus heteroclitus*, that is most parsimoniously explained by evolution by natural selection. Replicate populations across different thermal effluents demonstrate both unique and shared adaptive responses. Further analysis provides insight into whether selection has acted on *de novo* mutation or the standing genetic variation among the populations recently adapted to increased temperature.

23.3 DE JONG, D.; SEAVER, E.C.*; University of Florida; *seaver@whitney.ufl.edu*

Hox genes and re−establishment of anterior−posterior patterning during Capitella teleta posterior regeneration

Hox genes encode transcription factors that play essential roles in anterior−posterior patterning during development of most metazoans. While most research has concentrated on their involvement in development of the body plan, their role in regeneration is poorly understood. The annelid *Capitella teleta* contains 12 Hox genes, 11 of which are expressed in staggered anterior−posterior domains along the body axis. *Capitella* displays robust posterior regeneration following transverse amputation at most axial positions along the body, although regeneration cannot proceed following amputation anterior to segment 6. We are investigating the dynamics of Hox gene expression during posterior regeneration in *Capitella*, and we have examined Hox gene expression at various time points following transverse amputation between segments 10 and 11. Two Hox genes, *post2* and *hox3*, are expressed in unique domains at the new posterior end of the animal, within 4 hours (*post2*) or 48 hours (*hox3*) of amputation. In contrast, other Hox genes maintain expression domains similar to uncut controls. Recently we uncovered an axial position dependence for *post2* expression; amputations anterior to segment 9 do not express *post2* after 24hr, but those posterior to segment 9 do. We are currently investigating how expression of other Hox genes respond to amputations at multiple axial positions, and whether their expression is tied to the anterior boundary that defines regenerative success. This work will help elucidate rules governing the dynamics of the Hox code in *Capitella* regeneration, and lead to a greater understanding of the contribution of Hox genes to re−patterning during regeneration.

30.4 DE MEYER, J.*; IDE, C.; BELPAIRE, C.; GOEMANS, G.; ADRIAENS, D.; University Ghent, Belgium, Research Institute for Nature and Forest (INBO), Belgium, Research Institute for Nature and Forest (INBO), Belgium; *jendmeye.demeyer@ugent.be*

The search for the onset of head shape bimodality in European eel (Anguilla anguilla)

The life cycle of the European eel (*Anguilla anguilla*) remained a mystery until the 20th century, when Schmidt discovered that the Sargasso Sea was its spawning area. However, many aspects of the eel's life cycle remain poorly understood. Among these is the bimodal distribution in head shape, with broad− and narrowheaded phenotypes reported in the yellow eel stage. Although this has been linked to dietary preferences of the yellow eels, very little is known about why, how and when this dimorphism arises during their ontogeny. To find out whether this dimorphism indeed appears in relation to trophic niche segregation, we examined head shape variation at an earlier ontogenetic stage, the glass eel stage, as at this stage, eels are considered to be non−feeding. Head shape was studied in glass eels from the Yser river mouth, the Leopold Canal and from the rivers Severn, Trent and Parret by both taking measurements (head width/head length) and using an outline analysis. Our results show that there's already considerable variation in broadness and bluntness of the head at the glass eel stage, but no unambiguous support for head shape dimorphism was found. However, as variation in head width/head length ratios in non−feeding glass eels shows a similar range as in feeding yellow eels, head shape in European eel might be at least partially determined through other mechanisms than trophic segregation.

P1.39 DEAL, ME*; SMITH, KE; ARONSON, RB; AMSLER, MO; MCCLINTOCK, JB; Florida Institute of Technology, University of Alabama at Birmingham; *mdeal2011@my.fit.edu*

Distribution and abundance of benthopelagic hydromedusae in deep water off Anvers Island, western Antarctic Peninsula

Scant data are available on the abundance and distribution of benthopelagic hydromedusae in Antarctic waters. We conducted a photographic survey of the sea floor off Anvers Island, western Antarctic Peninsula (WAP) during November−December 2013. Our survey encompassed the slope and shelf environment from approximately 400−2000 m depth within a 100−km^2 study area. We describe the distribution and abundance of dense populations of hydromedusae in the deep water off the WAP. The data provide a record of hydromedusae in a largely unstudied region of the world.

42.4 DEBAN, SM*; SCALES, JA; University of South Florida, Tampa; *sdeban@usf.edu*

Evolution of high performance and thermal robustness of salamander tongue projection

Plethodontid salamanders are characterized by specialized feeding mechanisms, with ballistic and thermally robust tongue projection having evolved multiple times. All ballistic taxa project their tongues with an elastic−recoil mechanism that not only amplifies muscle power but also confers relative thermal insensitivity to projection. To understand the morphological foundation of this derived mechanism, we measured the performance of tongue projection and retraction at a range of temperatures and examined the morphology of the tongue apparatus in several ballistic and non−ballistic species from across the plethodontid phylogeny. Using phylogenetic comparative methods we found that taxa with greater projector muscle mass relative to projectile (i.e., tongue) mass produce higher power output and project their tongues with greater thermal robustness. This relationship appears to be largely driven by the evolution of relatively large projector muscles, high power output and high thermal robustness in the clade containing *Hydromantes* and *Ensatina* compared to its sister clade containing *Plethodon*. These results suggest that both thermal robustness and high power output are enabled by the ability to accommodate reduced mass−specific work of the projector muscle afforded by its relatively larger mass.

19.2 DELANEY, D.M.*; WARNER, D.A.; Univ. of Alabama, Birmingham; *dmdelane@uab.edu*

Does Inter−age Class Competition Influence Habitat Use in a Territorial Lizard?

All organisms have specific habitat requirements that allow them to properly function in their environment. For many organisms, optimal habitats differ across age classes, and individuals shift habitat choice as they age. Field observations of the brown anole lizard (*Anolis sagrei*) suggest that juveniles perch in open−canopy areas on shorter vegetation whereas adults reside in forested areas on higher vegetation. We manipulated adult densities in mesh enclosures with artificial trees to examine the response of juvenile habitat choice. We found that juveniles chose lower perches when adults were present, suggesting that adults force juveniles to less preferred habitat and that inter−age class competition contributes to the observed ontogenetic differences in habitat choice in the field. Perch width, substrate use, and orientation were all affected by time of day. Lizards perched on leaves much more frequently at night than during the day, which is consistent with observations of other *Anolis* species. Lizards had no preference in orientation when perched on horizontal branches during the day. However, lizards strongly preferred to face the trunk of the tree at night. This study suggests that adult *A. sagrei* may drive ontogenetic variation in habitat use in this species, and that time of day affects how *A. sagrei* uses its habitat.

38.4 DELANEY, DM*; ROBERTSON, MW; WATSON, CR; Millikin University; *dmdelaney4@gmail.com*

Influence of relatedness on cannibalism in successive instars of Phidippus audax (Araneae: Salticidae). INFLUENCE OF RELATEDNESS ON CANNIBALISM IN SUCCESSIVE INSTARS OF PHIDIPPUS AUDAX (ARANEAE: SALTICIDAE).

Kin selection is common in nature among cannibalistic organisms that have a high kin encounter rate. The jumping spider *Phidippus audax* (Araneae: Salticidae) has a high, localized population density and is widely distributed. We studied the effects of kinship on cannibalism in the second through the seventh instars of this species. We observed differential kin selection in various stages of the life cycle for related vs. unrelated pairs of spiders. Cannibalism was minimal in the second and third instars as a product of indirect, inclusive fitness. Although cannibalism did occur in the fourth through seventh instars in a manner consistent with a dispersal dependent hypothesis, this may have been caused by malnutrition rather than lack of kin−selection or recognition.

P1.144 DELMANOWSKI, R.M.; TSUKIMURA, B.*; California State University, Fresno; *briant@csufresno.edu*

Characterization of Vitellins from Petrolisthes cinctipes and Petrolisthes manimaculis and the Development of a Compatible ELISA

Petrolisthes cinctipes and *P. manimaculis* are two closely related species of anomurans that live in the upper intertidal zone along the Central California coast. The objective of this study is to isolate, purify, and characterize vitellins from these crabs, characterize anti−vitellin, and develop an ELISA. Vitellin, an egg yolk protein, is metabolized from a larger hemolymph protein, vitellogenin (Vg). We set to describe the egg yolk proteins of these two animals. Vitellin was isolated from homogenized ovaries through a series of centrifugations and salting out extraneous proteins with saturated ammonium sulfate. After dialysis, SDS−PAGE was used to determine vitellin subunit composition. Interestingly, the conspecifics, *P. cinctipes* and *P. manimaculis*, vitellin consist of three major subunits that have a MW of 91±2 kDa, 82±2 kDa, and 65.7±1.4 kDa. Two minor bands were also detected at 111±2.3 kDa and 40±1.3 kDa. It is possible that these minor bands are either a dimer of the three main bands or a metabolite of a larger band. Through gel filtration chromatography, the native molecular mass of *P. cinctipes* vitellin was found to be 301±14 kDa with a small doublet. The native molecular mass for *P. manimaculis* vitellin is 324±11 kDa with a more pronounced doublet of 160±13 kDa. A Western blot was used to test the reactivity of the *Petrolisthes* vitellin with various antibodies. It was found that two of the major *Petrolisthes* vitellin subunits, 93±2 kDa and 65.7±1.4 kDa, successfully bind with *Homarus* anti−vitellin antibodies. It is now possible to develop an ELISA that can be used to measure the concentration of vitellogenin in the hemolymph of both species.

P3.32 DEMORANVILLE, K.J.*; RUSSELL, D.E.; HUSS, J.M.; SCHAFFER, P.J.; Miami University, Beckman Research Institute; *demorakj@miamioh.edu*

Characterization of metabolic and muscle plasticity in a Neotropical migrant, Dumetella carolinesis (Gray Catbird)

Flexible and reversible phenotypes across the annual cycle allow birds to match fluctuating environmental and ecological demands. Varying energetic demands associated with time of year have been demonstrated to drive metabolic and muscle plasticity in birds, and this study examines physiological plasticity in organismal metabolism, muscle structure, and muscle metabolism. Across the Gray Catbird's annual cycle, cold induced metabolic rate (VO2summits) is highest during migration and lowest during tropical wintering. Heart and flight muscle mass is greatest during migratory periods compared to non−migratory periods. Mitochondrial function of the pectoralis muscle remained constant across the annual cycle as quantified by aerobic regulatory enzyme activities (citrate synthase and cytochrome C oxidase). The Gray Catbird displays phenotypic plasticity at the organismal and tissue levels during migration compared to non−migratory periods.

P3.55 DEPAOLA, T.S.*; RODDA, C.; ALBERTS , J.R.; Indiana University − Bloomington, Indiana; *tsd42@nau.edu*

Modulation of Mouse Maternal Behavior by Pup Phenotype and Familiarity

Modulation of Mouse Maternal Behavior by Pup Phenotype and Familiarity By: Taran S. DePaola, Cathleen Rodda, and Jeffrey R. Alberts The quantity and quality of maternal care is known to shape the course and outcome of offspring development, but less understood is whether and how offspring characteristics can affect the expression of maternal behavior. We observed and quantified the maternal behavior of C57BL/6J (C57) mouse dams as they interacted with pups in a controlled setting. Mouse dams were habituated to an observation cage with daily, 4−hr exposures to an illuminated chamber containing 60ml of home−cage bedding. In Experiment 1, habituated dams were presented with unfamiliar postnatal day (PD) 4 pups in the observation chamber for 3 hours. The next day, the dam's own PD 5 pups were presented. Both sessions were video−recorded for analysis. Analyses suggest that dams displayed more maternal behaviors to their own pups than to unfamiliar C57 pups. In Experiment 2, C57 dams were similarly tested with oxytocin knock−out pups (OTKO) and wild type (WT) pups of the same strain (B6;129S). We found dams did not display differential maternal behaviors to the two types of pups. Results suggest, in addition to familiarity, pup phenotype can alter quantitative aspects of maternal behavior. Phenotypic differences in offspring can be associated with maternal behaviors exhibited by the mouse dam, and those maternal behaviors are in turn modulated by pup genotype and phenotype.

P3.111 DEPAOLO, SE*; TRONSTAD, L; DILLON, ME; University of Wyoming; *sdepaolo@uwyo.edu*

Are early blooming, specialist plants more susceptible to phenological mismatch in changing climates?

Climate change is shifting phenology of diverse organisms and plant−pollinator mutualisms may be particularly sensitive to climate−driven phenological shifts. Flower characteristics, including when they bloom and whether they attract generalist or specialist pollinators, may determine the degree to which phenological changes affect plants and their target pollinators. In particular, potential differences in pollen limitation between these flower types will help determine fitness impacts of phenological mismatch. We measured pollen limitation of four forb species (*Delphinium nutallianum, D. bicolor, Opuntia polyacantha, Allium textile*) that are common in the sagebrush steppe ecosystems of Wyoming and that vary in bloom time (early vs. late) and flower type (attracting generalist vs. specialist pollinators). We hand−pollinated and bagged (to exclude pollinators) flowers of each species and left a control group of flowers of each species open to animal pollinators. We allowed flowers to senesce before collecting fruits and seeds of each flower. Flowers denied pollinators produced fewer, smaller seeds, suggesting little potential for autogamy in these species. Hand pollinated flowers produced more seeds of greater mass compared to open control flowers, suggesting strong pollen limitation in all four forb species. Open flowers on the earliest blooming flower, a generalist species, *A. textile*, produced fewer seeds than did open flowers on the early blooming specialist, *D. nutallianum*, potentially due to limited pollinators and low nutritional rewards of generalist flowers. Climate change may shift the phenology of plants and pollinators potentially limiting the size and number of seeds that native forbs produce, especially plants depending on specialized pollinators.

24.2 DESANTIS, LM*; BOWMAN, J; LAHODA, CV; BOONSTRA, R; BURNESS, G; Trent University, Peterborough, ON, Ontario Ministry of Natural Resources and Forestry, Peterborough, ON, University of Toronto Scarborough, ON; *lannadesantis@trentu.ca*

Responses of New World Flying Squirrels to Capture Stress: Functioning in the Absence of Corticosteroid Binding Capacity

Northern (*Glaucomys sabrinus*) and southern (*G. volans*) flying squirrels have glucocorticoid (GC) levels that are considerably higher than those in the majority of vertebrates, but oddly, this is coupled with virtually no binding capacity for their GCs via the protective carrier protein, corticosteroid−binding globulin. These GC values however, come from blood samples taken after squirrels had been in live−traps for 2−3 hours. Obtaining baseline values for endocrinological and haematological variables is valuable for assessing the response of vertebrates to events in their environment, and thus in the current study, we compared baseline plasma total cortisol levels (collected within 3 minutes of capture) to acute stress−induced levels in the same individuals (collected after 30 minutes of trap−restraint stress) to evaluate stress axis−function in two species with unique physiology. We also measured five other indices of stress responsiveness (androgens, free fatty acids, glucose, hematocrit and neutrophil:lymphocyte ratio) and compared these with values reported for other vertebrates. In both species, baseline cortisol levels were among the highest reported for any vertebrate, exceeding stress−induced levels in most other species. Although, as predicted, cortisol and free fatty acids increased with acute stress, the remaining variables displayed patterns that differed from most other species. The selective factors driving the stress response in New World flying squirrels remain elusive, but this lineage may provide an interesting new model for the study of stress axis function and its evolution among wild, domestic and laboratory vertebrates.

39.6 DEVICHE, P.J.*; BITTNER, S.; CARPENTIER, E.; DAVIES, S.; VALLE, S.; Arizona St. Univ., Tempe, Univ. Poitiers, France; *deviche@asu.edu*

Short−term vs. delayed endocrine and metabolic responses to acute stress in a male songbird

Wild birds are used extensively to study the effects of acute stress on the hypothalamic−pituitary−adrenal axis. By contrast, we know little in these birds about the effects of acute stress on other endocrine systems and metabolism, and even less about the persistence of these effects and their behavioral consequences once subjects are returned to their habitat. We caught adult male Rufous−winged Sparrows, *Peucaea carpalis*, bled them within two minutes (Initial) and again after 30 min of restraint (Stress), released them on site, and re−captured and re−sampled them the next day. Acute stress significantly elevated plasma corticosterone (CORT; 313%) and significantly decreased plasma testosterone (T; 51%), uric acid (UA; 37%), and glucose (GLU; 7%). One day later, plasma CORT and UA had returned to Initial levels but plasma T remained decreased, and plasma GLU was 30% above Initial level. Thus, a brief stressful event had persistent endocrine and metabolic consequences for blood parameters. The stress−associated decrease (within 30 min) followed with increase (next day) in plasma GLU may reflect its rapid utilization followed with CORT−mediated increase of production and secretion. The stress−related decrease in plasma UA was negatively correlated to the corresponding increase in plasma CORT, suggesting an inhibitory effect of CORT on plasma UA. The aggressive response to conspecific song playback did not differ before first capture and before re−capture, suggesting no close temporal relationship between plasma T and the expression of aggressive behavior. In sum, a brief stressful event elicits marked endocrine and metabolic changes, some of which (CORT, UA) are labile whereas others (T, GLU) persist for at least one day after release. Supported by NSF Award 1026620 (P.D.)

P2.129 DEVICHE, P.*; BITTNER, S.; DAVIES, S.; GAO, S.; HUTTON, P.; VALLE, S.; Arizona St. Univ.; *deviche@asu.edu*
Food availability modulates the reproductive axis sensitivity to GnRH and LH in a male songbird

The energetic status of wild vertebrates can profoundly affect their reproductive system activity, but the mechanisms mediating these effects remain poorly understood. Addressing this issue, we investigated the reproductive system activity of captive adult male Abert's Towhees, *Melozone aberti*, that were either subjected to mild chronic food restriction (FR) to decrease their body condition or fed *ad libitum* (CTRL), and were initially exposed to short days (SD) followed with transfer to long days (LD). The food restriction regime decreased the body mass, fat reserves, and pectoral muscle size. Transfer from SD to LD increased the size of the cloacal protuberance (a proxy for testis size) and plasma testosterone (T). These increases were similar in FR and CTRL birds, suggesting that food restriction does not limit photoinduced testicular growth or baseline T secretion. Under SDs, an injection either of gonadotropin−releasing hormone (GnRH) or of luteinizing hormone (LH) increased T in CTRL but not FR towhees. Thus, food restriction during SDs attenuated the pituitary gland and/or testis sensitivity to acute stimulation. During LD exposure, T increased in response to GnRH or LH challenge in both FR and CTRL birds. In addition, T increased more in CTRL than FR birds after LH, but not GnRH injection. This observation again suggests that the androgen response of the testes to LH stimulation is food availability− and/or energetic status−related. Collectively, the data identify food availability and/or energetic status as important factors modulating the sensitivity of the reproductive axis to GnRH or LH stimulation, and indicate that this modulation is day length−dependent. Support: ASU GPSA Award (S.D.) and NSF Award 1026620 (P.D.)

71.3 DEVRIES, MS*; TAYLOR, JRA; Scripps Institution of Oceanography, UC San Diego; *mdevries@ucsd.edu*
The effects of ocean acidification on the structure and material properties of the mantis shrimp exoskeleton

Mantis shrimp are fierce predators that use specialized appendages to deliver fast and forceful punches to their prey. This predatory strike is powered by the energy storage capacity of the calcified exoskeleton. Given the substantial evidence that calcified structures of many marine organisms are affected by acidified ocean conditions, we studied the potential effects of ocean acidification (OA) and increased temperature on the mantis shrimp exoskeleton. Specifically, we examined the structure, mineral content, and material properties of the raptorial appendage and carapace exoskeleton. Individuals of the mantis shrimp species, *Neogonodactylus bredini*, were maintained in three water conditions: ambient pH and temperature (7.9, 27°C), reduced pH and ambient temperature (7.6, 27°C), and reduced pH and increased temperature (7.6, 30°C) for six months. At 3 months, we subsampled eight animals per treatment to test for short−term responses to OA. Exoskeleton structure and calcification were examined using scanning electron microscopy and energy−dispersive x−ray spectroscopy, and hardness and stiffness were examined using nanoindentation. Our results show that OA conditions do not significantly affect the mantis shrimp exoskeleton; cuticle structure, thickness, percent calcium, hardness, and stiffness of the appendage and carapace did not differ across treatments. These findings suggest that the integrity of the raptorial appendage, and thus the strike, is not compromised by moderate reductions in pH. The tropical, shallow waters that *N. bredini* inhabits exhibit seasonal and often daily fluctuations in pH and temperature. It is therefore likely that mantis shrimp, and possibly other reef flat crustaceans, are able to compensate for the OA conditions that could otherwise alter the exoskeleton and impact feeding mechanics.

13.4 DEWAR, EW*; DODGE, HM; Suffolk Univ., Boston; *edewar@suffolk.edu*
Evolutionary morphology of the shoulder in swimming mammals

We used linear measurements to study the changes in the proportions of the humerus and scapula of swimming mammal groups, within interest to glean information about the evolution of terrestrial mammals back to the water. We found differences between homologous structures of the shoulder by analyzing photographs of humeri and scapulae from 26 mammalian species (n = 413) that we classified as terrestrial, semi−aquatic, or aquatic in locomotory mode. Our data about skeletal morphology were used to reconstruct the position and function of the muscles of the shoulder joint.

We found highly significant differences ($p < 0.0001$) in the relative size of the length of the greater tuberosity and the narrowest width of the humerus for the three locomotory modes. We found significant differences (all $p < 0.02$) among the relative lengths of (1) the scapular spine and (2) the metacromion, (3) the distance between the metacromion and the acromion. These differences remained in the face of some intraspecies variation associated with body size. For example, in terrestrial mammals the greater tuberosity is less than half the total length of the humerus, but in aquatic mammals it is more than half. In terrestrial mammals, the posterior margin of the scapula is nearly straight, but is more rounded in swimmers, particularly those that use pectoral oscillation. Semi−aquatic species are intermediate in shape and proportions for these characteristics. The size of the deltoid's insertion is the primary influence on humeral measurements, but the scapular shape reflects the action of many more muscles for both locomotion and posture.

P3.3 DEWAR, EW; Suffolk Univ., Boston; *edewar@suffolk.edu*
Evolving hybrids: Converting a traditional evolution course to a hybrid delivery format

Hybrid courses promise to be a blend of the best aspects of online and face−to−face classes. These courses differ from fully−online classes in that students meet weekly, but more learning is shifted to self−directed online modules and reading assignments. What are the pitfalls of converting a traditional face−to−face course to a hybrid format? Are hybrids merely useful for institutional efficiency or is student learning enhanced with this meeting style?

I "hybridized" an evolution course to determine some best practices for design that would emphasize both biological knowledge and scientific thinking. Our time together in class was not used for lectures, because introduction of the primary course content was shifted to online modules that were completed before class. I used the modules to guide reading in the text, to introduce content with video slideshows, and to lead them in online data−acquisition simulations. I checked on their comprehension and interpretation of data with weekly online assignments. Because this class was designated as a reading−and−writing intensive course, students also wrote responses to their reading of the Origin of Species and recent peer−reviewed papers. Our face−to−face time was mainly spent in discussion of Darwin's ideas and how they were (or weren't) understood differently today.

Converting an existing course can have some drawbacks. Overbuilding the online modules can make them too time−consuming for the credit earned by a student. Like fully−online courses, the need for documentation requires a lot of up−front time to complete. Hybrid courses can have a larger enrollment than traditional ones, so there is more grading and administrative coordination. Student learning is not necessarily hindered by the hybrid format, but faculty need to be mindful about student engagement and connection to the course.

52.2 DEWHIRST, O. P.*; HUBEL, T. Y.; MYATT, J. P.; JORDAN, N. R.; MCNUTT , J. W.; WILSON, A. M.; Royal Veterinary College, Birmingham University, Botswana Predator Conservation Trust; *odewhirst@rvc.ac.uk*

Preferred speeds and gait classification in free ranging African carnivores

While animals are capable of moving at a broad range of speeds within each gait, they tend to use a relatively narrow set of preferred speeds. Explanations for this behaviour include maximising the efficiency of locomotion and minimising stresses on the musculoskeletal system. Previous work has investigated the use of preferred speeds, in a variety of animals, with measurements made on treadmills and observations of free ranging animals. These studies, however, have been limited by the accuracy with which speed could be measured, by the amount of data that could be collected and, especially in free ranging animals, with difficulty in determining gait. To address these issues, we have developed and deployed animal tracking collars containing a high resolution and accurate Global Positioning System and inertial (three axis accelerometer, gyroscope and magnetometer) sensors. Furthermore, we have shown how the application of a relatively simple unsupervised machine learning method can be used to classify gait using data from only the vertical axis accelerometer. The tracking collars have been used to collect data from lion (*Panthera leo*), African wild dog (*Lycaon pictus*) and cheetah (*Acinonyx jubatus*) in the Okavango Delta in Northern Botswana over a period of several months. Our equipment and analysis methods have enabled us to show how these free ranging animals utilise distinct preferred speeds within their different gaits and fit the hypothesis of dynamic similarity.

13.1 DIAMOND, K. M.*; SCHOENFUSS, H. L.; BLOB, R. B.; Clemson Univ., St. Cloud State Univ.; *kmdiamo@clemson.edu*

Fast−start escape behavior in juvenile Hawaiian gobies, Sicyopterus stimpsoni: testing effects of flow speed and stimulus direction

Studies have typically evaluated the escape responses of fishes in still water; however, such environmental conditions are rare in nature due to waves and currents exposing fishes to unsteady and/or directional flow. We examined the effects of water flow on the escape behavior of fish, using juveniles of the amphidromous Hawaiian gobiid *Sicyopterus stimpsoni* as a model. After metamorphosis from marine larvae, juvenile *S. stimpsoni* enter fresh water streams and, as they commence migration to adult habitats, they must avoid a sit−and−wait predator, the sleeper *Eleotris sandwicensis*. Thus, in nature, these fish must escape predation while exposed to rapidly flowing water. We used high−speed video (1000 Hz) to measure the escape trajectories of juvenile gobies while exposing them to different water velocities encountered in natural streams (0, 15, and 30 cm/s), using a custom−built flow tank. Trials were conducted with stimuli (water jets) imposed from three different directions (front, side, and rear). MANOVA results indicate significant differences in escape trajectories among the different flow speeds and attack directions. High flow speeds showed the greatest percentage of trials in which stimuli failed to elicit an escape response. However, when responses were elicited, escape angles were greater when fish were attacked from the front than from other directions. Given the presence of varying flow conditions in aquatic habitats, this environmental context is relevant to the escape responses of many fish species.

80.1 DICK, T.J.*; CLEMENTE, C.J.; Simon Fraser University, Burnaby, University of Queensland, St Lucia; *taylor_dick@sfu.ca*

Scaling of muscle architecture in arboreal and terrestrial Varanus lizards: from V. tristis to V. komodoensis

Some animals appear to counter size−related increases in bone and muscle stress through changes in posture, with larger animals adopting an upright posture. Varanid lizards are a model system to study scaling as they exhibit a 3−fold increase in body size within a single genus, reducing phylogenentic influences. We would expect these lizards to become more upright as they increase in size, but posture does not change with body size. Instead, variations in posture are associated with habitat arboreal species adopt a more crouched posture than terrestrial species. However, the underlying morphological basis for these differences in both posture and kinematics with habitat remains unclear. We present the first set of data of hindlimb muscle architecture, kinematics, and scaling of muscle properties in arboreal and terrestrial varanids. Architecture and masses of 12 hindlimb muscles were recorded for 15 varanids (body mass: 0.1 to 40 kg). Fascicle lengths scale with geometric similarity ($M^{0.33}$) but muscle mass for thigh retractors do not scale with $M^{1.0}$, but rather with a larger exponent $M^{1.17}$. Terrestrial lizards have longer fascicles in the ankle flexors and extensors, likely related to the increased ankle range of motion during running in terrestrial as compared to arboreal species. Further, we collected 3D kinematics and ground reaction forces for 7 individuals running at various speeds. We look at differences in joint moments during running to determine how muscle stress changes with size and posture. Understanding the kinematic and musculoskeletal differences associated with size and posture provides valuable insight into the morphological adaptations associated with locomotor performance, size and habitat in animals.

51.5 DICK, MF*; GUGLIELMO, CG; University of Western Ontario; *mdick23@uwo.ca*

Seasonal and flight−related alterations in the flight muscle transcriptome of a migratory songbird

The flight muscles of birds undergo physiological changes during migratory seasons. These alterations include increased aerobic and fatty acid oxidation capacity, which help sustain the high−intensity endurance exercise needed for long migratory flights. The degree and full coordination to which birds prepare for migratory season and flight is unknown. We used RNAseq to study flight muscle changes occurring in preparation for and during migratory flight. We sampled flight muscles from captive yellow−rumped warblers (*Steophaga coronata*) during the fall migratory period at rest, after a 4 h flight in a wind tunnel, and during the winter non−migratory period at rest. Maximum enzyme activity of carnitine palmitoyl transferase, lactate dehydrogenase, citrate synthase and 3−hydroxyacyl CoA dehydrogenase were measured on 5 birds from each condition. The mRNA of 3 birds per condition was sequenced using Illumina HiSeq technology. Trinity was used for the de novo transcriptome assembly, generating 68577 unique transcripts. Differential gene expression analysis will be performed using edgeR and ALDEX to examine changes in KEGG pathways and gene ontologies. Preliminary results from metabolic enzymes activities revealed higher aerobic and oxidative capacity in migratory conditioned birds. No effect of flight was found on enzyme activity, suggesting that birds increase aerobic and oxidative capacity during migration, which is maintained during flight. The results from differential gene expression will be presented and discussed in relation to preparation for and maintenance of endurance migratory flights.

S8.5 DICKENS, Molly J.; Univ. of California, Berkeley;
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Sex, stress, and rapid estradiol changes in the male brain

Envisioning the stereotype of human masculinity − chest puffing, competing, boasting of sexual prowess − we may be inclined to attribute such behavior to Testosterone. However, studies in a range of vertebrate species continue to demonstrate that estrogens are the predominant steroid hormone regulating male sexual behavior. More specifically, the neural conversion of testosterone into 17²−Estradiol (E2) via the aromatase enzyme is the critical step required to initiate such behaviors. Since aromatase activity (AA) can be rapidly altered, the time scale in which local E2 in the brain can be changed is predicted to relate to its fast, non−genomic effects on behavior. Focusing on the medial preoptic nuclei (POM), a region in the hypothalamus shown to regulate male sexual behavior, Japanese quail (*Coturnix japonica*) show rapid changes in AA follow both brief sexual interaction (5 min) and acute stress (15 min restraint). The directionality of these changes, however, seem counterintuitive − sexual interaction results in decreased AA in the POM while acute stress results in a increase in AA. Follow−up studies suggested that E2 regulation may be more complicated than simply using AA as a proxy for E2 changes. Measurements of E2 in the brain tissue (isolated POM) show a similar, but minor, decrease in E2 following sexual interaction, but the same measurement following acute stress show a strong decrease (in contradiction to the AA directionality). This decrease following stress suggests that local E2 regulation during or following stress may involve a catabolic pathway not yet fully characterized. These data highlight the complexity of rapid control of neurosteroid concentrations while opening additional questions concerning the regulation and role of these changes in stress conditions.

P3.48 DICKENS, MJ*; HILL, MN; BENTLEY , GE; UC Berkeley, Integ Biol, U Calgary, Cell Biol and Anatomy;
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Endocannabinoid signaling and HPA axis plasticity

When the brain responds to acute stress, pathways connecting the hippocampus, amygdala and hypothalamus use endocannabinoid (eCB) signaling to regulate the response of the hypothalamic pituitary adrenal (HPA) axis. Functioning predominantly through retrograde signaling, the eCBs (2−arachidonoylglycerol, 2−AG, and anandamide, AEA) bind cannabinoid 1 (CB1) receptors located on the pre−synaptic neuron to generally inhibit HPA activity. In our study, we used European starlings *(Sturnus vulgaris)* to investigate the role of eCB signaling in the transition between breeding season and molt when the most dynamic changes in HPA responsiveness occur. We measured eCB concentrations in dissected hypothalamus, amygdala and hippocampus at baseline and after acute stress (30min restraint). In the amygdala, stress−induced decreases in AEA and 2−AG content were robust during the breeding season but reduced or non−existent during molt. CB1 in the amygdala has been shown to "gate" the initiation of the HPA response by stress−induced metabolism of ligand releasing inhibition on hypothalamus. The observed difference suggests a potential role for amygdalar eCB signaling in HPA plasticity since the rapid change in content occurs when the response requires a dynamic range (breeding) but not when the response is restricted (molt). In contrast, there were no changes in tissue eCB content in response to stress in hypothalamus or hippocampus where the predominant role of eCB signaling is glucocorticoid negative feedback. These data provide new insight into neural mechanisms that may regulate the transition in HPA responsiveness between breeding season and molt and further demonstrate the comparative nature of neural stress signals.

107.1 DICKERSON, B.H.*; MUNK, Y.; ROTH, E.; DANIEL, T.L.; University of Washington, Seattle; *bdicker@uw.edu*

Wing mechanosensing enhances flight responses to visual pitch stimuli.

Flying insects combine information from multiple sensory modalities in flight control. For example, flies combine visual input with mechanosensory information from the halteres and these two systems exhibit opposite, and thus complementary, sensitivity to rotational stimuli. In contrast to the thorough analysis of these sensory streams in flies, there is little work examining if the vast majority of insects, which lack halteres, use similar strategies in flight control. Recent behavioral work suggests wings of the hawkmoth *Manduca sexta* convey information for flight control. However, these experiments were performed under low light levels and at only one frequency. Thus, while we could test for the capacity of wings to act as inertial sensors, we did not address how responses mediated by wing mechanosensory systems respond across a broader frequency range. To further understand the response properties of these modalities, we attached magnets to the wings of moths and subjected animals to a sum of sines pitch stimulus (f= 0.4−3.4 Hz) via a rotating magnetic field in combination with a visual pattern during tethered flight in dim light, conditions consistent with when moths are most active. Surprisingly, moths subject to either a visual pattern alone or both visual and mechanosensory stimuli show a flat frequency response of similar gain across all tested frequencies (ANOVA, n= 7). Additionally, while the means were not significantly different (Wilcoxon, P<0.06) the modest sample size and P−level suggests that even in conditions with reasonable light levels, mechanosensors on wings can play a role in flight control.

P2.150 DICKIE, R*; BENNETT, D; YANCONE, A; Towson University; *rdickie@towson.edu*

Inhibition of tumor suppressor p53 prevents tail regeneration in axolotls

Previous work has suggested a link between the biological processes underlying regeneration and those underlying cancer. The tumor suppressor protein P53 is mutated in the majority of tumors and has recently been implicated in playing a role in tissue plasticity. We compared the effect of inhibition and stabilization of p53 on tail regeneration in axolotls (*Ambystoma mexicanum*) and zebrafish (*Danio rerio*). All fish treatment groups regenerated tail fins, but regenerative outgrowth was slightly diminished and endothelial sprouting occurred earlier in tp53 mutant fish and those treated with the p53 inhibitor pifithrin−alpha. The effect was reversible with washout of the inhibitor. In contrast, p53 inhibition in salamanders eliminated regenerative outgrowth of the tail and the effect was not reversible with washout of the inhibitor. The effects of the p53 stabilizer nutlin on tail regeneration were more modest. Our results provide evidence that the effect of p53 inhibition by pifithrin on tail regeneration in ectothermic vertebrates is species− and tissue−specific. We are continuing to analyze the effects of p53 alteration on regeneration at the histological level. This work will give us a broader understanding of how tumor suppressors exert their effects within different non−cancerous but proliferative tissue environments.

P2.54 DIEBBOLL, H.D.*; BERGMANN, P.J.; Clark University; *hdiebboll@clarku.edu*

Environmental, Biological and Behavioral Effects on the Dehydration Rates of Amphibians

The semi−permeable skin of amphibians is particularly susceptible to water loss. As a result, amphibians experience more rapid rates of dehydration compared to other terrestrial vertebrate taxa. Many variables interact to determine these rates of water loss. We examined the effects of various environmental, biological and behavioral factors on the dehydration rates of green frogs (*Lithobates clamitans*) from central Massachusetts. Rates of evaporative water loss were tested at a range of temperatures (16.6−29.0ºC) and relative humidities (1.3−66.6%) for specimens ranging from 4.2−50.3 g. The effectiveness of a common behavior exhibited by many amphibians, the assumption of a water conserving posture, was also considered in determining rates of evaporative water loss. After running a multiple regression analysis, we found that environmental temperature ($t = -5.21$, $p<0.0005$), relative humidity ($t = 11.419$, $p<0.0005$), standard mass ($t = 9.91$, $p<0.0005$), and the relative time an individual assumes a full or near water conserving posture ($t = 4.05$, $p<0.0005$) significantly predicted dehydration rates of *L. clamitans* at a constant wind speed. Rates of evaporative water loss increased with increased environmental temperature, and decreased relative humidity, standard mass and the proportion of time specimens assumed a full or near water conserving posture in the time it took them to reach 80% of their standard mass.

P3.59 DIETZ, S.L.*; KIMMITT, A.A.; KETTERSON, E.D.; North Carolina State University, Indiana University, Bloomington; *sldietz@ncsu.edu*

No conflict between extra−pair courtship and male parental behavior detected in a socially monogamous songbird

Organisms utilize a variety of mating systems in order to achieve high reproductive success. In monogamy, a male and female mate exclusively. Monogamy was once believed to be common among songbirds until further developments in genetic techniques demonstrated that social monogamy is more prevalent than true genetic monogamy (Barelli *et al*., 2013). In social monogamy, males and females form a pair bond, share resources and contribute to parental care of offspring. One or both members of the pair, however, may seek out extra−pair copulations (EPCs). Therefore, socially monogamous species may face a trade−off between parental behavior and EPCs. The dark−eyed junco, *Junco hyemalis*, is a socially monogamous songbird in which extra−pair paternity is prevalent (Ketterson *et al*., 1997). We investigated the relationship between parental and extra−pair courtship behavior of male juncos. To assess extra−pair courtship behavior, we stimulated the male to court a live, caged female using a playback of a female pre−copulatory trill and recorded all of the male's courtship displays. To assess parental investment, we used a video camera to record the number of times a male fed his nestlings that were 6 days old. In contrast to our prediction of a trade−off between parental behavior and EPCs, we found no significant relationship between the intensity of extra−pair behavior and the number of times males fed their nestlings. One possible reason for failing to detect a trade−off between parental and courtship behavior may be variation in male quality, in which some males are better able to invest time in both parental and extra−pair behaviors. A larger sample and measures of male quality will be necessary before drawing final conclusions.

59.7 DILLON, M.E.; GIRI, S*; University of Wyoming, Laramie; *sgiri@uwyo.edu*

New evidence for homeoviscous adaptation across altitude and season in native bees

Fatty acids (FAs), key components of lipids, are important energy resources in organisms. The structure and function of FAs are affected by changes in environmental temperatures, ultimately impacting organism physiology. However, both plants and animals can adapt to temperature changes by adjusting FA composition to manipulate fluidity, as explained by the 'homeoviscous adaptation' hypothesis. FA fluidity varies with the ratio of unsaturated to saturated fatty acids (UFA: SFA). As ectotherms, insects are particularly vulnerable to changes in environmental temperature. Pronounced thermal gradients across altitude and seasons may therefore challenge lipid physiology in insects. We compared UFA:SFA in four native bee genera (*Andrena, Bombus, Megachile* & *Osmia*) collected throughout the growing season (May through September) at two different altitudes in Wyoming. Analysis of FAs using GC−FID revealed a significant increase in UFA:SFA ratios at higher altitudes in *Andrena*, *Bombus*, and *Osmia* and a significant decrease in UFA:SFA ratio across the growing season for *Bombus*. These data provide new evidence for homeoviscous adaptation across altitude and season.

35.7 DILLON, M.E.*; WANG, G.; University of Wyoming, Max Planck Institute for Developmental Biology; *Michael.Dillon@uwyo.edu*

Biological implications of recent geographic convergence in daily and annual temperature cycles

Warming mean temperatures have shifted distributions, altered phenology, and increased extinction risks of diverse organisms, and have impacted human agriculture and health. However, knowledge of mean temperatures alone does not provide a complete understanding either of changes in climate itself or of how changing climate will affect organisms. Temporal temperature variation, primarily driven by daily and annual temperature cycles, has profound effects on organism physiology and ecology, yet changes in temperature cycling are still poorly understood. Here we estimate global changes in the magnitudes of diurnal and annual temperature cycles from 1975−2013 from an analysis of over 1.4 billion hourly temperature measurements from 7906 weather stations. Increases in daily temperature variation since 1975 in polar, temperate, and tropical regions parallel increases in mean temperature. Concurrently, magnitudes of annual temperature cycles decreased by in polar regions, increased in temperate regions, and remained largely unchanged in tropical regions. Stronger increases in daily temperature cycling relative to changes in annual temperature cycling in temperate and polar regions mean that, with respect to diurnal and annual cycling, the world is flattening as temperate and polar regions converge on tropical temperature cycling profiles. These shifts in temperature cycling will likely have profound and, as yet, unknown biological impacts.

74.7 DILUZIO, A. R.*; HIGGINS, B. A.; MEHTA, R. S.; Univ. of California, Santa Cruz; *adiluzio@ucsc.edu*

Determining Maximum Prey Size and Quantifying Prey Manipulation Strategy in the California Moray

Moray eels (Anguilliformes: Muraenidae) comprise a large radiation of snake−like marine predators. Morays have a reduced capacity to use suction during prey capture; instead they apprehend prey by biting and use their pharyngeal jaws to transport and swallow prey. The pharyngeal jaws enable morays to maintain at least one set of jaws on their large struggling prey at all times. While morays are known to swallow prey whole, they have also been observed using a diversity of strategies, including shaking, body rotation, knotting, and ramming prey against other objects to manipulate prey into more manageable pieces and assist in feeding. There is little diet data informing us of how large of prey morays can consume and whether manipulation strategy differs between prey items. In this present study, we supplemented field dietary data of the California moray (*Gymnothorax mordax*) with feeding performance trials in a controlled laboratory environment. Both ingestion ratio (IR) and relative prey mass (RPM) were calculated from various cephalopod and fish prey varying in size. Each trial was recorded for further analysis to determine behavioral differences in feeding strategy. We find that while morays can consume prey with IRs and RPMs as high as 1.18 and 0.28, the material properties strongly affect the maximum size of prey morays can consume whole. Morays had greater success tearing apart fish prey with behaviors such as knotting, while cephalopods were either swallowed whole or only their tentacles were consumed. Tentacles were removed mostly by rotational feeding. Shaking most frequently occurred at the beginning of feeding trials, while other behaviors were more randomly dispersed. Knotting seemed to be induced when IRs surpassed 0.4. We find a strong positive relationship between both IR and RPM and duration of prey manipulation behaviors in cephalopod prey (r^2 = 0.47, r^2 = 0.94).

S9.6 DINIZ BEHN, CG*; LOPP, S; GLEIT, RD; BOOTH, V; Colorado School of Mines, Carmen Middle/High School of Science and Technology, University of Michigan; *cdinizbe@mines.edu*

Who needs sleep? Engaging students in mathematical modeling of sleep and circadian interactions

Mathematical modeling has a rich history of helping to shape the way we think about sleep. In the early 1980s, the introduction of the 2−process model by Borbély and colleagues provided a formal (and accessible) mathematical way to conceptualize the interactions between sleep and circadian systems. We have developed an interactive application that simulates sleep/wake behavior using the 2−process model and allows students to explore the model from several perspectives. Depending on student mathematical level, the model can be represented using either algebraic or differential equations. First, students must choose baseline parameters for the model: we include pre−programmed "Adult" and "Teen" models, or, alternatively, students can compute and fit their own average sleep/wake behavior based on a sleep journal kept over the course of a week. Once baseline parameters are specified, students can explore different behavioral scenarios including sleep deprivation and shift work. Within these scenarios, a range of metrics compares the effects of various sleep deprivation protocols and work schedules on sleep/wake behavior. The use of this module will provide an introduction to mathematical modeling in a context that is highly relevant in students' lives, and student exploration of model predictions will lead to increased awareness of and engagement with features of healthy sleep/wake behavior.

41.4 DITSCHE, P*; FAHLBUSH, J; SUMMERS, A.P.; University of Washington; *pditsche@UW.edu*

Biomechanics of suction attachment in Northern Clingfish

Northern clingfish have a remarkable ability to stick to smooth and rough surfaces. Specimens longer than 10 cm can attach to surfaces as rough as 2−4 mm grain size, which is considerably rougher than the roughest ready made sandpaper. These small fish stick with higher tenacity to many rough surfaces than smooth ones. The margin of the suction disc of Northern clingfish is covered with hierarchical structures; papillae (~150µm) that are covered with rods (~5µm), which themselves are divided into small filaments at their tips (~0.2µm). We assumed that these structures on the disc margin in combination with the elastic properties of the suction disc enable adaptation to the irregularities of the substrate surface and by this cause higher friction of the disc margin on rough surfaces. We tested this by measuring friction of the isolated margin of the suction disc using a tilting table. There is a higher friction coefficient on rougher surfaces than on smooth ones. Moreover, we measured attachment forces/tenacity of clingfish using a mechanical testing machine. Applying a paired design, we measured the complete suction disc first then repeated the measurement after removing part of the disc margin. On surfaces over a roughness threshold of 78µm (grain size) the suction disc usually totally failed. Interestingly, removing parts of the disc margin had a minimal effect on attachment to smooth and slightly rough surfaces (35µm grain size). On the latter the tenacity just marginally decreased. The disc margin is not essential for clinging to the smoother substrates where friction is lower.

41.7 DITSCHE, P.; SUMMERS, A.P. *; Friday Harbor Labs, UW; *fishguy@uw.edu*

Aquatic versus terrestrial animal attachment − water makes a difference

Animals attaching to a substrate face very different conditions in terrestrial and aquatic environments. We compare both the forces of attachment and the forces acting to detach animals. In the terrestrial environment gravity is commonly understood as the most important detachment force, while under submersed conditions gravity is nearly balanced out by buoyancy and therefore matters little. Moreover, flow forces like drag and lift are more important in an aquatic environment. They can reach much higher values than gravity and vary in magnitude and direction. Attachment mechanisms, such as suction, adhesion including glue, friction, and mechanical principles as hook, lock or clamp and spacer differ when under water compared to terrestrial environment. For example the main principles of dry adhesion, van der Waals forces, which allow a gecko to stick to a wall, are weak in submerged conditions. Capillary forces are very important for wet adhesion e.g. in terrestrial beetles or flies, but do not matter under water. Viscous forces likely contribute to adhesion under water in mobile animals such as torrent frogs and mayflies. Viscous forces and the lack of surface tension also affect frictional interactions in the aquatic environment. Glue is the dominant adhesive mechanism of sessile aquatic animals. However, the aquatic realm presents many challenges to this mode of attachment. Moreover, due to the increasing pressure with water depth, the limitation of suction to the pressure difference at vacuum conditions is ameliorated under water.

31.2 DIXON, GB*; DAVIES, SW; AGLYAMOVA, GA; MEYER, E; BAY, LK; MATZ, MV; Univ. of Texas, Austin, Oregon State University, Australian Institute of Marine Science; *grovesdixon@gmail.com*

Mapping heat tolerance loci in the coral genome

The impact of climate change on populations of reef−building corals will depend on the rate at which they can adapt to increasing temperature, which will in turn depend on the extent of heritable variation in heat tolerance in coral metapopulations. Here we identify regions in the genome of the coral *Acropora millepora* harboring alleles responsible for variation in thermotolerance across latitudes. Reciprocal crosses were made between two *A. millepora* colonies from locations separated by five degrees of latitude and differing in average annual temperatures by 1.5 degrees Celsius. The resulting larval cultures were either subjected to strong selection by heat resulting in >95% mortality, or to benign conditions resulting in no mortality over the experimental period. The selection experiment was replicated twice for each of the reciprocal crosses. The larvae and the parental colonies were then genotyped individually using 2bRAD methodology. The genotyping results were used to construct a high density genetic linkage map of the *A.millepora* genome. Regions responsible for variation in larval heat tolerance were identified as those displaying reproducible shifts in allele frequency between heat−selected and unselected larval cohorts. Two genomic regions displayed extremely strong selection signals, and four additional regions were significantly enriched by less pronounced selection signals. Notably, selection varied between reciprocal crosses and was predominantly directed against paternal haplotypes, suggesting the importance of compatibility of paternal alleles with a particular maternal background. This most likely reflects the importance of mitochondrial type in determining heat tolerance. Our results demonstrate the presence of selectable genetic variation for heat tolerance within natural populations of *A. millepora*.

P2.6 DIXON, GB*; BAY, LK; MATZ, MV; Univ. of Texas, Austin, Australian Institute of Marine Science; *grovesdixon@gmail.com*

Gene body methylation is associated with stable expression and reduced evolutionary rates in Acropora corals

In invertebrates, genes belonging to dynamically regulated functional categories appear to be less methylated than "housekeeping" genes, suggesting that DNA methylation may modulate gene expression plasticity. It has also been shown that, despite the fact that methylated cytosine is hypermutable, methylated genes show greater sequences conservation than non−methylated genes. These observations imply that gene body methylation should lead to stability at two time scales: transcriptional stability within individuals and evolutionarily stability within lineages. Here we used a combination of experimental and comparative methods to validate this hypothesis using scleractinian corals as a study system. To examine the relationship with transcriptional stability, gene expression was profiled in 30 pairs of genetically identical fragments of the coral *Acropora millepora* reciprocally transplanted between distinct natural habitats. Genes with weak methylation signatures were substantially more likely to demonstrate differential expression than genes with strong methylation signatures, supporting a link between gene body methylation and transcriptional stability. To examine the link with sequence conservation, we correlated the methylation signatures with synonymous substitution rates and dN/dS ratios across orthologous protein−coding sequences from five species of *Acropora* species.

P3.16 DOLAN, JE*; SHIRKEY, NJ; HAMMOND, KA; Univ. of California, Riverside; *khammond@ucr.edu*

Altitude induced changes in spleen mass and hematocrit in deer mice

Deer mice (*Peromyscus manipulates*) typically increase hematocrit during acclimation to high altitude in response to low oxygen tensions. When returning to low altitude, however, excess erythrocytes are unnecessary and costly due to increased viscosity that can increase the cost of circulation. Humans moving from high to low altitude have been shown to shunt excess erythrocytes from the circulating blood to the spleen causing an increased spleen size at low altitude. To determine if this is occurring in deer mice, we acclimated them to either low (390m) or high altitude (3800m) for 9 weeks (n=15 at each altitude). At the end of the acclimation period 8 mice from each altitude were moved to the reciprocal altitude for 48 hours to determine the effect of an abrupt change in oxygen availability on spleen mass and hematocrit. The remaining 7 mice were measured at the acclimation altitude. Spleen mass in the continuously high altitude mice was significantly smaller (28%) than in the continuously low altitude mice. However, hematocrit in the continuously high altitude mice was significantly higher (10%) than in the continuously low altitude group. There was no difference in hematocrit or spleen mass between continuously low altitude and high altitude mice that were moved to low altitude in the previous 48 hours but there was a significant negative correlation of r=0.77 between spleen mass and hematocrit in the high altitude mice moved to low altitude, suggesting that these mice had sequestered the excess erythrocytes in the spleen. Our results show that in addition to changes in lung and heart mass, deer mice possess another avenue of rapid phenotypic flexibility to maintain efficient oxygen delivery to tissues in variable oxygen tensions.

S7.7 DOMENICI, Paolo; IAMC CNR Italy; *paolo.domenici@cnr.it*

Unsteady swimming and predator−prey interactions in fish

Unsteady swimming is typically used by fish and other aquatic vertebrates during predator−prey interactions. Large fish are expected to eventually catch small fish if both predator and prey are swimming in a straight line. However, prey tend to perform frequent maneuvers and accelerations when under attack. In addition to providing some degree of unpredictability, this behavior may be advantageous to the prey because scaling relationships show that small fish have higher performance than large fish when unsteady swimming variables (i.e. maneuvering and accelerating) are considered. Some large predators possess morphological adaptations such as elongated bills and tails that can be maneuvered effectively, thus allowing them to overcome their potential disadvantage in unsteady swimming performance when attacking their evasive smaller prey. These body extensions can be moved more rapidly than the whole body itself, and are used by various large aquatic predators to facilitate prey capture. Large aquatic predators such as billfishes, killer whales and dolphins can reduce the disadvantage between predator and prey maneuverability by concentrating, disturbing and disorienting prey. This can result in alternatives to whole−body attacks on single prey, such as attacking as a group or the use of weapons (e.g. tails and bills) which can deal with a concentrated group of prey by slapping and slashing them and then consuming stunned and injured individuals. The use of body parts as weapons in large aquatic vertebrates will be discussed within the context of scaling of swimming performance and of predator−prey size ratios.

P3.95 DOMINGUEZ, AA*; COVI, JA; Univ. of North Carolina at Wilmington; *aad4549@uncw.edu*

Effects of the pesticides, fenoxycarb and carbaryl, on post−diapause development in Artemia franciscana.

Pesticides have the potential to impact development and growth in non−target organisms like zooplankton. Most toxicological studies involving zooplankton test the effects of potential toxicants on active adults or larvae, but fail to consider dormant life−stages. *Artemia franciscana*, commonly known as the brine shrimp, is a species of zooplankton that lives in diverse hyper−saline environments. We used *A. franciscana* as a model organism for this study because it is commercially available as a dormant (post−diapause) embryo, and has high hatching rates under simple culture conditions. We hypothesized that the pesticides, fenoxycarb and carbaryl, would delay post−diapause development in *A. franciscana* by disrupting endocrine signaling and neurotransmission, respectively. Fenoxycarb is an insect growth regulator that blocks metamorphosis and interferes with molting. Carbaryl, on the other hand, disrupts neurotransmission in insects, and thereby alters behavior and muscle control. Dechorionated embryos were exposed to carbaryl or fenoxycarb for 24 h on ice prior to a 72 h hatching test in the continued presence of the chemical. Preliminary results suggest that 1ug/ml fenoxycarb delays emergence and hatching without decreasing hatching success. Preliminary results for carbaryl suggest that disruption of neurotransmission decreases hatching success in an all−or−none fashion; animals treated with 5 ug/ml carbaryl either hatch normally or stop developing as E2 prenauplii. A comparison with published data on *Daphnia magna* indicates that generalizations about the effects of these compounds on branchiopod zooplankton is not possible.

P2.168 DONATELLI, CM*; SUMMERS, AP; FARINA, SC; Tufts University, University of Washington, Cornell University; *cassandra.donatelli@tufts.edu*

A New Metric for Measuring Swimming Kinematics in Elongate Fishes

Many species of elongate fishes use anguilliform swimming to propel themselves through the water. During anguilliform swimming, a fish passes a wave of motion from the head, through the body, to the tail producing thrust; but some long−axis rotation of the body also occurs. In dorsal view, alternating views of the lateral side of the fish can be seen as the wave passes along the body. The amount of the lateral surface visible changes along the body as well as by species. We quantified this long−axis roll, or wobble, on a scale from 0 (no lateral surface visible) to 1 (complete lateral surface visible). Wobble data from three species of elongate fishes, Apodichthys flavidus, Xiphister atropurpureus, and Lumpenus sagitta, were compared using an automated video analysis developed in MatLab, which we also used to compute wave parameters (tail beat frequency, wave speed, amplitude). We found that wobble increased with wave speed (SL/s) and tail beat frequency (hz), and was independent of total speed (SL/s) and maximum amplitude (SL). The mobility and deformation forces of fish vertebral joints (and biomimetic propulsors) is bound to be a major determinant of the emergent property of wobble.

P3.28 DONES, PM*; KRANS, JL; Western New England Univ.; *p_dones@hotmail.com*

A novel expression system in Drosophila to investigate gSAP (e.g. titin) physiology in vivo

Mechanisms of neuromuscular plasticity continue to be of interest as new models of integral muscle proteins are presented. We are specifically interesting in Nishikawa et al.'s winding filament theory (2012; *Proc R Soc B*) and its implications for understanding plastic events like catch tension, which have been difficult to explain at the molecular level. Here we describe our new model for investigating the role of giant sarcomere associated proteins (gSAPs), such as titin, in a simple arthropod model: the larval fruit fly. Much research has shown that among mollusks and arthropods, gSAPs contribute significantly to force production and are modulated by neurotransmitters (e.g. 5−HT), neuromodulators (e.g. octopamine), and divalent cations (i.e. Ca^{2+}). We further suspect many instances of neuromuscular plasticity might be explained by the physiology of gSAPs. We describe here a novel *in vivo* system to examine the physiological role(s) of gSAPs using an RNAi approach. We utilize temperature sensitive [Gal80(ts)] regulation of the Gal4−UAS system to invoke RNAi against the sallimus gene (sls) while over−expressing Dicer2. sls encodes at least five gSAPs in *D. melanogaster*, all of which may exist in multiple isoforms. Our expression system allows us to vary the magnitude of *sls* expression by varying RNAi activation. We report here early findings on the difference between reduced gSAP expression and wildtype neuromuscular physiology; namely, principal components of isometric contraction − amplitude, rise, and decay constants. Lastly, we propose an extension of the winding filament theory; that gSAP wrapping should yield a tether between actin and myosin with progressively increased damping as acto−myosin interaction increases. We hypothesize that in the absence of such a tether (gSAPs), force should vary more widely when driven by a range of motoneuron frequencies.

97.7 DONG, H.; LIU, G.*; REN, Y.; LI, C.; BART−SMITH, H.; FISH, F.; University of Virginia, West Chester University; *hd6q@eservices.virginia.edu*

Understanding the Role of Fin Flexion in Rays' Forward Swimming

Flexion in flapping fins is a hallmark of fish swimming. It's widely thought that this flexion may be the source of fish's efficient swimming. However, there is a lack of literatures on studying the fin flexion and its hydrodynamic role of swimming rays. In this work, a combined experimental and computational study of a swimming manta ray is being conducted. High resolution videos of forward swimming manta rays are obtained and used as a basis for developing high fidelity geometrical models of the ray body and fins. A 3D image−based surface reconstruction method is then used to obtain the kinematics and flexibility of ray fins. The observed fin flexion is highly complex and a number of different strategies including singular vector decomposition (SVD) of the fin kinematics are used to examine the various kinematical features and their impact on the fin performance. Immersed boundary method based CFD simulations are carried out to examine the hydrodynamic performance of fin flexion involving different kinematical features and understand the corresponding wake structures. A cownose ray is also used to compare the variety of the fin flexion in a similar swimming motion. Results have shown that the bending angle and bending rate of the fin tip play important roles in rays' fin propulsion.

P1.61 DOOLEY, T.C.*; PODOLSKY, R.D.; College of Charleston; *dooleytc@g.cofc.edu*

Effects of single− vs. multiple−male spawning on fertilization success under current and future CO_2 conditions.

Uptake of anthropogenic carbon dioxide (CO_2) by the ocean has led to a 30% drop in the average pH of surface waters since the start of the Industrial Revolution. This process, known as ocean acidification (OA), results from the reaction of CO_2 with water to form carbonic acid. OA is of major ecological concern because it can interfere with pH−sensitive biological processes, including fertilization. Recent research in our lab suggested that predicted near−future (50−100 y) levels of atmospheric CO_2 will negatively affect gamete function (e.g., sperm speed, motility, and fertilization success) in the free−spawning sea urchin *Arbacia punctulata*. However, a recent review noted that OA tends to more weakly affect fertilization success in studies that mixed sperm and eggs from more than one mating pair as compared with single pair spawnings. To test the hypothesis that group spawning reduces the negative effects of OA, we measured fertilization success under current and 2.5x−current CO_2 conditions using single−and multiple−male crosses. Surprisingly, we did not find a significant effect of CO_2 on fertilization and the multiple−male crosses did not show greater resistance to the effects of increased CO_2. However, the multiple−male crosses showed significantly lower fertilization than the average fertilization of single−male crosses involving the same males. These results suggest an interaction among sperm from different males that could reduce fertilization success for females that spawn in larger aggregations, which could have important implications for differences in optimal aggregation strategies for males and females.

P3.176 DORTS, J*; SCHOOFS, E; FALISSE, E; FLAMION, E; KESTEMONT, P; SILVESTRE, F; University of Namur; *jennifer.dorts@unamur.be*

Effects of early−life exposure to heat and copper on DNA methylation and gene expression in zebrafish

DNA methylation, a well−studied epigenetic mark, is important for gene regulation and is vulnerable to early−life exposure to environmental challenges. In this context, the present study aimed at evaluating the combined effects of heat stress and copper (Cu) exposure on DNA methylation during early zebrafish (*Danio rerio*) embryogenesis. Zebrafish embryos were exposed to 325 µg Cu/L from fertilization to 4 hours post fertilization (hpf) (when remethylation of the zygotic genome is restored) at either 26.5 °C or 34 °C, followed by incubation within clean water at 26.5 °C to 96 hpf. Overall, significant decreased survival rate and delayed embryo hatching were observed following exposure to high temperature and Cu from fertilization to 4 hpf. Quantitative real−time PCR assays showed a significant increase (45 %) in the metallothionein 2 (*mt2*) mRNA expression in 96 hpf larvae following Cu exposure, independently of heat stress. Despite alterations in *mt2* mRNA expression, we did not observe any significant change in the DNA methylation levels of seven CpG sites located in the promoter region of *mt2* gene in 96 hpf zebrafish larvae by using pyrosequencing. All CpG positions were hypomethylated (on average between 2.0 and 6.3 %). The methylation levels of individual CpG sites located in other *mt2* gene regions (e.g., the first intron) are being analyzed, as well as global DNA methylation using the LUminometric Methylation Assay. Our preliminary results suggest that further research is needed to better understand the effects of environmental stressors and the role of epigenetic mechanisms within susceptible windows of early vertebrate development.

19.5 DOUGHERTY, L.F.*; NIEBERGALL, A.K.; CALDWELL, R.L.; University of California, Berkeley; *lindseydougherty@berkeley.edu*

Flashing in Ctenoides ales "disco" clams: behavioral function and visual cues

The "disco" clam *Ctenoides ales* has a vivid flashing display that results from a dense collection of silica nanospheres on one side of the mantle tissue which causes broadband reflectance. This tissue alternates rapidly with the opposite absorbent side. The fitness value of the flashing display remains unknown, as well as the visual ability to distinguish the display in conspecifics. Three hypotheses were tested; that the display acts in phototaxic prey luring, aposematic signaling, and/or conspecific recruitment. Effects of ecological variations in light intensity on flash rate were tested, and the visual capabilities of *C. ales* were assessed through transmission electron microscopy and opsin expression analysis. Prey luring and aposematism were tested by presenting clams with stimuli of food or predators, and analyzing flash rate 5s before and after the stimulus. Results showed a significant increase in flash rate to both. Conspecific recruitment was tested by dividing nine tanks in half using barriers and giving *C. ales* various stimuli to test settlement, orientation and proximity. Visual and chemosensory cues were controlled by inhibiting water flow, using opaque barriers, and implementing varying stimuli including other *C. ales*, video of *C. ales*, the non−flashing congener *C. scaber*, a rock or an empty control. Preliminary results indicate that both chemosensory and visual cues of *C. ales* caused the experimental *C. ales* to move closer than in the control tank. Varying intensities of blue light to mimic increasing depth showed no significant difference in flash rate. Preliminary analysis of visual capabilities suggests the pallial eyes of *C. ales* have light−detecting capabilities and may possess reflective pigments. Behavioral and optical analyses are ongoing.

P2.52 DOW, E/G*; BARNER, A/K; POOLE, A/Z; WEIS, V/M; Florida International University , Oregon State University; *edow002@fiu.edu*

Effects of light and thermal variation on symbiotic and aposymbiotic states of the temperate sea anemone, Anthopleura elegantissima

The temperate aggregating anemone *Anthopleura elegantissima* occurs in the symbiotic state while developing and residing in direct light exposure and the aposymbiotic state on the undersides of rock benches that consistently block light. Present in diverse intertidal and sub−tidal environments, it is adapted to relatively cool water temperatures in light deprived regions and to endure desiccating environments characterized by large temperature variability. Cnidarians, corals and anemones, possessing symbionts may undergo more extreme environmental changes than their aposymbiotic counterparts. Facultative symbiosis allows *A. elegantissima* to act as a model system for analyzing the physiology, ecology, and molecular biology of temperate cnidarian−dinoflagellate symbioses. To further understand the interactions between symbiosis and environment in temperate cnidarians, symbiotic and aposymbiotic *A. elegantissima* were subjected to light and temperature variations and sampled over several days to examine the mitotic index and relative gene expression between symbiotic states. Haemocytometer counts were used to calculate the mitotic index, percentage of dividing symbionts. Relative gene expression was determined by qPCR analysis. Two of the analyzed genes are associated with the vitamin K cycle: sym32, which is related to symbiosis and encodes a fasciclin domain protein and calumenin, an inhibitory protein. HSP90 and ferritin genes were analyzed for heat stress effects. The consequent mitotic indices and relative gene expressions demonstrate an involved story of symbiosis in relation to light and temperature in *A. elegantissima*.

P3.164 DOWNEY, R.M.*; GARRITY, B.M.; CASSIDY, G.P.; BAIER, D.B.; Providence College, St. George's University School of Medicine; *rdowney@friars.providence.edu*

Constraints on the mobility of the avian coracosternal joint

The unique design of the avian shoulder girdle is generally attributed to flight adaptations: the large sternal keel for expanded flight muscle attachment and elongate strut−like coracoids for resisting compression of those muscles. X−ray video studies have shown that the furcula spreads laterally during flapping flight. The ends of the furcula are firmly attached to the anterolaterally projecting coracoids which imply that any spreading of the furcula is due to movement of the coracosternal joints. In this study we ask, what limits the lateral extent of coracosternal mobility? The furcula is linked to the sternum and coracoids by a membranous system called the sternocoracoclavicular membrane (SCCM), in which two sheets of the membrane connect the furcular arms to the coracoids along their length and then converge to form a single sheet running from the rostral sternum to the ventral tip of the furcula. The SCCM in pigeons has a thickened band running parallel to the coracoids. We initially hypothesized that SCCM−furcular complex were primarily responsible for limiting lateral excursion of the coracosternal joint. To test this, we applied a lateral torque to the coracosternal joint of dissection preparations of pigeon carcasses in which various parts of the SCCM complex were cut and the measured difference of lateral movement was compared to that of the intact specimens. Surprisingly neither the furcula nor membrane appears to limit lateral coracosternal movement, but instead collateral sternocoracoid ligaments arising from the internal surface of the coracoid and inserting onto the left and right pila coracoidea limit lateral spreading.

34.6 DOWNS, C.J.*; STEWART, K.M.; MORANO, S.; WOLFF, P. L.; University of Nevada, Reno, Nevada Department of Wildlife; *cdowns@unr.edu*

Small−scale environmental gradients: effects on trace mineral levels, immune function, and disease prevalence in mule deer

Environmental conditions directly affect the nutritional quality of food. Nutritional quality of food, in turn, mediates individual−level heterogeneity in phenotypes physiological. We investigated how habitat use at small scales affected constitutive immune function and trace−mineral levels in mule deer (*Odocoileus hemionus*) in the Jackson mountain range in Nevada. Using GPS collar data we assigned deer to a land−use groups: field (primarily used alfalfa fields), uplands (primarily used natural, upland habitat), and split (split time between habitats). We found that habitat use on a small scale resulted in differences in serum levels of selenium, magnesium, and iron, but not differences in levels of calcium, copper, phosphorous, and zinc. Levels of calcium, phosphorous, and zinc differed among study years. These results indicate that differences in environmental conditions over short ranges can affect nutritional status of individuals. Interestingly, we found evidence of immunosenescence for one functional measures of constitutive immune function, bactericidal capacity, but not another measure of constitutive immune function, reactive nitrogen metabolites; neither measure of immune function differed among study groups. We found no differences in disease prevalence among study groups, but we found links between constitutive immunity and disease prevalence. Because physiology is regulated by a complex network of response and many aspects of physiology must be studies to understand how environmental conditions and ontogeny affect phenotypes. Our study shows that new insights can be gained by investigating linkages among physiological measures.

S9.3 DREW, J.A.; Columbia University; *jd2977@columbia.edu*

Using technology to expand the classroom in time and space

One of the hallmarks of modern evolutionary and ecological thinking is that diversity is a fundamentally a good thing for natural systems. Here, I ask if a similar line of reasoning can be applied to our teaching STEM fields. Specifically how can increasing the diversity of voices in the classroom lead to a greater integration of new information and increased ability to parse the nuances of STEM lessons. Here I present data from three different classroom experiences that highlight the ways we can use technology to better integrate global classes into the classroom. First I highlight how peer−to−peer learning was used to foster marine conservation in high school youth in Fiji and Chicago. Second I show how social media can be used to facilitate conversations in a post−natural disaster conditions in New York City. Lastly I show how integrating digital and real world learning can help a diverse group of conservation practitioners from the Pacific Islands gain actionable STEM knowledge in an extended workshop format. Taken together these examples show how digital technology can expand the classroom beyond the traditionally spatially/temporal fixed location. From Fiji we see how brining different voices helps personify global climate change, in New York we see how social media can bring together physically disrupted communities and lastly we can see how exposing practitioners to on−line quantitative analytical techniques can improve their on the ground conservation. Taken together we can see that technology can help show students the vivid splendor of life outside the classroom

100.4 DREWELL, R A; DRESCH, J M*; Amherst College; *rdrewell@amherst.edu*

Integrating research and teaching in quantitative biology: mathematical modeling of gene regulation

The 4 College Biomath Consortium (4CBC) consists of faculty and students from Amherst, Hampshire, Mount Holyoke and Smith Colleges. Through the 4CBC, a course titled "Frontiers in Biomath" is offered each year to give students the opportunity to explore biological questions using tools from the life sciences together with modeling and analytical tools from the mathematical and statistical sciences. We have developed a module for this course that focuses on modeling Drosophila gene regulation. In the fruit fly Drosophila, the identity of cells in the developing embryo falls under the control of a complex network of genes. The expression of each of these genes is in turn controlled by interactions between protein transcription factors (TFs) and cis−regulatory modules (CRMs) in the neighboring intergenic DNA regions. A major goal of current research is to understand how the sequence architecture of TF binding sites mediates the functional activity of these CRMs using integrated computational and molecular genetic experimental approaches. In this module we explore some of the research tools that are available to study protein−DNA interactions and investigate mathematical models of their functional activity.

11.6 DU, X.*; OLEKSIAK, M.F.; CRAWFORD, D.L.; University of Miami; *xdu2011@gmail.com*

A Genotyping by Sequencing Study of Natural Populations of Fundulus heteroclitus Inhabiting a Strong Pollution Cline

Persistent organic pollutants (POPs) are some of the most prevalent pollutants because of their resistance to environment degradation and propensity to bioaccumulate. Moreover, POPs contribute significantly to human diseases. A population of the salt marsh teleost, *Fundulus heteroclitus*, inhabit New Bedford, Harbor, MA, a site highly contaminated with POPs, in particular polychlorinated biphenyls (PCBs). Compared to nearby reference fish, the New Bedford Harbor fish are resistant to the PCBs in their environment. New Bedford Harbor exhibits a strong pollution cline with sediment concentrations of PCBs ranging from 22,666 ng/g dry weight at the source of pollution to 13 ng/g dry weight at the base of the harbor. Using genotyping by sequencing, we asked whether fish along this cline exhibit significant changes in genetic structure. Fish from five sites within the harbor and two flanking reference sites were genotyped at ~14,000 loci. When comparing fish from the most polluted New Bedford Harbor site to the clean reference populations, there were about 500 SNPs with evolutionary significant F_{ST} values ($p < 0.01$). We will examine the clinal variation in allele frequencies relative to PCB sediment concentrations. After controlling for demography, SNPs that have a change of allele frequency related to the clinal variation in PCB concentrations would indicate that those alleles are affected by PCB contamination and potentially linked to the New Bedford Harbor population's tolerance to PCB toxicity.

P3.83 DUCKWORTH, B/M*; JAWOR, J/M; Univ. of Southern Mississippi; *benjaminduckworth@hotmail.com*

Seasonal Modulation of Corticosterone in Northern Cardinals (Cardinalis cardinalis)

Seasonal regulation of the adrenocortical response (e.g., stress response') appears to be ubiquitous in mid− to high−latitude vertebrates. Northern Cardinals (Cardinalis cardinalis) are a temperate dwelling passerine of tropical−descent and a wide species range. This species has encountered a wide variety of environmental variation and corticosterone (CORT) has not been studied in it with an eye towards seasonal changes in levels. We analyzed cardinal samples collected between 2007−11from the Lake Thoreau Environmental Research and Educational Center (Hattiesburg, Mississippi, USA). The data suggested seasonal differences of CORT, with higher concentrations during the winter and decreasing in prebreeding, and even further during breeding where the lowest average concentrations were observed. In 2012−13 we used the same banded population of cardinals to monitor seasonal changes in stress responses. Now with more stringent initial CORT (≤3min) samples collected we observed an even more pronounced variation in seasonal CORT modulation. The data suggests significant differences of initial CORT levels between nonbreeding and that of pre− and breeding seasons. Seasonal variation was also found in the magnitude of stress responses with pre− and breeding seasons varying significantly from nonbreeding CORT concentrations. This is the first study to analyze year−round concentrations of initial CORT and magnitude of stress responses in cardinals as they progress through from one life history stage to the next.

P2.112 DUDEK, A.M.*; SCHOENLE, L.A.; GONG, S.; VAN TOL, A.; BONIER, F.; MOORE, I.T.; Virginia Tech, Queen's University, Queen's University; *alana33@vt.edu*

Does female ornamentation predict reproductive investment in red−winged blackbirds?

Variation in avian plumage coloration can act as a signal, conveying information about individual dominance status, quality, and condition. Yet much of what we know about plumage color signaling comes from studies of male birds. For example, in red−winged blackbird males, the red epaulets (upper wing feathers) are known to function in mate attraction and to signal aggression to rival males. Carotenoid pigments are responsible for red feathers, and brighter red feathers usually indicate that a bird is in better body condition. Female red−winged blackbirds show individual variation in epaulet and throat feather coloration, and brighter red epaulets can be associated with age, body condition, and reproductive effort pre−molt. However, the possible signaling function of female red−winged blackbird coloration is unknown. Here, we investigate whether epaulet and throat color could convey information about female red−winged blackbirds' condition and potential reproductive quality. We describe the relationships between variation in epaulet and throat color and incubation behavior, clutch size and mass, hatching success, and metrics of body condition. We predicted that females with brighter red coloration would be in better condition, and spend more time incubating, have larger clutch sizes and masses, as well as a higher hatching success. Preliminary results suggest that female epaulet color is not correlated with incubation behavior, but might predict some metrics of body condition. Our findings demonstrate the potential for individual variation in female plumage to convey information about a female's condition and reproductive investment, indicating that it could be used as a signal in intraspecific communication.

P3.154 DUELL, M.*; HARRISON, J.F.; Arizona State University; *meduell@asu.edu*

Miniaturization is associated with novel scaling of flight parameters in stingless bees

Miniaturization, a pervasive condition in the Animal Kingdom, occurs when species evolve extremely small body size with respect to ancestral species. Stingless bees, Meliponini, are a tropical group that evolved miniaturization in 11 separate genera with species ranging in size across three orders of magnitude. To explore how these bees might be affected by small size, we examined scaling of flight metabolic rate, wing beat frequency, body temperature, and wing area of foragers in 13 Panamanian stingless bee species with masses from 1.5−115mg. We compared our results to prior studies of Eugolossine bees that ranged in size from 47−1065mg. In Meliponini, flight metabolic rates scaled hypermetrically and wing beat frequency did not vary with size, contrasting with Euglossines, in which flight metabolic rate scaled hypometrically and wingbeat frequency declined with size. Thorax mass scaled isometrically with body mass while abdomen mass scaled slightly hypermetrically and head mass scaled hypometrically. Thus all bees had roughly the same relative investment in flight muscles while small bees had relatively large heads and less investment in abdominal tissues. Bees heavier than 70mg (roughly ancestral size of stingless bees) had thorax temperatures more than 10°C above air temperature, while bees less than 20 mg had thoraxes only 1−2°C above air. Together, these observations suggest that increased heat loss rates cause reductions in flight muscle temperatures in miniaturized bees, causing them to have reduced wing beat frequencies and mass−specific metabolic rates, and likely lower power output in flight compared to the expected pattern based on changes in body size alone. While these cooler body temperatures may have performance costs, they will also reduce energetic requirements of the colonies. We thank W. Wcislo, D.Roubik, Smithsonian Tropical Research Institute, and NSF IOS 1122157 for help and funding.

P1.16 DUFFIELD, K. R.*; RAPKIN, J.; HUNT, J.; SADD, B. M.; SAKALUK, S. K.; Illinois State Univ., Normal, Univ. of Exeter, Cornwall ; *krduffi@ilstu.edu*

Terminal investment in gustatory appeal of male decorated cricket nuptial food gifts

Investment in current versus future reproduction is a prominent trade−off in life−history theory, and is likely dependent on an individual's life expectancy. The terminal investment hypothesis posits that a reduction in residual reproductive value (i.e. potential for future offspring production) will result in increased investment in current reproduction. We tested the hypothesis that male decorated crickets (*Gryllodes sigillatus*), when cued to their impending mortality, increase investment in current reproduction by shifting the composition of their nuptial food gifts, or spermatophylaxes, in a way that increases their gustatory appeal to females. Using a repeated measures design, we analyzed the amino acid composition of spermatophylaxes derived from males both before and after injection of either a saline control or an immune challenge solution of heat−killed gram−negative bacteria, the latter of which, although non−pathogenic, may signal an impending threat to the survival of the cricket. The gustatory appeal of spermatophylaxes was assessed by mapping their composition on a fitness surface derived in an earlier study that identified female preference for amino acid composition of nuptial food gifts. We found that immune−challenged males maintained the level of attractiveness post−treatment, while control males produced significantly less attractive gifts post−injection. These results are consistent with the hypothesis that cues of a survival threatening infection stimulate terminal investment in male decorated crickets with respect to the quality of their nuptial food gifts.

P3.33 DUFFIN, PJ*; WADDELL, DS; University of North Florida; *d.s.waddell@unf.edu*

Activation of RING Finger/SPRY Domain Containing 1 (Rspry1) and NEFA−interacting Nuclear Protein 30 (Nip30) During Skeletal Muscle Atrophy

Skeletal muscle atrophy results from a wide range of conditions, including immobilization, spinal cord damage, inflammation and aging. An investigation designed to identify and characterize changes in gene expression in skeletal muscle following denervation revealed a set of genes that show differential expression patterns in response to neurogenic atrophy, including Nip30 and Rspry1. In order to further characterize the transcriptional regulation of Nip30 and Rspry1, a fragment of the promoter region of each gene was cloned, fused to a reporter gene, and transfected into muscle cells in combination with expression plasmids for Muscle RING Finger 1 (MuRF1) and myogenic regulatory factors (MRFs). The MuRF1 protein is an E3 ubiquitin ligase that is induced under most atrophic conditions and is believed to promote protein degradation; however, data presented in this study suggests that MuRF1 may also regulate the transcriptional activity of genes that are differentially expressed following neurogenic atrophy. Myogenic regulatory factors (MRFs) are a class of E−box binding proteins that regulate muscle−specific gene expression. The results of this study demonstrate that MuRF1 and MRFs cooperatively repress Rspry1 and Nip30 reporter activity. Furthermore, mutation of a conserved E−box element in the shared regulatory region of Nip30 and Rspry11 eliminated the MuRF1 and MRF cooperative repression of these genes. Identifying novel atrophy−induced genes, elucidating the transcriptional regulatory role of MuRF1 and MRFs, and characterizing how these genes impact the atrophy cascade may help further our understanding of the molecular mechanisms of muscle wasting.

S6.6 DUNLAP, Aimee S.*; HORACK, Patricia; MAHARAJ, Gyanpriya; YODER, Marisa; University of Missouri− St. Louis; *aimee.dunlap@umsl.edu*

Tracking a changing environment: reliability, certainty, and foraging bumblebees

Rates of change in the environment influence when learning evolves and when prepared learning evolves. However change also influences the evolution of unlearned preferences such as biases of various kinds. Both learning and unlearned bias interact to influence how animals track changing environments, across evolutionary time and also within individual lifetimes. For an individual, inherited bias may help promote learning in some cases. But a strong initial bias in a mismatched world might interfere with the acquisition of new information when sampling and tracking changes in resource quality. How should animals balance inherited and acquired information to best track change? We present experimental work where we ask how an unlearned preference is modified by experience, and specifically, how this might bias individuals towards or against sampling resources, and then tracking those sampled changes. We apply a classic foraging theory framework of two resource types: one steady and one which varies. Testing foraging bumblebees, *Bombus impatiens*, in a serial Y−maze, we manipulated the strength of the unlearned preference and whether the reward of the preferred color varied or not. Bumblebees sampled more frequently when they lacked an initial bias in preference, while they reduced sampling when there was an initial preference for an unvarying resource. This bias towards or against sampling information was also present in how quickly and accurately bees then used their experiences to track sampled changes. We discuss how initial bias in preference may influence how well bees can track modified floral environments in an ever changing world.

10.5 DUNN, P.O.*; ARMENTA, J.K.; WHITTINGHAM, L.A.; Univ. of Wisconsin−MIlwaukee; *pdunn@uwm.edu*

Natural and Sexual Selection Act on Different Types of Variation in Avian Plumage Color

Birds display a bewildering variety of colors that have fascinated biologists since Darwin and Wallace, who began a long−running debate about the causes of sexual differences in plumage color (dichromatism). There are, however, many monochromatic species of birds, with both sexes dull or both brightly colored, but, to date, the causes of this variation have received little study. Here we show using plumage reflectance data from a worldwide sample of 977 species of birds that most variation in bird plumage occurs along an axis of sexual similarity, rather than dichromatism. Dichromatism is associated primarily with indices of sexual selection, such as social mating system and testes size, while the extent and direction of similar plumage in both sexes is associated with ecological and behavioral variables, such as habitat type, migratory behavior and mode of development. Both natural and sexual selection have influenced the evolution of bird coloration, but in many respects they have acted on two different axes: sexual selection on an axis of sexual differences and natural selection on an axis of sexual similarity. Since most evolutionary transitions have been to monochromatism, we suggest that natural selection on both sexes has been the most common source of selection on plumage color.

71.6 DUQUETTE, A.M.*; MCCLINTOCK, J.B.; AMSLER, C.D.; PEREZ−HUERTA, A.; HALL−SPENCER, J.M.; MILAZZO, M; University of Alabama at Birmingham, Birmingham, AL, University of Alabama, Tuscaloosa, AL, University of Plymouth, England, University of Palermo, Italy; *amd82886@gmail.com*

Effects of reduced pH on shell mineral composition and integrity of three common gastropods from a natural undersea CO_2 vent community off Vulcano Island, Italy

The limpets *Patella caerulea*, *P. rustica* and the whelk *Hexaplex trunculus* are widespread in the Mediterranean and play important roles in benthic ecosystem dynamics. Individuals of all three species are abundant in the shallow subtidal near Vulcano Island, Italy, where an undersea CO_2 vent provides a gradient of seawater acidification simulating future predicted levels of ocean acidification. Individuals were collected from three sites with declining pH [ambient (pH 8.18), medium (pH 8.05) and low (pH 7.49)]. Scanning electron microscopy was employed to provide a qualitative comparative assessment of prospective microscale impacts on shells. Dissolution of the shell was evident at the medium pH (smoothing of outer shell) and low pH (pitting and holes) collection sites. X ray diffraction (XRD) provided a quantitative comparative assessment of carbonate composition of shells in individuals collected from the three pH sites. The calcium to magnesium ratio, as well as the aragonite to calcite ratio of the shells varied with pH collection site. To further assess the impacts of seawater pH on shell microstructure, electron backscatter diffraction (EBSD) was conducted. The present study indicates that near−future ocean acidification may be expected to cause alterations in shell mineral composition and shell integrity that render individuals more susceptible to infection and predation. Supported by funds from Abercrombie and Kent Philanthropy and an Endowed Professorship to JBM.

P1.34 DUREN, K*; CHANDLER, A; BENNETT, S; California Academy of Sciences; *durenk@kenyon.edu*

Potential integration of Cell Fusing Agent Virus into the genome of the Thai population of Aedes aegypti mosquitoes

The genus *Flavivirus* contains at least 70 viruses including both mosquito−borne human pathogens, and non−pathogenic viruses that are limited to insect hosts. The insect−specific *flaviviruses* are ancestral to mosquito−borne *flaviviruses* and understanding their diversity and distribution could reveal important evolutionary processes behind the emergence of pathogenic forms. In addition, reports of insect−specific *Flaviviruses* that have become integrated into the genomes of their hosts, *Aedes* mosquitoes, reveal important evolutionary routes for host genetic diversification that may ultimately contribute to viral defense. This research seeks to determine whether the insect−specific *Flavivirus* cell fusing agent virus (CFAV), discovered in field−caught *Aedes aegypti* mosquito populations from Thailand, represents circulation of this virus in this population or evidence of virus integration into the mosquito genome. Mosquitoes were trapped in central Thailand in 2008 from many sites. Unbiased shotgun sequencing of total RNA revealed the presence of sequences similar to the first half of the CFAV genome. Since the second half of the CFAV genome contains essential genes, their absence may suggest the integration of CFAV into the *A. aegypti* genome. Alternatively, truncated CFAV might represent differential virus degradation due to host defense mechanisms. Preliminary results on DNA from the Thai samples are positive for CFAV. These RNA viruses are not known to have a DNA stage, suggesting integration into the host genome. This integration event would be novel because CFAV is not found in the sequenced strain of West African *A. aegypti*, meaning integration occurred after a divergence between African and Asian *A. aegypti*. Current studies involve genome walking to determine sequence origin adjacent to the known CFAV sequence. *A. aegypti* sequences would provide evidence for an integration event.

108.6 EASSON, C/G*; THACKER, R/W; University of Alabama at Birmingham; *cgeasson@uab.edu*

Host−specific community structure of tropical sponge microbiomes

Sponges (Porifera) can host diverse and abundant communities of microbial symbionts that make critical contributions to host metabolism. Observations suggest that these microbiomes may be transferred by a combination of vertical and horizontal transmission, and although direct evidence of this process is rare, current research indicates that most associated microbial communities are species−specific. While species specificity is commonly shown, the evolutionary history of the host species is often not considered. In collaboration with the Earth Microbiome Project (EMP), we investigated the microbiomes associated with sponges collected over a narrow geographic range in the Bocas del Toro archipelago, Panama. We used high−throughput sequencing of the V4 region of the 16S ribosomal RNA gene to assess community structure in 90 specimens representing 20 sponge species. The number of bacterial operational taxonomic units varied significantly among host species, with a strong phylogenetic signal for microbial community diversity. Host identity and phylogeny explained 73% of the observed variance in microbial community composition, and 91% of the observed variance in microbial phylogenetic dissimilarity. These results suggest that host identity and relatedness encompass the major factors that structure sponge−associated microbial communities.

88.3 EBERLE, AL*; DICKERSON, BH; DANIEL, TL; Univ. of Washington, Seattle; *eberle10@uw.edu*

Scaling of gyroscopic and aerodynamic forces on flapping insect wings during body rotations

The halteres of flies, heralded as biological gyroscopes, have an enigmatic evolutionary history. Though halteres are derived from wings, the mechanisms favoring this transition are unclear. While flapping halteres encounter large inertial forces and produce negligible aerodynamic forces, flapping wings both experience and produce large inertial and aerodynamic forces. Additionally, recent studies have shown that inertial forces on insect wings could convey sensory information about body rotations via a gyroscopic mechanism similar to halteres. However, the scaling of inertial to aerodynamic forces that wings encounter during complex body trajectories remains an open problem. Thus, we ask how body rotation rate, wing shape (span and outline), and wingbeat frequency interact to determine the inertial and aerodynamic forces on an insect wing. To understand the origins of gyroscopic sensing, we focused on the relative magnitude of the Coriolis force experienced by flapping wings. Using Lagrange's equation combined with aerodynamic blade element methods, we modeled inertial and aerodynamic forces on flapping wings during a constant orthogonal body rotation. We used wingbeat frequencies, wing shapes, and body rotation rates that correspond to experimentally measured values for a range of insect taxa. Our results show that the ratio of Coriolis to aerodynamic forces decreases from 40% for model moth wings to 0.4% for model fly wings. We also find that wing shape is an important determinant of the relative importance of inertial to aerodynamic loads. These results point to a mechanism that can drive selection for angular rate detection in insect wings and explain their increased specialization for haltere geometries.

P1.138 EDENIUS, ML*; TARRANT, AM; Woods Hole Oceanographic Institution; *medenius@mit.edu*
Characterization of the Integrated Stress Response in Sea Anemone Acclimation to Environmental Stress
Understanding the mechanisms and potential for physiological adaptation to various stressors is essential in predicting how cnidarians will respond to environmental threats. The integrated stress response (ISR) plays a central role in regulating physiological adaptation to stress in mammals, nematodes, flies, and yeast; however, its role in cnidarians has not been described and the origins of specific components within the Metazoa are unclear. We seek to characterize the ISR pathway in the cnidarian model, *Nematostella vectensis*, in order to gain insight into cnidarian physiology and the evolution of this pathway within the metazoan lineage. The core components of this major signaling pathway are conserved in the *N. vectensis* genome and commercial antibodies can be used to monitor pathway activation. To investigate activation of the ISR, anemones were exposed to environmental stressors or treated with pharmaceuticals, and protein and post−translational modifications significant to activation of this pathway were analyzed by immunoblot. We found that several relevant environmental stressors and pharmaceutical inducers activate the ISR in *N. vectensis*. This study will characterize a previously unreported stress pathway in cnidarians and provide a foundation for understanding signaling networks regulating stress adaptation in this sentinel marine organism.

P2.20 EDGERTON, S.V.*; GUBLER, D.J.; BENNETT, S.N.; California Academy of Sciences, Duke−NUS Graduate Medical School; *seanedgerton@gmail.com*
Dengue virus type 3 evolution and epidemic activity in Indonesia, a historical study of outbreaks from 1976−1979
Dengue viruses are one of today's most significant vector−borne disease agents threatening human health throughout the tropics and subtropics, infecting hundreds of millions of people annually.There are four known serotypes circulating in humans (DENV−1 to −4) all of which can cause a febrile illness known as dengue fever that can progress to more severe and potentially fatal disease involving hemorrhage or shock (DHF/DSS). We report follow up sequence data on DENV−3 strains isolated during epidemics that occurred in Indonesia from 1976−1979. The epidemics began with the detection of fatal DHF/DSS associated with DENV−3 in Jakarta in Jan−Mar, 1976. The virus spread to Bantul, Central Java in Oct. 1976, and to Surabaya, East Java and Pontianak, West Kalimantan in 1977. All were explosive epidemics with severe disease. A smaller outbreak with more sporadic transmission, milder illness and lower viremia levels occurred in Sleman, Central Java in 1978. Viruses were isolated by one of us (DJG) from all of these epidemics and stored in infected mosquitoes at −70 C for nearly 40 years. The viruses had not been passaged in mice nor mammalian cell cultures. Full genomic sequence analysis suggests that a single strain of DENV−3 with greater epidemic potential and possibly virulence emerged in Jakarta and spread rapidly along the main routes to Central and East Java, and Kalimantan. Interestingly, the Sleman DENV−3 viruses were genetically distinct, belonging to a separate clade from the other strains. There were two unique Bantul isolates that also belonged to the Sleman clade, suggesting that the Sleman virus descended from these Bantul viruses. Our findings emphasize the importance of dengue evolution and genetic variation as a contributor to epidemic intensity and severe dengue disease.

S10.3 EDISON, Arthur S; Univ. of Florida; *aedison@ufl.edu*
Metabolomics as a tool to study chemical communication
Caenorhabditis elegans and other nematodes use a rich "chemical language" that is formed by ascarosides, small molecules with a common carbohydrate core (ascarylose), various fatty−acid−like substituents, and various other substituents such as amino acids, organic acids, or carbohydrates. Hundreds of ascarosides have been identified, but currently only a few have clear functional roles. They are known to be involved in mating behavior, development, dispersal, aggregation, and olfaction; there are likely several other functions that have not yet been characterized. Ascarosides are released into the environment but are synthesized from major primary metabolic pathways. Our working hypothesis is that nematodes sense the environment and modulate metabolic pathways to produce appropriate behaviors. Much of the work on ascarosides has been targeted, either through activity−guided fractionation for biological identification or through targeted mass spectrometry−based assays for chemical identification. We are developing tools that can be used to extract global metabolomic information related to nematode and other organism behavior. I will present a mass spectrometry approach called IROA (isotopic ratio outlier analysis), which allows for the quantitative characterization of hundreds to thousands of small molecules in response to an environmental perturbation. We are also developing approaches using nuclear magnetic resonance (NMR) investigations of isotopically labeled worms to obtain detailed chemical information. These large−scale metabolomic approaches should open up new ways of investigating the chemical interactions of organisms with their environments.

114.1 EDMONDS, K.E.; Indiana University Southeast; *kedmonds@ius.edu*
Do Photoperiod, Castration, or Melatonin Affect Swimming, Pelage and Reproduction in the Marsh Rice Rat (Oryzomys palustris)?
Marsh rice rats reportedly are excellent swimmers with swimming largely confined to the nighttime. I examined whether photoperiod, castration, and melatonin implants affect growth, pelage, reproduction, and the swimming behavior of rice rats. Juvenile males housed on 14L:10D (a long photoperiod) were weaned at 21 days of age, weighed, and left on 14L:10D or transferred to 11L:13D (a short photoperiod). On day 68 of age, rice rats were weighed and swum for ten minutes in a ten gallon glass aquarium. Animals were videotaped while swimming in order to quantify the swimming and floating times. Animals were reweighed after the swim to determine whether water absorption by the pelage caused a change in body mass. On day 69 of age, rice rats were sacrificed and the following organs removed and weighed: both testes, seminal vesicles (SV), spleen, and Harderian glands (HG). Photoperiod significantly affected body mass and the masses of the testes, SV, and HG. The pelage absorbed more water on 14L:10D than on 11L:13D, but pelage lengths were not different between the two photoperiods. The swimming and floating times also were not different between the two photoperiods. Castration affected body mass and the growth of the SV, HG, and spleen only. Lastly, melatonin implants affected body mass, the growth of the testes, SV, HG, pelage length, and absorption of water by the pelage. Taken together, these results show that photoperiod, castration, and melatonin, although they affect growth and reproduction, do not affect swimming behavior in rice rats. It is hypothesized that changes characteristic of winter (short photoperiod, decreased testes size and testosterone, and increased melatonin) are not sufficient to alter aspects of swimming behavior. (Supported by the Indiana Academy of Science)

P3.88 EDWARDS, M.K.*; MCCOY, M.W.; MCCOY, K.A.; East Carolina University; *edwardsmat13@students.ecu.edu*
Developmental Carry−Over Effects from Early Exposure of an Amphibian to Endosulfan
During ontogeny, organisms pass through critical developmental periods of heightened vulnerability to disruptive exogenous agents. In organisms with complex life cycles, these developmental windows result in variable susceptibility or differential effects across life stages. In addition, developmental anomalies that occur during early life can carry−over to affect later stages and ultimately individual fitness. In this study, we examine the stage specific and carry−over effects of exposure to presumably sub−lethal doses of endosulfan during two early life history stages   embryos and larvae. Endosulfan is a commonly used insecticide and a known neurotoxic endocrine disruptor that alters somatic and reproductive development in some taxa. We exposed green tree frog (*Hyla cinerea*) embryos and larvae, individually and across stages, to a gradient of environmentally relevant concentrations (0, 0.1, 1, 10, 100, and 1,000ng/L) of endosulfan. These concentrations range from low levels found in Artic meltwater to those measured in agricultural runoff, but are over an order of magnitude less than quantities found in human breast milk. We are examining how dose and the window of exposure affects tadpole growth, metamorphosis, and gonadal development. We will present results on larval stage duration and mass and length at metamorphosis, and effects on gonad length, width, developmental stage, and numbers of gametocytes (determined histologically). Because our endpoints are strong correlates of fecundity and overall fitness, our findings have important implications for understanding and mitigating amphibian population declines arising from sub−lethal exposures to endocrine disrupting environmental pollutants.

68.1 EDWARDS, D/D*; MOORE, P/A; Bowling Green State University; *davide@bgsu.edu*
GO WITH THE FLOW: STREAMS FOLLOWING GEOMORPHIC FORM
The geomorphic construct of a stream system can greatly influence the unidirectional stream flow. Because of this in stream processes (i.e. − nutrient spiraling) can be altered as well as chemical plumes that are introduced to stream habitats will contain a spatial and temporal structure with fluxes in concentration. The same stream flow can influence organisms as they interact with their physical habitat and reside on or around in stream obstructions. Therefore, knowledge of how the physical construct of a habitat affects the movement of suspended material can elucidate the relationship between an organism's life history and experiencing that suspended material. Here, we expound results from using dopamine as a tracer chemical and various sized obstructions in an artificial flume to help describe this relationship. We also outline a process to scale the geomorphic influences to a stream reach as we overlay common organism habitats with the movement of dopamine around in stream obstructions. Results indicate the potential for a spatial dependency of exposure to suspended material. Spatial analysis techniques (i.e. − remote sensing) to profile the geomorphic construct of a stream system and the surrounding landscape can be integrated with ecotoxicological risk assessments in response to a contaminant introduced to a stream system. In addition, geomorphic information can be utilized for a better understanding of in stream processes (i.e. − nutrient spiraling). The geomorphic influence to these processes and the ecotoxicology of a chemical is interdependently linked to the interaction of flow and the ecology (i.e. − organism) in question.

103.4 EHLMAN, SM*; SANDKAM, B; SIH, A; BREDEN, F; Univ of California, Davis, Simon Fraser Univ; *smehlman@ucdavis.edu*
Developmental plasticity in gene expression and behavior in turbid environments
Upstream human disturbance can cause major changes in aquatic environments by increasing sedimentation in streams and rivers. This increase in turbidity is of growing concern, as important visual information available to aquatic organisms declines. Thus, for predators and prey that rely on sight, increasing turbidity is likely to be of great consequence. To investigate the effects of turbidity on predator−prey interactions, we reared Trinidadian guppies from birth through adulthood in clear or turbid water and measured the effects of these developmental treatments on guppies' visual systems and behavioral responses to olfactory predator cues (i.e. kairomones). To assess treatment differences, we measured gene expression in guppy eyes using probe−based qPCR of nine opsin genes, one rhodopsin gene, and three housekeeping genes. We also measured anti−predator behaviors of guppies when exposed to predator kairomones. Anti−predator behavior was measured as the difference in activity before and after an olfactory predator cue was introduced into an individual's assay tank. We found significant treatment effects on opsin expression, notably in mid−wave−sensitive and long−wave−sensitive opsins, which reflected changes in light absorbance in turbid water as measured with a spectrophotometer. We also found differences in prey behavior between treatments, suggesting that guppies may be compensating for lack of visual information in turbid environments by responding more to olfactory cues. Thus, guppies in turbid water are (1) restructuring the distribution of opsins in the retina and (2) adjusting behavioral responses to olfactory predator stimuli when visual information is poor. These results highlight the critical nature of developmental plasticity and behavior as means through which organisms cope with novel, human−altered environments.

P3.77 ELDERBROCK, E.K.*; SMALL, T.S.; SCHOECH, S.J.; University of Memphis; *kldrbrck@memphis.edu*
Does corticosterone influence nestling begging and sibling competition in Florida Scrub−Jays?
Begging, thought to be an honest signal of an individual's nutritional need, elicits feeding from parents. However, a parent is limited in the amount of food it can provide to its offspring, thus creating potential competition among siblings. Corticosterone (CORT), a metabolic hormone, is hypothesized to play a role in regulating a nestling's behavior. We investigated whether increased exposure to CORT affects nestling behavior in an altricial bird, the Florida Scrub−Jay (*Aphelocoma coerulescens*). During nestling development, we treated one nestling per treatment nest with a twice−daily dose of exogenous CORT via an injected wax−worm. A second individual within the treatment nest received an oil−injected wax−worm. Additional non−treated jay nests were monitored to serve as controls. We monitored individual nestling and parental behavior at all nests with the use of high−definition cameras for two hours on three different days. Our results found no difference in begging rate between CORT−fed and oil−fed nestlings within a treatment nest. However, all nestlings within the nests containing a CORT−treated individual begged more than those in control nests, regardless of individual treatment. This result, repeatable across multiple years, suggests that CORT treatment of an individual alters its siblings' behavior. Current work on this species finds that begging rate correlates with physiological stress response as an adult, suggesting that sibling interactions that influence nestling behavior may have long−term implications for an individual's life.

68.5 ELLIS, D.S.*; ARONSON, R.B.; SMITH, K.E.; Florida Institute of Technology; *dellis2013@my.fit.edu*

Penguins and POPs: Bioaccumulation of Pollutants in Antarctica

Penguin populations have been declining in Antarctica for the last three decades. Populations of Chinstrap and Adélie penguins alone have decreased by 1.1 and 3.4 % per year respectively. Antarctic penguins are highly susceptible to the accumulation of persistent organic pollutants (POPs) in their tissues as a result of their intense feeding activity during the short Antarctic summer. Since 1966, penguins have been assessed for levels of POPs, which are toxic chemicals found in pesticides, flame retardants, industrial byproducts, and burned waste. POPs are transported to Antarctica via atmospheric circulation, where they are deposited and readily accumulate in biological tissues. Can penguins be used as bioindicators of the spatial and temporal patters of deposition of POPs in Antarctica? We conducted a meta−analysis of existing, published data on POPs in Antarctic penguins. Concentrations of POPs in different tissues from the same individuals were compared to obtain bio−accumulative ratios amongst tissue types, allowing the tissue types analyzed in different studies to be compared. Comparisons among three penguin species suggest patterns of accumulation are driven by differences in feeding behavior. Spatial and temporal trends in penguin bioaccumulation were used to infer levels of pollution in the Antarctic ecosystem. Regions of Antarctica with the highest levels of POPs were identified with potential implications for penguin populations over the coming decades to centuries.

29.7 ELLIS, EA*; OAKLEY, TH; Univ. of California, Santa Barbara; *emily.ellis@lifesci.ucsb.edu*

Higher diversification rates are associated with the evolution of bioluminescent courtship displays

One of the great mysteries of evolutionary biology is why closely related lineages, even sister lineages, diversify at different rates. Previous work has attributed this phenomenon to varying amounts of ecological opportunity. A trait−based approach would allow for large−scale patterns to be detected under a variety of habitats and ecological variables. Theory predicts that organisms undergoing sexual selection will have higher diversification rates because of the increased probability of genetic isolation. One way to test whether diversification rate heterogeneity could be linked to the presence or absence of a single trait would be to investigate a single trait which is under sexual selection in some species and nonsexual selection in others. Bioluminescence is an ideal candidate because it has evolved over 50 times and can be used for courtship display (sexual selection) or defense (nonsexual selection). We hypothesize that traits under sexual selection cause shifts in diversification rates, while traits under nonsexual selection do not. We chose two functions of bioluminescence (courtship display and defense) that have been demonstrated in recent years. Using previously published phylogenies, we compared diversity in bioluminescent clades to their non−luminescent sister lineages. When bioluminescence serves as a courtship display (under sexual selection), we find a significant pattern of higher diversification rate. We compare this finding to bioluminescence serving defensive functions (under nonsexual selection). This study demonstrates that a single trait may be under different selective regimes, and in turn, have different effects on diversification rate.

62.5 EMER, SA*; MORA, CV; HARVEY, MT; GRACE, MS; Florida Institute of Technology, Bowling Green State University; *semer2007@fit.edu*

Hot or Not? Behavioral Sensitivity of Burmese Pythons to Thermal Stimuli Detected by Pit Organs

The thermal imaging system of Burmese pythons is a unique sensory modality that detects and images thermal stimuli in the environment allowing the snakes to effectively detect and acquire prey, detect and avoid predators, and seek thermal refugia to meet thermoregulatory requirements. Special facial structures called pit organs detect thermal stimulus information that is processed in the brain to function with vision or alone in complete darkness when visual input is limited. Behavioral assays of the thermal imaging system provide information regarding the sensitivity of the system to environmentally relevant stimuli; conditioned discriminations of stimuli eliminates complicating effects of other cues and habituation often encountered in natural behavior studies. We report the first results of thermal sensitivity using pit organ−based thermal discrimination training in wild caught Burmese pythons. Pythons trained to perform left and right choices to 24°C and 37°C stimuli exhibited a mean percentage of correct choices (76%) significantly greater than chance (50%). During behavioral sensitivity trials, the trained pythons were presented with randomized temperature differentials ranging from 0.5°C to 12.8°C. The pythons continued to perform at significantly greater than chance levels (mean = 61%), even when presented with the 0.5°C differential. This is the most sensitive value for behavioral responsiveness yet reported for the thermal imaging system of a boid snake. These results produce a more complete understanding of the functional relationship between the brain, behavior and environment and its role in python survival and ecological success in a changing environment.

P3.175 EMERY, K.Q.*; O'CONNELL, K.J.; KOMPELLI, A.R.; DEAROLF, J.L.; AVERY, J.P.; Hendrix College, Conway, AR, Univ. of North Florida, Jacksonville, FL; *EmeryKQ@Hendrix.edu*

Morphology of a neonatal guinea pig accessory ventilatory muscle

Prenatal steroids are known to accelerate the development of the lungs of premature human babies; however, to date it is unknown whether they have a similar effect on ventilatory muscles. To determine if exposure to a multi−course treatment of betamethasone, a commonly used prenatal steroid, accelerates breathing muscle development in guinea pigs (*Cavia porcellus*), the percentages and sizes of types IIA and IIX fast−twitch fibers of the neonatal guinea pig rectus abdominis (RA), an accessory ventilatory muscle, were determined. In addition, the citrate synthase (CS) activity and myoglobin concentration in this muscle were quantified. These features were compared to those of fetal guinea pig muscles that were exposed to multi−course betamethasone to see if the characteristics of the treated fetal muscles match those of the neonatal muscles. Immunocytochemistry using an antibody to type IIA myosin (2F7) was used to identify and determine the percentages of the fast IIA and IIX fiber−types in one−day−old neonatal RA muscles. In addition, CS activity in these muscles was measured using kinetic assays. Finally, SDS−PAGE was performed to separate and measure the myoglobin concentration relative to actin in the neonatal muscle samples. If the characteristics of the neonatal and prenatal steroid−treated RA muscles are similar, these results would support the hypothesis that prenatal steroids accelerate breathing muscle development. This result would be incredibly important for babies and mothers exposed to prenatal steroids. Increased understanding about the effects of these steroids will help mothers at risk for premature birth of their infants make more informed decisions during their pregnancies and keep their babies safe.

38.6 ERMAK, J; GIBSON, Q*; Univ. of North Florida, Jacksonville; *quincy.gibson@unf.edu*

Social structure analyses indicate Northeast Florida bottlenose dolphins (Tursiops truncatus) form multi−level alliances

Bottlenose dolphins live in fission−fusion societies where female and male bonds are shaped by different ecological pressures. Across most study sites females form moderate within−sex bonds, while male bonds are highly variable; males range from primarily solitary to strongly bonded within first−order alliances, which cooperatively herd females. Also, multi−level alliances have been documented in one site (Shark Bay, Australia). Here, we use two years (2011−2013) of photo−identification data from the St. Johns River (SJR), Jacksonville, Florida to examine within and between sex bonds. Coefficients of association (half−weight index, HWI), a test for preferred/avoided associations, and a Mantel test were calculated within SOCPROG 2.5. Analyses were limited to females (FEM, n=37) and unknown sex individuals (UNK, n=80, including 10 known males), with 10+ sightings. UNKs were further divided into allied (HWIe0.8) and unallied (HWI<0.8). The community interacted non−randomly (p<0.01) with 172 preferred associations, largely between UNK−UNK dyads. Within−sex bonds were significantly stronger than between−sex bonds (Mantel test, p=1); FEM−FEM top associations averaged 0.3±0.1 and UNK−UNK top associations averaged 0.6±0.3. Twenty−six UNKs met the criteria for alliance status (11 dyads and one quad). Twelve of these individuals had HWIe0.3 with other alliances, indicative of 2nd order alliances. This is the first report of 2nd order alliances in bottlenose dolphins outside of Shark Bay, suggesting similar ecological pressures shaped male mating strategies in the SJR. Continued research regarding regional differences in social complexity will facilitate comparison and clarify the variables governing alliance formation.

24.6 ERNST, D.K.*; LANE, V.A.; BAKER, C.; TSAI, R.; BENTLEY, G.E.; Univ. of California, Berkeley; *dfkernst@berkeley.edu*

Perception of food affects corticosterone, behavior, and hypothalamic gene expression in the zebra finch

Increase in food availability stimulates reproductive activity in zebra finches. It is not known if it is increased energy intake, the visual stimulus of food, or both that affects reproductive status. We hypothesize that physical interaction with food as well as visualization of food affects reproduction. To test this, singly−housed birds were videotaped for 1 hour and then randomly assigned to one of four groups: control (ad libitum food), 7 hours of complete food restriction, 7 hours of exposure to a food dish with seed hulls only (no nutritive value), or 7 hours of a food dish covered in clear plastic so birds were able to see food but not touch it (n=10 per group). At the end of treatment birds were videotaped for an hour followed by collection of tissue. Corticosterone was significantly higher in the food restricted group and the group receiving seed hulls than in controls (p<05). Birds exposed to seed hulls spent significantly more time at their food dish (p<.02) than did control birds or birds with plastic−covered food dishes, while food restricted birds spent an intermediate amount of time at their food dish. Total activity was higher than controls in all experimental groups (p<.05). Perception of food affected expression of neuropeptide Y and gonadotropin−releasing hormone in the hypothalamus (p<.05) and expression of steroidogenic enzymes in the testes. Overall, our data suggest that, while metabolically similar, a visual food stimulus affects zebra finches differently from a food stimulus that they can interact with but receive no nutritional value. These data highlight the importance of physical interaction with food when considering how food availability stimulates reproductive activity.

P2.130 ESCALLóN, C; BECKER, M/H; WALKE, J/B; JENSEN, R/V; CORMIER, G; BELDEN, L/K; MOORE, I/T*; Virginia Tech; *itmoore@vt.edu*

Sexually transmitted infections as a potential cost of testosterone in the Rufous−collared sparrow

Sexually transmitted infections have been suggested as major costs of sexual reproduction, but the mechanisms underlying transmission have been largely overlooked. Testosterone is a hormone that mediates several aspects of reproduction, including the number of sexual contacts. Therefore, testosterone has the potential to affect sexually transmitted infections, either indirectly by behaviors that increase contact rates and potential exposures to cloacal pathogens, or directly by altering immune function. We investigated the relationship between plasma testosterone levels and cloacal bacterial diversity and community composition in tropical populations of male *Zonotrichi capensis* in Ecuador. We collected cloacal swabs to assess their bacterial communities using Illumina amplicon sequencing of the 16S rRNA gene. There was a positive correlation between testosterone levels and bacterial phylogenetic diversity. Contrary to our expectations, high and medium testosterone individuals had bacterial communities that were more similar to each other than to low testosterone individuals. Finally, looking at several groups of potential avian pathogenic bacteria, the relative abundance of Chlamydiae was positively correlated with testosterone levels. Two nonexclusive explanations for these results are that testosterone is mediating sexual contact rates and thus the acquisition of more bacterial strains, or that testosterone is directly altering immune function and bacteria become established more easily. Overall, increased exposure to sexually transmitted pathogens in the form of cloacal bacteria can constitute a strong selective pressure for the modulation of testosterone levels.

P3.119 ESHERICK, LY*; LEHNERT, E; PRINGLE, JR; Stanford University School of Medicine; *lisl.esherick@stanford.edu*

Possible Role of C−Type Lectins in the Establishment of Cnidarian−Dinoflagellate Symbiosis

It is well documented that the cnidarian−dinoflagellate symbiosis is highly specific: a given host is capable of forming a stable symbiosis with only some types within the diverse *Symbiodinium* genus. However, the cellular and molecular mechanisms underlying this specificity are poorly understood. During the initial establishment of symbiosis in larvae, or during its reestablishment in adults that have lost their symbionts, hosts must recognize compatible dinoflagellates among a diversity of microbes in the environment. Recent research has raised the hypothesis that recognition depends on the binding of extracellular host lectins to oligosaccharide glycans on the dinoflagellate cell surface. Using the small symbiotic sea anemone *Aiptasia* as a model system, we have identified by transcriptome sequencing and RT−PCR several genes encoding lectin−like proteins that are differentially expressed between symbiotic and aposymbiotic (without symbionts) anemones. Notably, a majority of the putative lectins that were differentially expressed showed increased expression in aposymbiotic anemones, suggesting that hosts may up−regulate genes involved in pattern−recognition when lacking symbionts. One of these differentially expressed genes, encoding the C−type lectin−like protein Ctl−1, is expressed eight−fold higher in aposymbiotic animals. We have expressed a recombinant GST−tagged form of Ctl−1 in bacteria and found that it binds strongly to an incompatible strain of *Symbiodinium in vitro*, though it also binds weakly to a compatible strain. Analysis of the *Aiptasia* genome has revealed Ctl−1 to be a member of a family of related lectins originating from at least 5 loci in a tandem array; though the binding properties of these related lectins are still unknown.

48.6 ESSOCK−BURNS, T.*; LEARY, D.; SOLDERBLOOM, E.; ORIHUELA, B.; MOSELEY, A.; SPILLMANN, C.; WAHL, K.; RITTSCHOF, D.; DUKE UNIVERSITY, U.S. NAVAL RESEARCH LAB; *tara.essock−burns@duke.edu*

Use of Arthropod Wound Healing Mechanisms in Barnacles Amphibalanus (=Balanus) amphitrite

Wound healing is critical for survival. Plants and animals have mechanisms to heal wounds and there are common themes. Common themes in insect and crustacean immune systems include the prophenoloxidase cascade, production of reactive oxygen species (ROS), enzymes that scavenge ROS, and antimicrobial peptides. Crustacean hemolymph coagulation systems involve some aspects of vertebrate blood coagulation, like transglutaminase and hemocytes. Transglutaminase crosslinks protein and is evolutionarily conserved in many coagulation systems and are in barnacles. Barnacles have an epithelial layer that we have observed tearing during cuticle expansion and leaking fluid. We hypothesized that cuticle tear and wound healing are integral parts of barnacle adhesion. We assayed living barnacle baseplates with enzyme−specific substrates and inhibitors and ROS−specific substrates and inhibitors to characterize activity of secretions. We qualitatively measured activity using fluorescent ROS−specific substrates and confocal scanning laser microscopy (CLSM) and characterized proteins in barnacle secretions further with proteomics. There is oxidative activity at the outer edge of the barnacle baseplate and associated with expanding cuticle as seen by CLSM. Proteomics show prophenoloxidase activating factor in barnacle secretions. Antimicrobial pretreatment of a surface lowers the risk of infection when the cuticle tears and a wound response is activated. Oxidative activity functions in crosslinking and as an antimicrobial. This work informs an aspect of barnacle adhesion and bacterial management and also suggests that barnacles share wound response mechanisms found in many insects and a few other aquatic crustaceans.

91.3 EVANGELISTA, D*; KHANDELWAL, P; RADER, J; HEDRICK, T; Univ. of North Carolina at Chapel Hill; *devangel77b@gmail.com*

Free−flight kinematics of massed Chimney Swifts entering a chimney roost at dusk

Chimney Swifts (*Chaetura pelagica*) are highly maneuverable social birds notable for roosting overnight in chimneys in groups of hundreds or thousands of birds. At dusk, birds gather in large numbers from surrounding areas near a few suitable roost sites. They then enter a very small aperture within a very short time, with the whole flock employing an orderly, but dynamic, circling pattern, even as winds shift and light levels decrease. Such repeatable, reliable behavior in a convenient urban area with fixed landmarks provides an excellent opportunity to use multi−camera videography to measure three dimensional kinematics of natural flight behavior, in the field and under challenging lighting conditions. We present results from automatic tracking of every bird in the flock, discuss kinematic and information metrics appropriate for analyzing the tracks and modeling components of the behaviors, and provide comparison with Cliff Swallow field 3D kinematics to examine differences between strongly and weakly ordered group flight behaviors.

P1.162 EVANS, H*; ROSKILLY, K; LOWE, J; DEWHIRST, OP; HUBEL, TY; WILSON, AM; Royal Veterinary College; *hevans@rvc.ac.uk*

Can dead reckoning techniques improve temporal resolution of measurements from tracking collars?

GPS measurement of position and speed is an important tool for animal locomotion and behaviour research in the field. A major limitation of frequent GPS localisation is the high power requirement of the receiver. Tracking collars for deployment on wild animals are typically designed to last months or years to avoid the need for frequent battery replacement. The tight power budget restricts the number of GPS measurements that can be made, giving only a limited picture of an animal's movement, speed and locomotor repertoire. Accelerometers, gyroscopes based on MEMS (micro−electromechanical systems) technology, and magnetometers operate at much lower power so that measurements can be made more frequently. Here we investigated how data from MEMS sensors can be used to interpolate between infrequent GPS measurements, and hence give an effective improvement in temporal resolution from a collar system deployed on quadrupeds. This was assessed using data from custom−built collars deployed on carnivores in the wild, and over short test periods on dogs and horses in controlled conditions of high and low speed locomotion. Each collar recorded data from a triaxial accelerometer, triaxial gyroscope and triaxial magnetometer. Reference speeds and positions were obtained from GPS measurements, recorded at maximum rate in short tests. Different approaches were evaluated to estimate speed, distance travelled, heading and hence dead reckoned change in position from accelerometer and magnetometer data, for comparison with the reference data. Automatic algorithm tuning and smoothing between infrequent GPS measurements was also investigated and validated with high rate GPS observations.

66.2 EWERS−SAUCEDO, C*; PAPPALARDO, MP; WARES, JP; University of Georgia; *chewers@uga.edu*

Adaptative potential of larval dispersal in barnacles

Dispersal of many marine species is limited to the larval phase. This larval phase is diverse with regard to duration and feeding mode, even between closely related taxa. In brooding species, the larval phase is nearly absent, while feeding larvae disperse for weeks or months. Several taxa can adjust larval duration by changes in egg size. Initial studies on barnacles indicated a lack of such adaptations. We re−evaluated the adaptive potential of barnacles, using a large number of species with data on pelagic larval duration, larval mode, egg and larval size, and taking phylogenetic relationships into account. We found that barnacles exhibit adaptive potential but also phylogenetic constraints.

P3.41 FABIENNE, M*; BOISETTE, B; BESS, F; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College; *catapane@mec.cuny.edu*

Western Blot Identification of Dopamine and GABA Receptors in Gill of the Bivalve Crassostrea viginica

Ganglia and innervated organs of the bivalve *Crassostrea virginica* contain serotonin and dopamine (DA)which mediate physiologic functions in gill and other organs. Gill lateral cells are controlled by serotonin and DA nerves from their ganglia that regulate cilia beating. DA slows down cilia beating and serotonin speeds them up. GABA is a neurotransmitter in nervous systems of vertebrates and invertebrates, but studies in bivalves have rarely been reported. Recently we used HPLC to show GABA is present in ganglia and tissues of *C. virginica* and GABA acts as a ganglionic neurotransmitter modulating gill lateral cell cilia activity. We used immunohistofluorescence to localize GABA in ganglia and gill, and identify DA receptors in gill lateral cells as D2−like (D2DR). We hypothesize Western Blot analysis would verify the presence of D2DR and GABA receptors in gill of *C. virginica*. For Western Blot analysis, gill cell lysate was prepared by polytron disruption in ice−cold NP−40 detergent buffer containing protease inhibitor, followed by centrifugation to obtain supernatant with solubilized membrane proteins. Up to 30 µg of solubilized protein was subjected to SDS−PAGE with 10% acrylamide gels and electroblotted onto nitrocellulose. D2DR and GABA receptor immunoreactivity was revealed after incubation with primary antibodies followed by incubation with HRP−conjugated secondary antibodies. The Western Blots showed strong bands between 70 − 75 kD corresponding to D2DR and GABA RA1−6 receptors in gill. The present project confirms our previous immunohistofluorescence studies showing the presence of DA GABA and furthers the understanding of their physiological roles in *C. virginica*.

12.5 FALKINGHAM, P L*; GATESY, S M; Royal Veterinary College, Brown University; *pfalkingham@rvc.ac.uk*

The birth of a dinosaur track: sub−surface 3−D motion reconstruction and discrete element simulation reveal footprint ontogeny'

Footprints, both modern and fossil, represent sedimentary distortions that provide anatomical, functional, and behavioural insight into trackmaker biology. Such interpretations can benefit from understanding the mechanisms of footprint formation. Yet the development of track morphology is obscured by both foot and sediment opacity, which conceals animal−substrate and substrate−substrate interactions. We used X−ray Reconstruction of Moving Morphology (XROMM) to image and animate the hind limb skeleton of guineafowl traversing a dry, granular material. The reconstructed 3−D foot motion was integrated with a validated substrate simulation employing the Discrete Element Method (DEM), resulting in a quantitative model of limb−induced substrate deformation. By defining sedimentary layers based on initial particle position, we were able to observe the track at multiple levels throughout its formation, and thus link morphological features of tracks with the motion of the foot, both at the surface and at depth. What was initially most striking was that even in loose, granular sediment, tracks with high definition were formed throughout the track volume beneath the sediment−air interface. Transmission played only a very minor role, with most observable deformation occurring close to the path of the foot. Despite the appearance of clear tracks on multiple surfaces, which could easily be misinterpreted as shallow tracks, none accurately represented the geometry of the foot due to its oblique interaction with the sediment. Linking the DEM and XROMM techniques has allowed for a direct correlation between track features and foot motions, and serves to illustrate the complexities inherent in interpreting fossil tracks in light of track maker, behaviour, or function.

P3.82 FALSO, P.G.*; NOBLE, C.A; ADAME, L.C.; RODRIGUEZ, S.A.; NGUYEN, M.N.; WESTHEAD, M.L.; HAYES, T.B.; Slippery Rock University, Univ. of California, Berkeley; *paul.falso@sru.edu*

An Assessment of Stress and Immune Function in an Invasive and Native Amphibian Following Exposure to an Agrochemical Mixture

Amphibian declines in the agricultural landscape are driven by many factors. However, a greater understanding of the relative impact of individual factors, and interspecific sensitivity to known drivers of amphibian decline is needed. In this study two amphibian species, American bullfrogs (*Lithobates catesbeianus*) and Northern leopard frogs (*Lithobates pipiens*), were exposed to a mixture of agrochemicals for 12 days. The American bullfrog is an invasive species with relatively stable populations in California, USA, while the Northern leopard frog is native to California but has experienced dramatic population declines at nearly all historic locations within the state. Our agrochemical mixture represented commonly applied pesticides and fertilizers in California, to which both native and invasive species inhabiting the agricultural environment are likely exposed. The mix included glyphosate isopropylamine salt, oxyfluorfen, chlorpyrifos, pendimethalin, paraquat dichloride, glufosinate−ammonium, maneb, propanil, trifluralin, 2,4−D dimethylamine salt, nitrates, and phosphates. Following exposure, plasma corticosterone and immune cell responses were examined. Given the ubiquitous presence of aquatic contamination and the importance of disease in global amphibian declines, this study may assist in prioritizing threats to the survival of sensitive native amphibians and address the relevance of invasive amphibian species as surrogate models for the impacts of contaminant exposure on a native amphibian species.

5.3 FARINA, S.C.*; FERRY, L.A.; KNOPE, M; SUMMERS, A.P.; BEMIS, W.E.; Cornell University, Arizona State University, Stanford University, Friday Harbor Laboratories; *scf59@cornell.edu*

The contribution of the branchiostegal apparatus to driving ventilatory current in cottoid fishes

The branchiostegal apparatus forms the ventro−lateral wall of the gill chamber of ray−finned fishes and consists of a membrane supported by many long bony rays that articulate with ventral elements of the hyoid arch. Its role in ventilation is to expand and compress the gill chamber, working in parallel with the operculum. Across ray−finned fishes, there is great diversity in skeletal and soft tissue components of the branchiostegal apparatus. Here, we focus on Cottoidei (sculpins and relatives), a group of mostly benthic fishes that exhibits a high amount of variation in branchiostegal morphology. We collected functional (pressure recordings in the oral and gill chamber) and anatomical measurements for four cottoid species representing three recently redefined families. Pressure recordings show that *Leptocottus armatus* (Cottidae) has a powerful oral pump, *Hemilepidotus hemilepidotus* (Agonidae) and *Dasycottus setiger* (Psychrolutidae) have powerful gill−chamber pumps, and *Myoxocephalus polyacanthocephalus* (Psychrolutidae) has an intermediate condition. Using recently published sequence data, we performed phylogenetically independent contrasts for each functional and anatomical variable and regressed contrasts of anatomical measurements against those of functional variables. We found that the relative size of the branchiostegal apparatus predicts the relative contributions of the oral and gill−chamber pumps to driving ventilatory currents. We use our findings to discuss the functional implications of branchiostegal morphology across Cottoidei. NSF DEB−1310812 (WEB and SCF) and Stephen and Ruth Wainwright Fellowship.

S3.5 FARMER, CG; University of Utah; *cg.frmr@gmail.com*
the evolution of unidirectional, pulmonary airflow
Bird lungs have conventionally been thought to be unique in having air flow through most of the conducting airways in the same direction during both inspiration and expiration. Aerodynamic valves cause unidirectional flow through a circular system of tubes, which are organized in an analogous manner to the arteries, capillaries and veins of the blood circulatory system. In contrast, the conducting airways of mammalian lungs arborize, with the branches ending in dead−end, gas−exchange units (the alveoli) and gases travel tidally in the bronchial tree. Although conventionally crocodilians have been thought to have tidal flow and dead−end gas exchange structures, it is becoming clear that their lungs have both avian−like anatomy and patterns of flow. These data raise new questions about the functional underpinnings of unidirectional flow, the selective drivers for this trait, and the evolutionary history this system. This research was funded by NSF (IOS − 0818973 and IOS 1055080).

P3.139 FASANO, M.L.*; PERLMAN, B.M.; ASHLEY−ROSS, M.A.; Wake Forest University; *perlbm0@wfu.edu*
Morphology and fiber type of the axial musculature in adult Kryptolebias marmoratus (Cyprinodontiformes) and juvenile Micropterus salmoides (Perciformes)
Kryptolebias marmoratus (Cyprinodontiformes), the mangrove rivulus, is a quasi−amphibious species of fish known to make directed movements on land by means of a tail−flip behavior involving the axial musculoskeletal system. We asked whether the morphology and fiber type of the axial myotomes have been specialized to facilitate this terrestrial behavior. We compared two different populations of *K. marmoratus*, one from Lighthouse Reef Atoll, Belize, and one from the Florida Keys, Florida, USA, to size−matched non−amphibious juvenile *Micropterus salmoides* (Perciformes), the largemouth bass, via gross dissection and muscle fiber typing using antibody staining. For gross dissection, preserved specimens of *K. marmoratus* (n = 4) and *M. salmoides* (n = 3) were skinned and stained with Lugol's iodine prior to being photographed by a light microscope. Detailed drawings of muscle morphology were made with a camera lucida along with taking and importing photographs into Canvas. We found that the myotomal arrangement of the mangrove rivulus has a "V" shape with respect to the long axis of the body, with distinct dorsal and ventral longitudinal bundles of muscle, differing from the characteristic "W" morphology of teleost myomeres as exemplified by the juvenile bass. For muscle fiber typing, specimens (n = 8 *K. marmoratus* [n = 4 per population]; n = 3 *M. salmoides*) were fixed in Carnoy's solution and stained with primary antibodies S58 and MF20 for immunohistochemistry. Both populations of *K. marmoratus* were found to have only fast glycolytic muscle fibers in both anterior and posterior axial regions, with no slow oxidative fibers present. We suggest that the morphological and fiber type differences in *K. marmoratus* represent specializations for terrestrial jumping.

P2.35 FASSBINDER−ORTH, C*; WALEK, M; SHRESTHA, R; KAWAMOTO, B; Creighton University; *carolfassbinder−orth@creighton.edu*
Feather structure and growth as indices of alphavirus disease severity in nestling house sparrows
Feathers are essential for flight, thermoregulation, water repellency, and visual communication in birds. Feather growth is an energetically costly process, and when feather growth occurs concurrently with pathogenic exposure, trade−offs in resource allocation may occur. Avian infections have been shown to alter feather development; specifically length, strength, and structure can be negatively impacted by infectious diseases. In this experiment, nestling house sparrows were inoculated at 7 days of age with one of two lineages (A or B) of an arthropod borne alphavirus called Buggy Creek virus (BCRV). An additional group received a saline injection and served as a negative control group. Birds from all three treatments were euthanized 2,3, or 4 days post inoculation (DPI). Primary (p1, p5, p9), secondary (s1, s5), and rectrix (r1, r6) feathers were obtained post mortem. Feather length, barb density, and barbule density were determined for each feather. Although peak viremia levels were similar between BCRV−A and B groups, the lineages exhibited different effects on feather development. On 4 DPI, birds in the BCRV−A treatment group exhibited significantly shorter p1, p5, and average primary feather lengths compared to both BCRV−B and control groups. Barbule densities of s5 and primary feathers were significantly higher in BCRV−B infected nestlings 4 DPI compared to the control group. No significant differences in barbule density were recorded for the BCRV−A treatment group. The results of this experiment indicate that feather quality measurements such as feather length and barbule density could be used as markers for infection effects in developing birds. The impacts of altered feather length and barbule density on fledging success should be further investigated to determine the effects of altered feather development on survival.

104.3 FATH, M.A.*; HSIEH, S.T.; Temple University; *michael.fath117@gmail.com*
A comparative analysis of medio−lateral forces in upright and sprawled systems
During the course of vertebrate evolution, multiple tetrapod lineages evolved from sprawled to erect postures. While most studies have focused on the kinetics of quadrupedal and bipedal locomotion using an upright stance, far fewer have examined sprawled locomotion. Sprawled postures have classically been associated with greater bending forces on proximal limb segments (e.g., turtles, iguanas, and alligators) and increased energetic cost. Interestingly, the production of medio−lateral forces associated with the sprawled posture has also credited for increasing stability and maneuverability (e.g., cockroaches and geckos). Yet, for erect bipedal systems, the role of medio−lateral forces are often considered negligible; nothing is known about medio−lateral force production in sprawled bipedal runners. The goal of this study was to quantify the forces being produced during bipedal running in a sprawled locomotor system. The basilisk lizard is an appropriate model system because they are one of the few vertebrates that exhibit a sprawled posture and bipedal running. For this study, we ran 12 basilisks on a trackway with an embedded 6 d.o.f. force plate (ATI Mini−40) while filming two views with a high speed camera (500 fps). On average lizards ran at 1.8 ± 0.2 m/s. Initial results show that vertical force was characterized by a large initial impact force spike followed by a more gradual force development. Excluding the impact force spike, peak vertical force was 2.3 ± 0.3 body weight [BW] and peaked coincident with maximum fore−aft force (0.9 ± 0.2 BW). Medio−lateral forces were variable (0.7 ± 0.3 BW), suggesting that these forces could be important for locomotor stabilization, or may be an outcome of the sprawled posture. Comparisons will be made with other sprawled and upright animal systems that run bipedally or quadrupedally.

P3.1 FAWAZ, A*; HOESE, W; California State University, Fullerton; *afawaz@fullerton.edu*

Students' Alternate Strategies in Reading Evolutionary Trees

Evolutionary trees present hypotheses of the relationships among taxa. Some undergraduate biology students have trouble properly interpreting relationships depicted in these trees. Instead of using the most recent common ancestor (MRCA), many students use alternate strategies in reading trees, including node counting, morphological similarity, or tip proximity to determine relationships. I examined these alternate strategies simultaneously along with the MRCA, to identify the most commonly used strategies and the consistency of their use. I developed a multiple−choice questionnaire to test students' use of these three alternate strategies simultaneously. I administered the questionnaire to 217 undergraduate students in their first core biology class after they received instruction on evolutionary trees. The questionnaire was highly reliable (± = 0.86). The proportion of students who chose tip proximity at least once was highest, followed by node counting, with morphological similarity used least. Over 48% of the tested students missed at least one question, 37% at least two, 32% at least three, and 23% of students missed at least four questions. The type of alternate strategy used by individual students was not consistent throughout the questionnaire; patterns of the structure of the tree appeared to influence the strategies used by students. This questionnaire provides a better understanding of how students determine relatedness among species and can help instructors of introductory biology courses to improve student understanding of evolutionary trees. Future research will use eye−tracking equipment to determine if tree−interpretation strategy matches student eye movements.

3.5 FEDORKA, K.M.*; KUTCH, I.C.; SEVGILI, H; University of Central Florida; *fedorka@ucf.edu*

Temperature−Dependent Immune Investment in Insects

As temperatures decrease, many insects increase the amount of melanin in their cuticle for a variety of purposes; including improved thermoregulation or desiccation resistance. However, melanin is also central to insect immunity, leading to the novel hypothesis that the thermal environment indirectly shapes immune function via direct selection on cuticle color. If true, then then insect immune investment may be significantly constrained in warm environments where melanin investment is expected to be low, but infection risk high. Here, we address this hypothesis in the cricket *Allonemobius socius* and in the fruit fly *Drosophila melanogaster*. We found that individuals reared in a "warm" environment (28°C) exhibited lighter cuticles and inferior bacterial defense compared with those in a "cool" environment (22°C; immune assays were conducted at 25°C to minimize treatment metabolic rate differences). Furthermore, we found that crickets from southern (warmer) latitudes exhibited lighter cuticles and inferior immune defense compared with their northern counterparts (all individuals reared in a common environment). These data suggest that seasonally or geographically distinct thermal environments directly shape cuticle color, which indirectly shapes immune function through pleiotropy. Our hypothesis may represent a widespread mechanism governing immunity in numerous systems, considering that most insects operate in variable thermal environments.

S9.5 FEFFERMAN, Nina H.; Rutgers University; *feffermn@dimacs.rutgers.edu*

The Definition of Communication: one way biology and math people accidentally talk past each other and what we might be able to do to fix it.

Successful communication implies that a speaker is able to provide a listener with a purposefully defined information set that is understood by the listener in the way the speaker intended. In this talk, we'll discuss how the communication training of biology and mathematics rely on different models of transmitted understanding. We'll go through some simple analogies and examples, and then discuss how these different models can lead very easily to "silent" miscommunication in which both sides believe the communication to have been successful, but don't wind up with a common understanding. We'll finish by talking about possible ways we can start to bridge these gaps at every level of interdisciplinary discourse from introductory through advanced educational settings, all the way to collaborative, cutting edge research.

7.4 FEILICH, K.L.; Harvard University, Cambridge; *kfeilich@fas.harvard.edu*

Covariation in body and median fin shape in cichlid fishes

Body and fin shape are considered chief determinants of fish swimming performance. Specific lateral profiles in conjunction with particular median fin shapes may enhance different aspects of locomotion. These body and fin shape combinations have been highlighted in extremely specialized taxa, such as tuna, where the deep anterior profile, narrow caudal peduncle and semi−lunate tail interact to reduce drag while maintaining thrust. Despite the importance of the interaction among the median fins and the body in swimming, there are few data indicating whether or not different body and fin shapes co−occur, or whether they vary independently. The cichlid fishes are a morphologically diverse family, whose well−studied phylogenetic relationships make them ideal candidates for a broad−scale study of morphological evolution and covariation. I studied the body, caudal fin, dorsal fin, and anal fin morphology from x−ray radiographs of over 150 cichlid genera, including all major tribes, using a combination of geometric and traditional morphometrics with phylogenetic comparative methods. Morphological variation of each structure was examined using principle components analysis. Covariation among structures was assessed using partial least squares canonical analysis. Interestingly, body shape, caudal fin shape, dorsal fin shape and anal fin shape all exhibited some degree of covariation with each other. Future research will address if and how the patterns of morphological covariation affect swimming performance, and whether or not covariation in fin shape is driven by developmental constraint.

10.7 FELICE, RN; Ohio University; *ryanfelice@gmail.com*
For Bird Tails, Beauty is Only Skin Deep: Assessing Caudal Skeletal Variation in Sexually Dimorphic Passeriforms
Tail feather (rectrix) morphology is highly variable among birds. This variation is driven both by the role of the tail as a functional part of the aerial locomotor apparatus and as a display structure. Indeed, the most spectacular tail feathers are the result of sexual selection for elaborate rectrices used for display. Previous work has shown that tail fan shape is correlated with the morphology of the underlying caudal skeleton that supports the rectrices, with forked− and graduated−tailed taxa taxa exhibiting characteristic pygostyle shapes. This study tests whether this general pattern holds in species with sexually dimorphic tail feathers in an effort to understand whether evolution in rectricial morphology is linked with phenotypic changes in the caudal skeleton. Feather and skeletal morphology was quantified in selected dimorphic passeriform species and closely related monomorphic species representing a diversity of tail shapes and body sizes. The dimorphic species examined include White−Rumped Shama (Muscicapidae), Scissor−Tailed Flycatcher (Tyrannidae), Pin−Tailed Whydah (Viduidae), Boat−Tailed Grackle, (Icteridae). Skeletal morphology was quantified using a combination of linear and geometric morphometics. Permutational MANOVA was used to assess differences in skeletal morphology between males and females of each taxon. None of the examined taxa exhibit sexual dimorphism in pygostyle shape. In just one taxon, Pin−Tailed Whydah, males have a significantly larger pygostyle surface area than females. These results suggest that evolution of large tail feathers does not require changes in the axial skeleton to support this heavy and aerodynamically costly structure. As such, caudal skeletal morphology in these taxa appears more influenced by phylogeny and locomotor function than by its relationship with tail fan shape.

108.4 FENG, H*; DUNCAN, RP; WILSON, ACC; Department of Biology, University of Miami, Coral Gables; *h.feng1984@gmail.com*
Symbiotic Recruitment of Amino Acid Transporters in the Green Peach Aphid, Myzus persicae
Aphids and their endosymbiont, Buchnera aphidicola, are metabolically integrated in their biosynthesis of several amino acids. At the aphid/Buchnera symbiotic interface amino acid transporters shuttle amino acids and/or metabolites thereby facilitating the metabolic integration. In general, amino acid transporters transport precursors amino acids from aphid hemolymph to Buchnera and return Buchnera synthesized amino acids in response to aphid demand. Here, we generated transcriptomes using next generation sequencing from guts, bacteriocytes (the aphid cells harboring Buchnera), and the whole insects of Myzus persicae. These data will be assembled de novo using Trinity. Then, bacteriocyte specific/enriched amino acid transporters will be annotated through a differential gene expression analysis and validated through quantitative real−time PCR. Our analyses will determine the subset of amino acid transporters recruited at the Myzus/Buchnera symbiotic interface and facilitate comparative analysis of the evolution of host/symbiont metabolic integration among aphids.

P1.166 FENG, R.*; CHEMLA, Y.R.; GRUEBELE, M.; Univ. of Illinois at Urbana−Champaign; *rfeng2@illinois.edu*
3D behavior analysis of zebrafish larvae swimming
Behavioral biologists have a strong interest in studying the behavior of larval zebrafish because the limited number of locomotor neurons in larval zebrafish coupled with the still rich repertoire of movements of a vertebrate animal. Current research uses a priori−selected parameters to describe their movements. Most research also considers only the 2D movements of zebrafish, leaving out the vertical component of their locomotion. Our lab has developed a method to reduce the dimensionality of the locomotion of zebrafish and achieved desirable results on 2D swimming movies. We are extending this work to capture 3D locomotion of zebrafish larvae. Here we present our preliminary analysis of the 3D locomotion of zebrafish.

2.6 FEO, TJ*; FIELD, DJ; PRUM, RO; Yale University; *teresa.feo@yale.edu*
Comparison of barb geometry in modern and Mesozoic asymmetrical flight feathers reveals a transitional morphology during the evolution of avian flight
The asymmetrical flight feathers of extant birds are an important adaptation for avian flight. Barb geometry (barb angle and barb length) controls feather asymmetry and stability, both of which are critical for aerodynamic performance. We hypothesize that different barb geometries can produce feathers with the same width, but with varying degrees of aerodynamic stability due to redundancy in theoretical morphospace. However, the relationship between barb geometry and vane asymmetry across the evolutionary history of asymmetrical flight feathers is unknown. Here we demonstrate that barb geometries significantly differ among vanes with different functions within the wing of extant birds. In particular, leading vanes that function as the cutting edge of an airfoil during flight exhibit a distinct range of barb geometries characterized by small barb angles, which have been shown to increase a vane's resistance to aerodynamic forces. We also observed small leading vane barb angles in the highly asymmetrical forewing feathers of volant Mesozoic stem birds (*Archaeopteryx, Sapeornis, Confuciusornis*), and in the asymmetrical hindwing feathers of *Microraptor*. However, unlike in crown birds, barb angles were small in the trailing vanes of Mesozoic flight feathers. Our results suggest that small barb angles in cutting−edge vanes are an important aerodynamic adaptation that arose by the late Jurassic, prior to the refinement of numerous features associated with powered flapping flight, whereas large trailing vane barb angles arose crownward of *Confuciusornis*. This demonstrates a previously unrecognized transitional morphology in the evolution of asymmetrical flight feathers at a critical interval in the refinement of avian flying potential.

47.6 FERGUSON, L.V.*; HEINRICHS, D.E.; SINCLAIR, B.J.; Western University, London, Ontario; *lfergus9@uwo.ca*
What is acclimation good for? Conflicting responses of physiological and immune systems in the cold
The beneficial acclimation hypothesis posits that acclimation improves the physiological performance of an organism under a particular set of environmental conditions. When temperature decreases, insect performance is affected by cold; however, it may also be affected by co−occurring stressors, such as pathogens. Thus, thermal acclimation may occur in multiple systems, including physiological and immune, to compensate for both the direct and indirect effects of a change in temperature. We hypothesized that cold and pathogen stress challenge insects at low temperatures and predicted that cold acclimation would simultaneously increase the low−temperature performance of physiological and immune systems. We acclimated spring field crickets, *Gryllus veletis*, to 6 °C or 25 °C and tested both physiological performance (e.g. CTmin) and low−temperature performance of the immune system across a range of temperatures (0.5 °C to 30 °C). We found that cold acclimation improved the locomotor performance of insects at low temperatures, in agreement with the beneficial acclimation hypothesis. Conversely, cold acclimation did not improve low−temperature performance of the immune system. Further, particular components of the immune system were deactivated at low temperatures, following cold acclimation. This suggests that insects do not experience a predictable immune challenge in the cold and that the immune system may trade−off with other systems at low temperatures. We propose that exposure to acclimation conditions can result in varied responses within an individual, including beneficial acclimation, activation, or deactivation of different physiological systems, which reflects their relative importance under a new set of environmental conditions.

P1.12 FERGUSON, H. A.*; HUSAK, J. F.; Univ. of St. Thomas; *ferg8725@stthomas.edu*
Trade−offs among performance, reproduction, and immune function in lizards
Life history theory predicts that investment of acquired energetic resources to a particular trait denies those same resources from being allocated to a different trait. This constitutes the basis for life−history trade−offs, such as the ubiquitous trade−off between survival and fecundity, which is thought to result from differential allocation of resources to traits promoting survival and reproduction. Whole−organism performance traits, such as locomotor capacity, are key to fitness and fit within this framework. Such traits are typically energetically expensive, but few have integrated performance into life−history studies. We manipulated diet and allocation of resources to performance, via exercise training, to examine tradeoffs among endurance capacity, growth, immune function, secondary sexual characters (in males), and reproduction (in females). Captive green anole lizards were assigned to one of four treatment combinations across two factors (diet restricted or not and endurance trained on a treadmill or not) over the course of nine weeks: not−trained, unrestricted diet; not−trained, restricted diet; trained, unrestricted diet; and trained, restricted diet. To measure immune function we quantified immune organ masses, bacterial killing capacity of plasma, and the swelling response to phytohemagglutinin Results indicated that the combination of diet restriction and training dramatically suppressed reproduction and immune function, as well as growth and male secondary sexual characters. When individual factors were considered, diet restriction alone had a greater impact than training alone. We also explored potential hormonal mechanisms for the responses. Our results suggest that allocating energy into something as costly as immune function is dependent on resource availability and how those resources are allocated to other traits, including individual performance capacity.

38.3 FERREE, E*; FLORIO, J; GODTFREDSEN, H; JOHNSON, S; SAUVAGE, L; Claremont McKenna, Scripps and Pitzer Colleges; *eferree@keckscі.claremont.edu*
Annual variation in the trade−offs associated with clustering in a facultatively aggregating spider
Most spider species are solitary, but in some species individuals facultatively aggregate. In a population of the golden−orb web spider *Nephila clavipes* near Baru, Costa Rica roughly 50% of spiders form clusters, consisting normally of 2−3 individuals of different size classes. We monitored 400 female spiders for 8 weeks in both 2013 and 2014 to determine whether clustering frequency was related to the trade−offs associated with being in a group, and to test the hypothesis that such trade−offs depend on spider size. We expected that clustering individuals would capture less food than solitary ones, but experience lower predation rates, and that small spiders would more likely experience these trade−offs than larger spiders due to their smaller web size and greater chance of being depredated. Here we report on inter−annual variation in the costs and benefits of clustering and differences between the years that might explain them. Most notably, in the first study year we found no trade−offs associated with clustering regardless of spider size, while in the second year small, but not medium, spiders had reduced prey capture but higher survival if clustered than if solitary. Additionally, small spiders were much less likely to be in clusters in 2013 than in 2014. These differences may be explained by the fact that in 2013 the amount of prey captured in webs was low and predation on the spiders themselves was only 35%, while food was more abundant, and 78% of spiders were depredated during the 2014 study. These results support the idea that fluctuating environmental factors influence the costs and benefits and hence frequency of clustering, and, further, that such trade−offs may not be equal for individuals of all life stages.

S10.9 FERRER, RP; Seattle Pacific University; *ferrer1@spu.edu*
Saxitoxin and the ochre sea star: Molecule of keystone significance and a classic keystone species
Saxitoxins (STX) are paralytic alkaloids produced by marine dinoflagellates in response to biotic and abiotic stressors yielding harmful algal blooms. Because STX impacts coastal communities to a greater extent than would be predicted by its relative abundance it has been referred to as a "molecule of keystone significance" in reference to Robert Paine's Keystone Species Concept. *Pisaster ochraceus*, the predator upon which Paine's concept was founded, inhabits waters regularly plagued by harmful algal blooms, but the effects of STX on *Pisaster* have not yet been investigated. Here, we used laboratory and field experiments to examine the potential consequences of STX exposure on sea star feeding, substrate attachment, and fertilization success. *Pisaster* exhibited similar feeding behaviors when offered non−toxic prey, STX−containing prey, or a combination of the two. Though feeding behavior is unaffected, consumption of STX poses a physiological tradeoff. Sea stars in the laboratory and field had significantly lower substrate attachment thresholds after either being exposed to or consuming STX. HPLC analysis indicated an accumulation of STX (and structural analogues) in sea star viscera, likely due to trophic transfer from toxic prey. Fertilization success tended to decrease when gametes were exposed to high, yet ecologically relevant STX concentrations. These findings suggest that the molecule of keystone significance, STX, produced during harmful algal blooms extends its impacts to rocky intertidal communities by way of the keystone predator *Pisaster ochraceus.*

S12.9 FERRY, LA*; GIBB, AC; PAIG−TRAN, EW; Arizona State University, Northern Arizona University, California State University, Fullerton; *lara.ferry@asu.edu*

This fish doesn't suck: Deviations suction feeding in a biomechanical morphospace

Suction is used as a primary mode of prey capture by the vast majority of aquatic−feeding vertebrates, and fishes exhibit a myriad of morphologies for suction feeding. Yet, even in radically divergent species, such as the cichlids of the African rift lakes, suction is still used to capture midwater prey. Under what circumstances is suction lost in the aquatic realm? Two categories of morphologies reflect a departure from suction as a key component of prey acquisition: 1) enlarged oral apertures that reduce wake phenomena and 2) structurally reinforced heads that resist ventro−lateral expansion. Species with enlarged oral apertures fall into two foraging guilds: ram filter−feeders and long−jawed piscivores. Ram filter−feeders are characterized by enlarged oral apertures and a food capturing mechanism that is located at the posterior end of the oropharyngeal cavity; this location facilitates laminar flow anterior to the particle collection sites. In piscivores, an elongated jaw is coupled with a deep V−shaped mouth opening that channels turbulent flow to the corners of the mouth, and behavioral limitation of gape size. In contrast, fish species with reinforced heads largely represent biting and scraping foraging guilds that remove their food as fragments of large or attached food sources. Although biters and scrapers can use suction to mobilize detatched particles, species that are characterized by reduction in the number of mobile elements in the skull/suspensorium seemingly cannot. Based on these behavioral and morphological characteristics, we define a suction−feeding morphospace and identify the physical parameters that are associated with a shift from suction feeding and a reliance on other modes of moving prey into the oral cavity.

P3.37 FIANA, B*; HARRIS, A; WELSH, C; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College; *catapane@mec.cuny.edu*

Presence of Octopamine Receptors in Heart of the Bivalve Crassostrea viginica

Octopamine (OA), a biogenic amine first identified in octopus, is well studied in arthropods and gastropods where it functions as a neurotransmitter and hormone. The presence or function of OA has rarely been reported in bivalves. Previously, using HPLC we found OA in cerebral ganglia, visceral ganglia, gill, heart, palps and hemolymph of the oyster *Crassostrea virginica* and using immunohistofluorescence we visualized OA in cerebral ganglia, visceral ganglia, gill and heart. Our physiological studies also found that octopamine was cardio−active when applied to *C. virginica* and *Mytilus edulis* hearts. We hypothesize that OA receptors are present in the heart of *C. virginica*. To test this we did Western Blot analysis using and pan TAAR (trace amine−associated receptor) primary antibodies, which are reactive with OA, beta−phenylethylamine (b−PEA), p−tyramine (p−TYR) and tryptamine receptors, but unresponsive to classical biogenic amines and histamine receptors. For Western Blot analysis, heart tissue lysate was prepared by polytron disruption in ice−cold NP−40 detergent buffer containing protease inhibitor, followed by centrifugation to obtain supernatant with solubilized membrane proteins. Up to 30 µg of solubilized protein was subjected to SDS−PAGE with 10% acrylamide gels and electroblotted onto nitrocellulose. pan TAARreceptor immunoreactivity was revealed after incubation with primary antibodies followed by incubation with HRP−conjugated secondary antibodies. The Western Blot studies showed a strong bands at 85 kD corresponding to OA receptors in heart. The present project, coupled with our immunohistofluorescence and cardio−physiology studies, confirms the presence of OA receptors and furthers the understanding of a physiological role for OA in *C. virginica*. This work was supported by grant 0516041071 of NYSDOE.

P1.198 FICKLIN, J.A.*; GERACE, M.E.; RAND, M.S.; Carleton College; *mrand@carleton.edu*

Tissue Morphology of the Dorsal Crest in the Lizard Genus Anolis

Male lizards of the genus *Anolis* use a variety of dynamic morphological modifiers to enhance social signaling. Colorful dewlaps, skin color changes, and dorsal crest erections are used by many species during behavioral interactions. Previous investigators have described interesting details of coloration and dewlap function, but the morphological and physiological dynamics of dorsal crest erections have been largely ignored. We initiated studies to understand the tissue−level mechanisms behind the erection of this behaviorally relevant structure. We examined the dorsal crests under light microscopy with and without stimulation by the ^{2}−adrenergic agonist isoproterenol in both males and females of two anole species, *Anolis sagrei* and *Anolis carolinensis*. We hypothesized that crest erection was mediated through either subcutaneous muscle contraction or hemotumescence, two physiologically mediated mechanisms used by a variety of vertebrates. Histological examination revealed no evidence of gross vascular changes (e.g. sinusoid filling) or the presence of associated muscular tissue, forcing us to reject our original hypotheses. The crests appear to become erect through an increase in interstitial fluid within an encapsulated organ just under the skin. Edema causes the volume of the "crest organ" to increase and the vertically oriented structure maintains its shape with what appear to be horizontally arranged collagen fibers. As the crests begin to deflate, edematous fluid appears to move into spaces lateral to the crest capsule, diminishing the amplitude of the crest. The mechanism of the crest erection is currently unknown, but preliminary results suggest that it is neither prostaglandin nor mast cell mediated. Adult females of both species appear to lack the crest organ entirely.

P2.182 FIELD, L.M.*; FAGERBERG, W.R.; BOETTGER, S.A.; West Chester University, Pennsylvania, University of New Hampshire; *lf776150@wcupa.edu*

Attachment in an unstable environment: Quantification of the algal attachment protein vitronectin.

Algae form a diverse group of organisms that vary in morphology and physiology across the different representatives within the chlorophyta, rhodophyta, and phaeophyta. However, an extraction assay that will yield consistently high amounts of protein from these different organisms has yet to be determined. The current research sought to establish a high yield protein extraction assay and to determine the presence/absence of the multifunctional glycoprotein vitronectin in different algal species and different areas of the algal thallus. Five protein extraction assays were tested and the extraction method that yielded the highest amount of protein was used for extraction of protein from different thallus components.

P2.108 FIELD, K.E.*; MARUSKA, K.P.; Louisiana State; *kfield3@lsu.edu*

Do females of the highly social African cichlid Astatotilapia burtoni use contextual chemosensory communication during social interactions?

Across vertebrates chemical communication is used to convey reproductive state and social status to conspecifics. Females are often senders of potent chemical cues that can elicit physiological and behavioral responses in male receivers. In fishes, these female−released compounds can be passively emitted through the skin and gills, or actively released through the urine. It was previously shown that males of the highly social African cichlid, *Astatotilapia burtoni*, alter urination behaviors depending on social context, but whether females have evolved a similar chemosensory signaling mechanism is unknown. Here we tested the hypothesis that gravid (reproductively receptive) females actively change urination rate and behavior depending on social context. Using an innocuous dye to visualize urine pulses, we exposed dye−injected gravid females to four different conditions: dominant male, gravid female, brooding (non−receptive) female, and control empty compartment, and then quantified urination and social behaviors. We found that gravid females do alter urination rates in a context−dependent manner. Further, the number of aggressive behaviors performed by dye−injected gravid females differed when exposed to females of different reproductive states. These results suggest *A. burtoni* females have a similar chemosensory signaling mechanism to that of males, conveying reproductive status or body condition to males as well as to other females. This study supports the hypothesis that female *A. burtoni* use urine pulses as contextual chemosensory signals for both intra− and inter−sexual communication. Coupled with previous research, these data provide insights on how chemosensory signaling may have helped shape the evolution of social communication during reproduction in cichlid fishes.

P3.143 FINDEN, A. N.*; MINICOZZI, M. R.; GIBB, A. C.; Northern Arizona Univ.; *anf54@nau.edu*

Does the morphology of the vertebral elements influence escape response timing and displacement in bony fishes?

Many teleosts respond to a negative stimuli using an escape mechanism called a C−start. During this behavior, they curl the entire body laterally into a C−shape (stage 1) then, using stored elastic energy and muscular contractions, swing the tail across the midline and accelerate away from the stimulus (stage 2). In some individuals, the time it takes to complete the C−start is shorter and the resulting net displacement is greater, which will increase the likelihood of escaping potential predators. We predicted that the following aspects of vertebral column morphology influence C−start performance: (1) longer vertebral (neural and hemal) spines store more elastic energy when bent and (2) decreased vertebral spine angle (the angle between a given spine and the vertebral column) will increase the effective spine length, which will also enhance elastic energy storage. We hypothesized that longer spines and shallower spine angles are associated with improved timing of the C−start behavior (i.e., shorter stage 1 & 2 durations) and greater net displacement. To test this hypothesis, we analyzed the C−starts of multiple individuals of *Gambusia affinis* using high−speed cinematography, then cleared and double−stained each individual and measured vertebral spine lengths and angles with *ImageJ*. Our preliminary analysis suggests that there are no significant correlations between vertebral element morphology and C−start performance. In fact, several spines actually show a weak positive association between spine length and stage durations, which is the opposite of our initial prediction. Future studies analyzing additional *G. affinis* individuals and sister species will determine if a larger amount of variation in vertebral morphology is associated with observed variation in escape response performance.

P1.33 FINK, A.A.*; JOHNSON, M.A.; RIBBLE, D.O.; Trinity University; *afink@trinity.edu*

The value of corridors in conservation: Genetic diversity in urban lizard populations

Corridors that connect wildlife populations promote the movement of organisms among otherwise−isolated populations, and thus may allow for the maintenance of genetic diversity within them. San Antonio, Texas has recently established corridors connecting urban natural areas, providing an excellent opportunity to assess the effectiveness of corridors for population management. Here, we study the population genetics of the Texas Spiny Lizard (*Sceloporus olivaceus*) to determine if lizards from populations in isolated urban parks are genetically less variable than those in areas connected by corridors and those in natural, rural areas. We collected tissue samples from 164 lizards from 16 localities in and around San Antonio and we used 7 microsatellite loci to analyze geographical and genetic population structure. Analyses to date have indicated that some loci are more variable between localities than others. A Mantel Test indicated that there was no isolation by distance among individuals, but analyses using STRUCTURE software suggested that the sampled lizards may be subdivided into 6 or 9 populations. This population structure may be caused by non−random dispersal among urban habitats, which is possibly associated with the geographical location of the corridors. Our ongoing work will assess the level of genetic diversity within each population.

P3.159 FINLEY, N. L.*; CONRADES, A. D.; GIDMARK, N. J.; Whitman College, Truman State University, University of Washington, Friday Harbor Laboratories; *finleynl@whitman.edu*

Comparative Functional Morphology and Evolution of the Feeding Apparatus in Sculpins (Cottoidea)

The diversity of jaw musculoskeletal systems across vertebrates is immense, and evolution of these systems can take place via changes within the skeleton, within the muscle, or in the way that skeletons and muscles connect. We measured 37 anatomical and 5 kinematic variables of the feeding mechanism across five species of sympatric Salish Sea sculpin (Cottoidea) and used a recent sculpin phylogeny (Smith and Busby 2014) to track how the musculoskeletal system evolves. Relating jaw muscle length changes to jaw bone movements ("gearing") was the focus of our study. We quantified anatomical gearing as the relative distances from the jaw tip and the coronoid process (adductor muscle attachment) to the jaw joint, and kinematic gearing as the amount of gape change for a given amount of jaw muscle length change in feeding sculpins. We found that evolutionary shifts to higher gear ratios were correlated with shifts to shorter muscle fiber lengths for both anatomical ($p = 0.0236$) and kinematic ($p = 0.0295$) gearing. The co−evolution of gearing and fiber length results in similar jaw muscle strain magnitudes across species: evolutionary shifts in fiber length do not correlate with changes in strain magnitude ($p = 0.6002$). Sculpins, therefore, can introduce musculoskeletal variation in their feeding system while avoiding confounding physiological performance limits such as the length−specific ability of muscle to produce high force. Morphological variations such as variable jaw muscle fiber length and gear ratio might be the key to allowing dozens of sculpins to partition distinct ecological niches and coexist sympatrically in the Salish Sea.

P2.119 FIRKE, M.*; SENFT, R.A.; LAUDER, A.; BAUGH, A.T.; Swarthmore College; *marian.firke@gmail.com*

Partitioning the integrated phenotype: multilevel relationships in risk−taking behavior and corticosterone dynamics in great tits (Parus major)

Understanding the physiological basis of individual differences in behavior has recently received considerable interest in behavioral ecology, and methods for partitioning variance in phenotypic characters are now well developed. Here we explore the hierarchical structure of behavioral and endocrine traits in a population of songbirds. We used a repeated measures design and mixed effects modeling to describe how individual great tits (*Parus major*) vary and covary in risk−taking behaviors under semi−natural conditions. We simultaneously examined how these same individuals vary and covary in four components of their acute endocrine stress response (plasma corticosterone), including initial concentrations, a natural stress response, negative feedback (dexamethosone challenge) and adrenal sensitivity (ACTH challenge). We estimated the repeatability and covariance of these behavioral and the hormonal traits, and used these estimates to inform our subsequent analyses concerning the relationships between hormones and behavior. Using this integrated hormone−behavior dataset, we test a set of hypotheses concerning how HPA physiology is linked with risk−taking phenotypes.

S7.1 FISH, FRANK/E*; HOFFMAN, JESSICA/L; West Chester Univ., PA; *ffish@wcupa.edu*

Stability design and response to waves by batoids

Unsteady flows in the marine environment can affect the stability and locomotor costs of animals. For fish swimming at shallow depths, waves represent a form of unsteady flow. Waves consist of cyclic oscillations, where the water moves in circular or elliptical orbits. Large gravity waves have the potential to displace fish both cyclically and in the direction of wave celerity for animals floating in the water column or holding station on the bottom. Displacement of a fish can exceed its stability control capability when the size of the wave orbits are equivalent to the size of the fish. Previous research into compensatory behaviors of fishes to waves has focused on pelagic actinopteryian fishes with laterally compressed bodies. However, dorsoventrally compressed batoid rays must also contend with waves. Examination of rays subjected to waves showed differing strategies for stability between pelagic and demersal species. Pelagic cownose rays (*Rhinoptera bonasus*) would drift through or be transported by waves, maintaining a positive dihedral of the wing−like pectoral fins. Demersal Atlantic stingrays (*Dasyatis sabina*) and freshwater rays (*Potamotrygon motoro*) maintained contact with the bottom and performed compensatory fin motions and body postures. The ability to limit displacement due to wave action by the demersal rays was also a function of the bottom texture. The ability of rays to maintain stability due to wave action suggests mechanisms to compensate for the flux density of the water impinging on the large projected area of the enlarged pectoral fins of rays.

4.1 FISH, F.E.*; HOLZMAN, R; West Chester Univ., PA, Tel Aviv Univ.; *ffish@wcupa.edu*

Swimming turned on its head: Stability and maneuverability of the shrimpfish (Aeoliscus punctulatus)

The typical orientation of a neutrally buoyant fish is with the venter down and the head pointed anteriorly along the longitudinal surge axis. However various advanced teleosts will reorient the body vertically for feeding, concealment or prehension. This change in body orientation requires active movement of the fins to generate the forces necessary to overcome the stabilizing torque resulting from the relative positions of the center of gravity (CG) and center of buoyancy (CB). Furthermore, maintenance of a vertical body orientation will impact the swimming performance. The shrimpfish (*Aeoliscus punctulatus*) maintains a vertical orientation with the head pointed downward. This posture is the stable orientation for the shrimpfish as CB is located posterior of CG along the longitudinal axis of the body. The shrimpfish swims with dorsum of the body moving anteriorly. The body has a fusiform design with a rounded leading edge at the dorsum and tapering trailing edge at the venter. The median fins (dorsal, caudal, anal) are positioned along the venter of the body and are beat or used as a passive rudder to effect movement of the body in concert with active movements of pectoral fins. Burst swimming and turning maneuvers by rolling were recorded at 500 frames/s. Maximum burst speed and turning rate were measured at 2.3 body lengths/s and 957.5 deg/s, respectively. Although such swimming performance is below that of fish with a typical orientation, modification of the design of the body and position of the fins allows the shrimpfish to effectively swim in the head−down orientation.

P1.152 FISHER, C.L.*; REIF, M.S.; CROSSLEY, D.A.; SECOR, S.M; University of Alabama, University of North Texas; *clfisher2@crimson.ua.edu*

Impact of incubation hypoxia on digestive energetics and performance for the snapping turtle

Snapping turtles (*Chelydra serpentina*) incubated as eggs under hypoxic (10% O_2) conditions exhibit a decrease in growth rate independent of food intake compared to individuals incubated under normoxic (21% O_2) conditions. Therefore we explored the effects of incubation environment on turtle digestive physiology by comparing pre− and postprandial metabolic rates, specific dynamic action (SDA), pancreatic function, and intestinal morphology and function of snapping turtles incubated as eggs under hypoxic and normoxic environments. We found incubation environment to have no significant effect on turtle standard metabolic rates, however hypoxia−incubated turtles experienced a 23% greater postprandial metabolic scope and a 45% greater SDA and SDA coefficient. We examine both fasted and fed turtles to explore the effects of incubation conditions on the form and function of digestive tissues. We found little difference in the mass of most organs between fasted and fed, and between hypoxic− and normoxic−incubated turtles, with the exception of the small intestine. Small intestinal mass did not differ as a function of incubation condition, but was significantly heavier for fed turtles. Fed turtles, regardless of incubation condition, possessed thinner serosa, whereas hypoxia−incubated turtles maintained enterocytes with larger volumes. Neither pancreatic trypsin nor amylase activities varied significantly among treatments. Similarly, the activities of the intestinal hydrolases aminopeptidase and maltase lack any significant differences among fed/fasted or hypoxia/normoxia treatments. Our only explanation for the reduced growth rate of the hypoxia−incubated turtles is that these turtles allocate more energy into the efforts of digestion, and hence less is channeled into growth.

41.3 FLAMMANG, B.E.*; BECKERT, M.; NADLER, J.H.; GARBORG, C.S.; ANDERSON, E.; NJIT/Rutgers−Newark, Georgia Tech, Georgia Tech Research Institute, Grove City College, WHOI; Grove City College; *flammang@njit.edu*

Functional morphology of the remora adhesive disc

Remoras (Family Echeneidae) are best known for their cranial suction disc modified from dorsal fin elements. Remoras use the disc to adhere to a number of different hosts (e.g. sharks, fish, turtles, marine mammals, and ship hulls) for several possible reasons, including efficient travel, feeding opportunities, and locating mates. While previous work has shown that remoras can generate suction forces opposing pull−off removal, our research has found that the remora disc is a complex hierarchical mechanism with many different factors contributing to the long term but easily reversible nature of the remora adhesive disc. Here we focus on two morphological features that are responsible for maintaining attachment to a host: lamellar spinules and cranial vasculature. Using a friction model to estimate the spinule contribution to shear resistance, we found that the tooth−like spinules on the flat lamellae that make up the disc generate friction an order of magnitude greater when interacting with a rough substrate like shark skin than with a smooth surface, thereby explaining the difference in adhesive strength on different surfaces observed in previous work. The cranial vasculature of remoras is highly modified with respect to the position and relative size of anterior veins as compared to other fishes. Most notably, the anterior cardinal sinus lies dorsal to the cranium, in direct contact with the ventral surface of the disc. Presumably the orientation of the remora cranial vessels contributes to applying pressure on the disc against the host to maintain strong adhesion for extended periods of time.

P1.96 FLORIO, J*; JOHNSON, S; FERREE, E; Pitzer College, Claremont, W.M Keck Science Department; *jflorio@students.pitzer.edu*

Effect of ontogenetic stage on facultative aggregation in a neotropical spider

Individuals in the vast majority of known spider species are either solitary or cluster into groups of webs. Because only a few species demonstrate facultative aggregation, where individuals choose between solitary and group living, these systems are ideal for investigating the factors that influence the trade−offs of aggregating. We examined the costs and benefits associated with clustering in *Nephila clavipes* and hypothesized that tradeoffs would vary with a spider's ontogenetic stage. Our study was conducted at the Firestone Center for Restoration Ecology, Baru, Costa Rica in the summer of 2014. We measured the cephalothorax width and web diameter of 400 spiders, and daily assessed the number of prey, males, and kleptoparasites in the web, web condition, the number of legs on the resident spider and its ultimate fate. Comparing clustered versus solitary spiders within each size class, we found that medium clustered and medium solitary spiders did not differ in any variable measured. However, small clustered spiders captured less small prey and less prey overall, but had ower depredation rate and longer web tenure than small solitary spiders. Finally, small spiders were more likely than expected to be clustered, while medium spiders were less likely than expected to be clustered. The data support the idea that the tradeoffs of clustering vary with the spider's ontogenetic stage. Small spiders traded lower prey capture potentially for increased protection from predation. While the data revealed no tradeoffs for medium spiders, these spiders were more likely to be solitary, which may indicate a hidden cost. Variation present in the data among previous study years suggests that predation risk may drive clustering behavior, and merits further inquiry.

P1.69 FODOR, A.C.A.*; MALISKA, M.; LOWE, E.; PAVANGADKAR, K.; WEBER, C.; SERRA, N.; BROWN, C. T.; SWALLA, B. J.; University of Washington, Michigan State University, Michigan State University, BEACON; Michigan State University, Friday Harbor Laboratories; University of Washington; Station Biologique de Roscoff; *zebinini@gmail.com*

Mighty Morphing Molgulids: Radical Heterochronic Shifts in Metamorphic Gene Networks of Molgulid Ascidians

Transcriptome and genome data offer new approaches to examine the origin and evolution of the chordate body plan. Chordate body plan evolution has been studied by comparing two closely related ascidian species with radically different larval body plans the tailed *Molgula oculata* and the tailless *M. occulta*. Embryos of tailed *M. oculata* have 40 notochord cells that converge and extend to form the notochord in the center of the tadpole larva's tail. Muscle cells flank the notochord in the tail of *M. oculata* and are critical for larval swimming. In the head is the otolith, a gravity−sensing organ that is important for larval settlement at metamorphosis. In contrast, the larva of *M. occulta* does not have a tail or an otolith. The embryo has only 20 notochord cells, and these cells do not converge and extend during larval development, but they do form a "notoball". We show by transcriptome analyses that the ascidian metamorphosis program begins earlier in molgulid ascidians than in other ascidian species. This radical heterochronic shift has been documented in another tailless ascidian, *Molgula tectiformis*, and is now reported for both the tailed, *Molgula oculata* and tailless *Molgula occulta*. Further functional data will be needed to test the hypothesis that this pronounced heterochrony is a preadaptation for evolution of tailless development in molgulid ascidians. These studies will also facilitate the identification of the genes involved in initiating metamorphosis in ascidian tadpole larvae.

P3.53 FOKIDIS, BH; MA, CC; RADIN, BM*; PRIOR , NH; ADOMAT, HH; GUNS, ES; SOMA, KK; Rollins College, Winter Park, University of British Columbia, Vancouver, The Prostate Centre, Vancouver; *bradin@rollins.edu*

Seasonal Variation in orexigenic neuropeptides and aromatase within the social behavior network of a free−living songbird.

Animal reproduction in seasonal breeders is typically timed to periods of high food availability. During this time territorial behavior may be used to monopolize food resources, and this aggression is largely maintained by the neural conversion of testosterone to estrogen, by the enzyme aromatase. In birds, that are territorial year−round, non−breeding aggression may be related to accessing food resources. Neuropeptide Y (NPY) and orexin are neural proteins that stimulate food intake and maintain energy balance and immunoreactive cell and fiber populations have been observed within the avian social behavior network, yet their specific role has not been identified. We tested the hypothesis that NPY and orexin immunoreactivity differs between breeding and nonbreeding year−round territorial song sparrows (*Melospiza melodia*) in concordance with seasonal changes in energy balance. We also explored regional colocalization of these neuropeptides with the aromatase to gain support for a possible interaction between energy balance and aromatase activity.

36.4 FONNER, C.W.*; GARBARK, C.; WOODLEY, S.W.; Duquesne University; *fonnerc@duq.edu*

Stress and Disease: The Effects of Corticosterone on Chytrid Fungus Susceptibility in the Red−Legged Salamander Plethodon shermani

The fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*) infects amphibians and can cause the disease chytridiomycosis. *Bd*−associated population declines have been reported worldwide, and research into the mechanisms underlying *Bd* susceptibility is needed. It is thought that long−term exposure to environmental stressors suppresses immunity via release of the stress hormone corticosterone (CORT), thus exacerbating the virulence and lethality of *Bd*. Therefore, we hypothesized that a repeated elevation of plasma CORT would increase *Bd* susceptibility and chytridiomycosis development in red−legged salamanders. Plasma CORT was exogenously elevated in animals for 7 consecutive days using dermal patches, then animals were inoculated with sub−lethal doses of *Bd* or vehicle, after which CORT was elevated for another 7 days. Compared to animals inoculated with vehicle, those inoculated with *Bd* had similar levels of activity, body weight change and mortality. However, *Bd*−inoculated animals sloughed their skin much more than control inoculated animals. Furthermore, *Bd*−treated animals with elevated CORT showed significantly more skin sloughing than *Bd*−treated animals exposed to oil patches. Skin sloughing may represent a mechanism for eliminating *Bd* infections. The effects of CORT on infection load, measured using real−time qPCR of skin swabs, will also be presented.

S4.2 FONTANETO, D.; National Research Council, Institute of Ecosystem Study, CNR−ISE, Largo Tonolli 50, 28922 Verbania Pallanza ITALY; *diego.fontaneto@gmail.com*

Solving complexes of cryptic species by using detailed analyses on jaw morphology in asexual rotifers

Jaws in rotifers, called trophi, are among the most important hard structure used for taxonomy and systematics. Selection on feeding ecology acts on these features and produced a wide array of shapes and adaptations, including filtering, piercing, grasping, pumping, etc. Bdelloid rotifers are completely asexual and morphological diversification in their trophi happened without the potentials offered by sexual recombination. I will review the approaches that have been used to couple studies on molecular evolution, mostly through phylogenetic approaches, and studies on morphological diversification of trophi, mostly through geometric morphometrics. Such studies cover both macroevolutionary scenarios and microevolutionary detailed analyses of differences between cryptic species and comparisons between populations. Evolution in the absence of sexual recombination in animals is an intriguing topic, and I will suggest further ways to use rotifer jaws as an invaluable window to explore evolutionary changes.

109.2 FORSMAN, AM*; ANGERT, ER; PERALTA−SANCHEZ, JM; KNIGHT, R; WINKLER, DW; Cornell University, University of Colorado, Boulder, University of Colorado, Boulder; *amf226@cornell.edu*

Unveiling the Nest Microbiome: characterizing bacterial communities in nests of North American tree swallows and their relationships with egg yolk antibodies

Birds deposit various immune compounds into their eggs that protect developing offspring. Infection risk may influence variation in deposition, but this has rarely been addressed in natural systems. We collected eggs and bacterial samples from tree swallow nests across the species range to investigate how characteristics of the nest microbiome relate to levels of egg yolk antibodies. Using next−generation sequencing of the 16S rRNA gene, we provide an in−depth look at the biogeography of avian−associated bacteria at a large geographic scale. Nest microbiomes were dominated by Proteobacteria, Actinobacteria, and Bacteroidetes, with the number of operational taxonomic units per sample ranging from 130 to 873. We found no evidence for a latitudinal species gradient, nor did we find any relationships between microbiota and longitude or elevation. As expected, phylogenetic distances between bacterial communities were smaller within sites than between sites. In contrast, the effect of geographic distance was weaker than expected, suggesting that nests provide similar microhabitat conditions that vary less than the environments in which they lie. In accordance with our predictions, preliminary analyses indicate a positive relationship between yolk antibody levels and nest bacterial richness across sites. To our knowledge, this is the first study to document a positive relationship between transgenerational immune investment and the diversity of bacteria in a wild host environment. Our results suggest that nest microbiota have the potential to influence important life history stages where microbe−host interactions are particularly intensive.

S6.9 FOSTER, Susan A; Clark University; *sfoster@clarku.edu*

Evolutionary Origins of Plastic Behavioral Responses to Environmental Challenges in the Adaptive Radiation of the Threespine Stickleback Fish

Rapid anthropogenic changes in the environment are imposing shifts in the patterns of selection on local populations. Behavior has long been considered a primary means of rapid response to environmental challenges given its often exceptional plasticity. When behavioral plasticity is adaptive it can rescue populations from extinction (Baldwin Effect), although plastic responses to novel environments need not be adaptive. The adaptive radiation of the threespine stickleback fish offers an unusual opportunity to evaluate factors that influence the patterns of plasticity and evolutionary responses to selection in a recent adaptive radiation. Ancestral patterns of plasticity can be inferred from regional oceanic populations likely to represent the ancestral condition relative to populations established since the last glacial retreat was initiated approximately 12,000 years ago. Comparisons among multiple ancestral (oceanic) populations and derivative freshwater populations of several ecotypes indicate that in some cases the responses to anthropogenic environmental modification reflect ancestral patterns of environmental variation. The responses in some cases involve modification ancestral patterns of plasticity and in one case apparent loss of plasticity (genetic assimilation). Evolutionary responses to anthropogenic habitat modification (predator introduction, increased productivity) have also led to contemporary evolution of plastic phenotypes, apparently including learning, over periods as short as 20 years, and to the re−emergence of ancestral traits that in multiple populations exhibit parallel evolutionary inhibition of a complex behavior. The evidence indicates that in this radiation at least, responses to anthropogenic modification of the environment will be complex, but in some cases predictable.

80.7 FOSTER, AD*; BUTCHER, MT; SMITH, GA; YOUNG, JW; NEOMED, Youngstown State University, Kent State University at Stark; *afoster@neomed.edu*

The spring in their step: ontogeny of ankle joint mechanics in eastern cottontail rabbits (Sylvilagus floridanus)

Previous research has shown that *triceps surae* mechanical advantage is typically highest in juvenile mammals and scales with negative allometry during growth. Because lower *triceps surae* mechanical advantage increases elastic energy storage in the Achilles tendon, improving locomotor performance, this suggests selection for force production in juveniles versus selection for locomotor economy in adults. We test this hypothesis using eastern cottontail rabbits (*Sylvilagus floridanus*) as a model system. We found that maximal ankle joint moments scale with isometry during growth ($M^{1.31}$; R^2=0.86), whereas proximal calcaneal length (i.e., *triceps surae* moment arm length) scales with negative allometry ($M^{0.23}$; R^2=0.87), suggesting that the maximal tensile force imparted to the Achilles tendon should scale with positive allometry ($M^{1.08}$). All else being equal, increasing force should increase tendon strain, improving the potential for elastic energy storage among adults. However, because the cross−sectional area (CSA) of the Achilles tendon scales with positive allometry ($M^{0.79}$; R^2=0.87), maximal tendon stress scales with slight negative allometry ($M^{0.29}$). These data suggest that, contrary to our hypothesis, tendon strain may actually decrease during ontogeny, particularly if adult tendons have greater elastic modulus, as previously shown in laboratory rabbits. Negative allometry of muscle lever lengths, combined with positive allometry of tendon CSA, may permit juvenile rabbits to optimize both force production and energy storage at the ankle, increasing locomotor performance despite small body size. Adults, by contrast, appear to optimize tendon safety factor in lieu of locomotor economy. Supported by NSF IOS−1146916.

97.6 FOSTER, KL*; HIGHAM, TE; Univ. of California, Riverside; *kfost001@ucr.edu*

The mechanical functions of muscle and tendon during arboreal locomotion in Anolis lizards

Lizards are exceptionally adept at moving through highly complex environments, and this extreme performance requires that their muscles function effectively under widely disparate conditions. Among the properties that can impact muscle function, the force−length relationship is of considerable importance in determining how force can be generated over a range of limb positions, as different joint angles may result in different muscle lengths. Unfortunately, due to the small size of most lizard muscles, it is difficult to use surgical techniques to directly measure muscle lengths and forces *in vivo* and in ecologically relevant contexts. We employed an integrative approach to explore the impact of substrate on muscle function in the arboreal lizard, *Anolis equestris*. We assessed muscle and tendon architecture to determine the potential for tendon strain to decouple muscle length from limb kinematics. Assuming 100% of muscle recruitment, maximum tendon stretch would be equal to less than 1% of muscle−tendon length for all hindlimb muscles. As this clearly precludes decoupling of kinematics and muscle strain, we quantified the relationship between muscle length and joint angle using high−speed video. We then used this relationship to link *in situ* force−length curves to kinematic and muscle activity data obtained from lizards running on perches of different diameter and incline. Thus, we have not only established that tendons are unlikely to deform and thus primarily function to connect muscle to structures rather than to store elastic energy in small lizards, but we have demonstrated the utility of using a combination of techniques to determine the impact of ecological factors such as substrate incline and diameter on muscle function in small animals. Supported by NSERC PGSD 405019−2011 and NSF IOS−1147043.

P1.197 FOSTER, KL*; GARLAND, JR, T; HIGHAM, TE; Univ. of California, Riverside; *kfost001@ucr.edu*

Ecomorphology of lygosomine skinks: the impact of habitat use on limb length

Habitat structure has a profound influence on the form, function, and behavior of animals. Although one of the best examples of ecomorphological specialization can be found in *Anolis* lizards, few relationships between limb length and habitat have been found in other lizard taxa. Further, few studies demonstrate a functional consequence of this ecomorphological relationship. Lygosomine skinks are extremely diverse, both ecologically and morphologically; they occupy habitats ranging from leaf−litter to cliffs and tree trunks, and they range from stocky with highly robust limbs to elongate with reduced or absent limbs, each form arising multiple times. Such patterns suggest a tight ecomorphological relationship, but few genera in this group have been studied and it is unclear if the relationship will hold across a broader sampling of species. We obtained morphological and ecological data for 103 species of lygosomine skinks to test for the relationship between limb morphology and habitat use in an evolutionary context. We compared non−phylogenetic and phylogenetic models, with and without Ornstein−Uhlenbeck (OU)−transformed branch lengths, and consistently found the OU models to best fit the data. We show that saxicolous and arboreal species have longer and more equal limbs than terrestrial species, and that these longer limbs translate to longer limb spans that would be advantageous for climbing on curved, vertical surfaces. Interestingly, however, although longer limbs should increase the distance between the center of mass and the edge of the base of support (static stability), this calculated variable did not correlate with habitat use. These data suggest that the different behavioral, but not stability, requirements of arboreality and fossoriality can explain the morphological patterns observed.

112.5 FOWLER, L.A*; POWELL, M.L; DENNIS, L.N; DAWSON, J.A; BARRY, R.J; DAVIS, J.L; GOWER, B.A; WATTS, S.A; University of Alabama, Birmingham; *fowlela@uab.edu*

Effects of Varying Levels and Ratios of Dietary Lipids on Growth, Body Composition, and Reproductive Success in the Zebrafish Danio rerio

Dietary requirements for both lipid quality and quantity have not been well−established in animals. Further definition is needed to achieve optimal health. In this study, we examined the effects of dietary lipid composition on weight gain, body composition, and reproductive success in wild−type zebrafish. Experimental diets were prepared by varying the ratios of n−6:n−3 fatty acids (1.2:1, 4:1, and 8.5:1) within three levels of total fat (9, 12, and 15%), resulting in a total of nine treatments. Larvae were raised on live feed until 21 days of age, and then fed experimental diets ad libitum for 16 weeks (during the period of rapid juvenile growth and reproductive maturity). At the termination of the 16−week feeding period, each treatment was evaluated based on weight gain, percent body fat, and embryo production. Body weight gain was highest in fish fed diets containing 9% total fat and the 1.2:1 n−6:n−3 ratio, and significantly decreased with increasing dietary lipid and n−6:n−3 ratios. Nominal data indicated that total body lipid and triglyceride storage was highest in fish consuming the 15%, 1.2:1 diet. Additionally, fish fed diets containing 9% total fat exhibited enhanced reproductive success. These results suggest that feeding zebrafish a low−fat diet will improve both reproductive and metabolic health. Further characterization of dietary lipid requirements will help to establish healthy levels of dietary lipid for the zebrafish, and contribute towards the development of a standardized reference diet for use in translational research.

111.6 FOX, J.L.*; HALL, J.M.; MCLOUGHLIN, D.P.; Case Western Reserve University; *jlf88@case.edu*

Diversity in haltere behaviors and sensing across Dipteran species

The halteres of flies are reduced hindwings that provide mechanosensory information during flight. Although these organs are crucial for flight , their role in other behaviors is not understood. Because afferent neurons are known to be sensitive to a wide range of motions, the information transduced by halteres is dependent on motion. We observed haltere movements of 20 fly families. By capturing high−speed video of halteres during tethered flight and during free walking, we discovered that all flies oscillate their halteres during flight, but only certain families of flies oscillate their halteres during walking. The oscillations seen in these flies were highly dependent on phylogeny. Some flies of the suborder Nematocera showed uncoordinated oscillations while walking and standing. Many more recently evolved families of flies do not move their halteres at all unless flying. However, two of the most recently evolved groups show characteristic patterns of oscillations. All families of flies in the Calyptratae oscillated their halteres during walking, and did so at their wingbeat frequency. Flies in the superfamily Tephritoidea moved their halteres with slow, irregular patterns, and did so during both walking and standing. Furthermore, we found that flies often moved their halteres independently, varying the phase of oscillation of one haltere relative to the other. This observation is in contrast to haltere movements in flight, in which case they are strictly in phase with each other. These observations suggest that in many flies, the halteres may be multi−functional and could provide different types of information depending on behavioral context. Our explicitly comparative and evolutionary approach has revealed previously undescribed diversity in haltere movements, and possibly new functional roles for the haltere in fly behavior.

P1.157 FOX, T.P.*; KLOK, C.J.; HARRISON, J.F.; FEWELL, J.H.; Arizona State University, Tempe , Arizona State University, Tempe; *trvrfx5@gmail.com*

The costs of aggressivity and the benefits of cooperation

Queens of the harvester ant *Pogonomrymex californicus* have been documented as having two distinct behavioral phenotypes controlling both aggression and the tendency to form foundress associations. Pleometrotic queens found colonies cooperatively with nest−mates while haplometrotic queens found solitary nests. Haplometrotic queens are larger and more aggressive to other queens, and produce eggs at a higher rate during colony founding. We tested for possible metabolic differences between these types, predicting that the non−aggressive pleometrotic queens would have lower metabolic rates, and that pairs of pleometrotic queens would have even lower rates (per ant) as prior studies have shown reduced work and per capita egg production in pairs relative to solitary founders. CO_2 emission and O_2 consumption was measured using a stop−flow respirometry system. We tested individual haplo− and pleometrotic individuals and pairs of pleometrotic queens. Respiratory quotients averaged .68 and did not differ among treatments, suggesting that these queens were primarily metabolizing lipids. Indeed, our results showed that the paired pleometrotic queens had a significantly lower metabolic rate (.0066 $mlCO_2$/hourÅanimal) than the individual pleometrotic queens (.0077 $mlCO_2$/hourÅanimal), while haplometrotic queens had the highest metabolic rate of the three groups (.009 $mlCO_2$/hourÅanimal), suggesting that the aggressivity and high egg−laying rates of the haplometrotic queens has a measurable and significant cost, and that cooperative founding reduces per capita energy use. These differences in energy use may partially explain differences in survival of queens, as queens do not forage during the prolonged period of colony founding. This research was partially supported by NSF IOS 1122157 and NSF DMS 1313312.

P1.20 FRANKEL, T.E.*; TOUB, S.P.; CARLSON, A.L.; ORLANDO, E.F.; University of Maryland, College Park; *frankelt@umd.edu*

Mate choice on body coloration in the platyfish

We compared the effects of male coloration (red, blue, and yellow) on female mate choice in the adult southern platyfish (*Xiphophorus maculatus*). Males were housed individually and standardized based on various body morphometrics. Females were housed in groups based on coloration. Experiments were conducted utilizing a 56.7 L aquarium with clear Plexiglas© partitions placed equidistant from the center of the tank, which created two isolated holding areas for the male subjects. A synonymously colored male was randomly placed into either the left or right holding chamber to account for side bias. A male of alternative coloration was placed into the opposite chamber. Females were placed into an isolation chamber in the center of the test tank and allowed to acclimate for 2 min, after which courtship behavior towards each male was recorded for 8 min. We recorded the initial preference of each female, as well as the total amount of time females spent associating with each male. Initial preferences were analyzed using a binomial distribution test, and overall preference data using Wilcoxon signed rank tests. Red females initially selected for dissimilar males, and spent more time associating with blue and yellow males. Yellow females also initially selected dissimilarly colored males and spent more time associating with red and blue males. Blue females initially selected and spent more time associating with red males; however, they showed no selection preference between blue and yellow males. Overall, the strong mate selection exhibited by female platyfish for dissimilar coloration in this experiment is suggestive of a negative assortative mating strategy and for how color polymorphism may be maintained in wild populations.

P1.7 FRANKLIN, D.T.*; HOLMES, A.E.; CRAIG, C; COHEN, C.S.; Georgia Southern University, San Francisco State University; *sarahcoh@sfsu.edu*

Distribution of Acartia spp. in central San Francisco Bay and San Pablo Bay is not related to temperature and salinity variation.

Copepods are the most abundant metazoans in the world, and due to their roles as primary consumers and critical food sources for higher trophic levels, they are ecologically important. Still, like many marine species, taxonomic identities and distributional patterns are not well known, leaving large gaps in our understanding of aquatic food webs and the potential for ongoing climate change to affect critical food web linkages. Cryptic species of *Acartia* in Chesapeake Bay show distributions related to salinity. In San Francisco Bay (SFB), *Acartia* species are not well defined ecologically or taxonomically. In this study, *Acartia* collections (n=14) were made at 6 locations spanning temperature and salinity ranges of 15.8−18.6 C and 19 to 34 ppt to test for distribution patterns related to environmental variation. Sixty samples were barcoded with ~ 500 nucleotides of the 18S rDNA locus and compared with available sequence in Genbank. Three distinct supported clades were found in SFB; two were inferred to represent *A. tonsa* and *A. hudsonica*. Environmental and geographic sampling information was mapped against the clade data to test for distribution patterns related to temperature, salinity, or other spatial variation. North American west coast *Acartia* show a different pattern from their east coast congeners with broad distributions for 3 clades in SFB. The results contribute to the first molecular comparison of *Acartia*spp. distribution in SFB, and suggest broad and overlapping use of varying habitats by distinct clades.

108.5 FREEMAN, C.J.*; BAKER, D.M.; EASSON, C.G.; PAUL, V.; Smithsonian Marine Station, Fort Pierce, FL; *freemanc@si.edu*
Metabolic Diversity and Niche Structure of Caribbean Sponges
By hosting symbionts, many eukaryotes gain access to the products of microbial metabolism that are crucial for host performance. Within oligotrophic coral reefs, some (High Microbial Abundance [HMA]), but not all (Low Microbial Abundance [LMA]) sponges host such communities. Recent research has revealed substantial disparity in these sponge−microbe associations (termed holobionts), with substantial host specificity for particular symbiont taxa and functional differences in the C and N metabolism of microbial consortia within distinct hosts. To assess how metabolically diverse holobionts are distributed in isotopic niche space, we investigated the niche size (as standard ellipse area [SEAc]) and relative placement of 14 common sponge species in bivariate ($\delta^{13}C$ and $\delta^{15}N$) plots. Sponges were collected at multiple sites within the recently explored reefs of the Miskito Cays of Honduras. These reefs support diverse communities of HMA and LMA species spanning a gradient of photosymbiont abundance, as revealed by chlorophyll *a* analysis. Although the SEAc of HMA sponges was larger than that of LMA, photosymbiont abundance was a better predictor of holobiont function than overall symbiont abundance, suggesting that autotrophic metabolism is an important process in the placement of species in isotopic space. We also observed substantial variation in the placement of individual species within isotopic niche space. We posit that hosting specific, functionally diverse symbiont communities may impact niche utilization across diverse holobionts, potentially contributing to the diversification of sponge communities within tropical reefs.

114.6 FREITAS, M.B.*; TSAI, C.A.; KARASOV, W.H.; Univ. of Wisconsin, Madison; *mfreitas@wisc.edu*
Effects of environmentally relevant concentrations of Polybrominated Diphenyl Ether (PBDE) on hormonal profiles of Lithobates pipiens during metamorphosis
Thyroid hormones play a critical role in metamorphosis in most amphibians, driving growth, development and tissue differentiation, whereas corticosterone (C) action is more complex and less known. We tested for changes in their levels in tadpoles exposed to PBDE, which is known to slow tadpole development and growth, and at different temperature, which is also known to alter development and growth. We raised leopard frog tadpoles at 23 and 28° C from the free−swimming stage (Gosner Stage (GS) 25) through the end of metamorphic climax (GS 46) on diets with 0 (control), 10 and 50 ng/g PBDE. Animals were collected at 6 developmental stages (GS 28, 31, 37, 41, 42 and 46) for whole−body determinations of triiodothyronine (T3), thyroxine (T4) and C via ELISA. A pronounced peak in T3 concentrations at metamorphic climax (GS 42) was observed in control animals raised at both temperatures (P=0.01). PBDE−exposed animals at both temperatures, however, failed to show this rise during metamorphic climax (P>0.3). C concentrations showed a progressive increase in control animals raised at both temperatures, reaching significantly higher concentrations at the end of metamorphic climax (GS 42 and 46). Exposed animals also presented a similar pattern, but levels were higher at early stages (P=0.01). Taken together, our results indicate that both oral exposure to environmentally relevant concentrations of PBDE as well as warmer temperatures, induce hormonal alterations in developing *Lithobates pipiens*, suggesting that, in addition to environmental contamination, a warming change scenario might also interfere with their hormone secretion. Support from CNPq (postdoctoral fellowship M.F.) and Sea Grant NOAA (NA10OAR4170070, Proj R/HCE−14).

P3.79 FRENCH, S.S.; NEUMAN−LEE, L.; GREENFIELD, S.M.*; Utah State University; *sydney.greenfield@aggiemail.usu.edu*
Effects of Corticosterone and ACTH on the unken reflex in Rough−skinned Newts, Taricha granulosa
Stressful events such as a predator attacks stimulate a multitude of physiological events, including the activation of the hypothalamic−pituitary−adrenal (HPA) axis. The consequential release of glucocorticoids, such as corticosterone, stimulates the mobilization of energy stores for antipredator behavior. When threatened, Rough−skinned Newts (*Taricha granulosa*) curl up to expose a brightly colored ventral side; a behavior known as the unken reflex. The exposed aposematic coloration warns potential predators of the newts' toxicity. This study sought to uncover the role of corticosterone and adrenocorticotropic hormone (ACTH) in the unken behavior of Rough−skinned Newts. Newts were injected with corticosterone, ACTH, metyrapone (a corticosterone blocker), and a control (saline). Time in unken was measured and compared to levels of corticosterone in the blood. We found the time in unken was correlated to corticosterone levels for newts given corticosterone injections. However, those given ACTH, metyrapone, and saline had unken times that were not significantly correlated to corticosterone levels in the blood. While there was a large amount of individual variation, corticosterone and ACTH−injected newts had elevated levels of corticosterone, but suppressed time in unken. Overall, this study provides evidence that corticosterone is involved albeit not directly in mediating anti−predator behavior in newts.

P3.165 FRICKE, SN*; STAAB, KL; McDaniel College; *snf002@mcdaniel.edu*
Characterization of the cellular morphology and extracellular matrix components of connective tissues in three cypriniform fishes
While there is a rich body of work examining the functional properties of the teleost feeding apparatus, it is surprising how little we know about the composition of connective tissues within the teleostean feeding elements. Whereas mammals are known to have discrete categories of connective tissues, including hyaline cartilage with abundant extracellular matrix and dense regular connective tissue that has few cells and many extracellular fibers, in contrast, teleosts have a wide spectrum of connective tissue types, including tissues that resemble mammalian cartilage but vary in their amounts of matrix, matrix composition, number of cells, and cellular morphology. The main goal of this study is to determine the cellular morphology and biochemical makeup of the primary feeding elements in the first and second visceral arches (mandibular and hyoid) of three cypriniform species: *Carassius auratus* (goldfish), *Danio rerio* (zebrafish), and *Cyprinus carpio* (koi). Cypriniforms have unique strategies for suction feeding, and this study seeks to elucidate tissue morphology, structure, and function of their feeding elements. A combination of several histological staining techniques was used to learn more about the chemical composition of the tissues, and the staining patterns were documented. Positive Alcian blue and periodic acid−Schiff (PAS) staining of the hyoid bones indicates an acidic, cartilage−like makeup of the extracellular matrix. Additionally, several interhyoid ligaments stained positively for elastin, suggesting that stretch is important for hyoid depression during suction feeding. This work thus provides a basis for future functional morphological studies on teleostean connective tissues associated with suction feeding.

70.6 FRITZENWANKER, J. H.*; DARRAS, S.; LOWE, C. J.; Hopkins Marine Station of Stanford University, Institut de Biologie du Développement de Marseille−Luminy; *Jensf@stanford.edu*

Wnt signaling in the hemichordate Saccoglossus kowalevskii

The Wnt signaling pathway is a key regulator of body plan organization and axis formation in all metazoans. We have analyzed the developmental role of Wnt signaling in the hemichordate *Saccoglossus kowalevskii* to gain insights into deuterostome and bilaterian body plan evolution. Our data shows that *S. kowalevskii* is the only known bilaterian with the full Wnt ligand complement predicted for the bilaterian ancestor. We have analyzed the roles of Wnt signaling in endomesoderm formation (Darras et al. 2011), anteroposterior axis formation, and posterior axis elongation. We demonstrate that in *S. kowalevskii* these three patterning roles of canonical Wnt signaling can be identified as three independent and discreet phases during development. We further demonstrate that during the establishment of the A/P axis, Wnt signaling in *S. kowalevskii* establishes the two most anterior body regions (anterior, center), but surprisingly is not involved in the establishment of the most posterior domain around the blastopore. Following gastrulation, canonical Wnt signaling mediates posterior elongation of the axis in a feedback loop with *brachyury*, as has been described in chordates. We discuss the comparative implications of this work for understanding the evolution of the bilaterian A/P axis.

102.3 FUDICKAR, A.M.*; GRIEVES, T; KETTERSON, E; Indiana University, North Dakota State University; *afudickar@gmail.com*

Timing mechanisms in a songbird: comparing hormones and gene expression in sping in migrant and resident populations held in a common garden

When migratory and sedentary populations co−occur, they experience the same biotic and abiotic cues, yet migratory individuals prepare for migration while sedentary individuals prepare to breed. The co−occurrence of migratory and sedentary populations during winter and early spring, a form of heteropatry, provides a unique opportunity for identifying the neuroendocrine mechanisms that regulate the timing of reproduction and migration. In a common garden experiment we tested 1) whether co−occurring migratory and sedentary male dark−eyed juncos (*Junco hyemalis*) maintain reproductive timing differences when held captive under natural photoperiod with abundant food, 2) whether seasonal elevation of circulating corticosterone (CORT) in migrants in early spring is associated with delayed reproduction and 3) whether and which genes are differentially expressed in migratory and sedentary juncos in early spring. To address these questions we compared the migratory and sedentary groups for circulating levels of testosterone (T), T in response to exogenous GnRH, circulating CORT, and differential gene expression in blood and pectoral muscle in early spring. We discuss our results, and the mechanisms regulating the timing of migration and breeding, in light of rapid climate change.

P3.80 FULK, AM*; WILCOXEN, TE; Millikin University; *afulk@millikin.edu*

Effects of stress during development on skin antioxidant capacity in western chorus frogs (Pseudacris triseriata)

Frogs, like all vertebrates, experience stressors through their developmental stages in life, including their free−living larval, or tadpole, stage. Studies across vertebrates have shown that stress effects the developmental processes that change the rate of age−specific transitions in early development, or in this case, metamorphosis. Increases in metabolic rate associated with faster metamorphosis in response to stressors are likely to lead to an increase in free radicals, and the potential for elevated oxidative damage. We are interested in antioxidant defense capabilities in tadpoles with the increase of stress in the environment. We manipulated stress levels of western chorus frog tadpoles by adding corticosterone to their water through their larval stage and determined total antioxidant capacity of the skin via swabbed samples of their skin surface. Using a subset of tadpoles given the same treatment as those in the experiment, we used a corticosterone enzyme immunoassay and confirmed that tadpoles with corticosterone added to their water had significantly higher corticosterone levels after 12, 24, and 48 hours than tadpoles that only received the ethanol control. Tadpoles given exogenous corticosterone developed significantly faster and had significantly lower total antioxidant capacity. Exploring these antioxidant levels in amphibians may reveal critical mechanisms by which amphibians maintain the health of their skin and costs associated with responding to stressors

S9.2 FULL, R.J.*; DUDLEY, R.; KOEHL, M.A.R.; LIBBY, T.; SCHWAB, C.; Univ. of California, Berkeley; *rjfull@berkeley.edu*

The Impact of Discovery−Based Instruction on Interdisciplinary Research Skills

We developed an interdisciplinary, discovery−based teaching laboratory that treats students as researchers. Our quantitative, biomechanics teaching laboratory allows students the chance to move toward original scientific discovery every week. Teams of biology and engineering students rotate to a new station each week to conduct experiments using state−of−the−art research equipment. Each week a team has two three−hour class periods. In the first period, students become familiar with equipment and are given a problem thought to be solvable. We intentionally design the laboratory so results do not meet student expectations, often because they must consider another parameter. In the second class period, a team uses the same station to design their own experiment to further investigate the problem. This approach scaffolds the students through the stages of critical thinking as described by Perry (1970) and demonstrates the value of both disciplines working in concert toward novel discovery. Laboratory stations include the locomotion energetics, mechanics and control of rapid running in insects and lizards, material testing of plants and insect muscle, PIV of hummingbird flight in a wind tunnel, fluid mechanics on physical models in a water flume, and flow measurements in nature. Teams have a three−week period at the end of the course to conduct an original research project that can be published. We measured students' interdisciplinary research skills of participation, communication, and critical thinking during the course over several years through surveys and student interviews. Findings support a model for interdisciplinary discovery−based instruction that contributes to the knowledge of how students learn to be interdisciplinary researchers.

91.2 FULLER, NW*; THERIAULT, DH; KONG, Z; WANG, S; BETKE, M; BAILLIEUL, J; Boston University; *nwfuller@bu.edu*

Understanding bat flight as a model for bio−inspired aircraft designs

Flight behaviors of bats provide an extraordinary study system for scientists to understand collective behavior, obstacle avoidance, and sensory systems of flying organisms. Until recently, the technologies needed to study bat flight in detail have not existed, thus only simple observations of their flight behaviors could be studied. Using an advanced thermal imaging system, custom software, and 3D imaging techniques, we have constructed detailed analyses of bat flight behaviors. Our objectives are twofold. First, we aim to use bats as a model organism to understand group behavior of flying animals using the large flight columns of the Brazilian free−tailed bat, *Tadarida brasiliensis*, as a model organism. Second, we use the cave bat, *Myotis velifer*, as a model organism for obstacle avoidance strategies employed by bats. This presentation will detail several of our past studies of bat flight behavior, including behavioral forces experienced by bats flying in a column of 200 conspecifics and variations in flight behaviors exhibited by bats that are challenged with a novel obstacle. Our results show that groups of bats often show counter−intuitive behaviors when flying in a group (i.e., accelerating or turning toward other individuals) and that echolocation call frequency and obstacle approach will change over time as bats adjust to the presence of new hazards in their flight corridor. These data will be used by our collaborators in an effort to define simplified models of the variables the govern flight and collective behavior. Eventually these models will be integrated into intelligent flight control algorithms that will lead to the development of a new generation of bio−inspired unmanned aircraft.

P3.97 FURIMSKY, M. M. *; RIEMER, R.A.; ROBERTSON, J.C.; Westminster College − PA; *furimsmm@westminster.edu*

Effects of chemically dispersed crude oil and salinity on anatomical and physiological parameters of the bluegill

The use of chemical dispersants to remediate crude oil spills is common, especially in estuarine areas, and its effectiveness is dependent upon many properties of water, such as salinity. Crude oil is composed of polycyclic aromatic hydrocarbons (PAHs), which are extremely toxic to aquatic organisms. Dispersants facilitate the breakup of oil molecules, dispersing them through the water column, which leads to the uptake of PAHs through gills of fish. Not only can PAH exposure lead to osmoregulatory imbalances, but it activates the stress response system and can cause structural damage to gill epithelia. To observe these effects, adult bluegill,*Lepomis macrochirus*, were exposed to treatments of crude oil, chemical dispersant, and chemically dispersed oil in both freshwater and 1.5% salinity for 48 hours. Blood parameters were tested and gill morphology was analyzed both qualitatively and quantitatively. There were profound qualitative proliferative and degenerative changes in gill epithelia for all treatment groups, as well as differences in lamellar length and width. Proliferative changes included hypertrophy and hyperplasia of epithelial cells, and degenerative changes observed were epithelial cell lifting and rupture, lamellar fusion, and necrosis of filamentary epithelium. Significant differences were observed in fish exposed to dispersed oil in freshwater for glucose relative to the control, and both hematocrit and hemoglobin were higher in fish in saltwater compared to the respective freshwater groups. These results support current similar research in fish toxicology and indicate that anthropogenic pollution, and ways in which it is remediated, affects various physiological and anatomical parameters of aquatic organisms.

93.4 GABLER, M.K.*; GAY, M.; WESTGATE, A.J.; KOOPMAN, H.N.; University of North Carolina Wilmington; *mkg5178@uncw.edu*

A comparative study of the microvascularity of adipose in a variety of diving tetrapods and terrestrial mammals

During dives, marine tetrapods experience physical changes in their surrounding environments, such as decreased temperature and increased pressure, which can introduce significant physiological challenges. Adipose tissue is of particular concern for diving physiology, because nitrogen gas is 5 times more soluble in fat than water/blood. Therefore, at any blood/tissue interface, gas will diffuse from blood into tissue, potentially forming gas bubbles upon decompression and increase the risk of decompression sickness. Exposure of tissues to N2 gas is a function of pressure, blood flow, and the number of blood vessels for exchange present. Interestingly, the degree of microvascularity (capillaries, microarterioles and microvenules) in the adipose tissue of diving tetrapods has not been studied. Percent microvascularity was determined by incubating frozen sections from four terrestrial mammals (*Sus scrofa*, *Ovis aries*, *Capra aegagrus hircus*, *Bos taurus*) and three diving tetrapods (*Hippopotamus amphibius*, *Dermochelys coriacea*, *Somateria mollissima*) in a solution of NBT/BCIP to stain for endogenous alkaline phosphatase. There is considerable variability in microvascular density across species. The percent microvascularity of terrestrial mammals was 0.81% (cow), 1.59% (pig), 5.38% (sheep), and 5.40% (goat). Comparatively, diving tetrapods had values of 2.03% (hippopotamus), 5.10% (eider duck) and 6.53% (leatherback turtle). The degree of microvascularity in diving tetrapods suggests the potential for gas exchange between blood and adipose at the microvessel level may be quite large.

P3.131 GABRIEL, S.M.*; AUSTER, P.J.; KRACKER, L.; Swarthmore College, Univ. of Connecticut and Sea Research Foundation, NOAA Center for Coastal Monitoring and Assessment; *sofiagabriel15@gmail.com*

Elements of the landscape of fear: assessing patterns of prey abundance and patchiness at sub−tropical reefs

At reefs dominated by higher trophic level piscivores, variations in distribution and abundance of prey species mediate community composition. Understanding prey patchiness provides important information about the community and aids in the interpretation of surveys monitoring the status of protected areas. We asked how distribution and abundance of small prey fish changed over space and time at Gray's Reef National Marine Sanctuary (GRNMS; off Georgia, USA) by comparing prey density (fishes <11cm TL in $100m^2$ segments) at reefs inside and outside an area closed to fishing using data derived from Simrad EK60 split−beam sonar surveys in 2011, 2012, and 2013. Surveys were conducted at dawn and dusk at 6 reefs in 2011 and 2012, and 5 reefs in 2013. Overall there were significant differences between years, fishing treatments, reefs, and time of day (GLM Procedure; $p<0.05$). Noteworthy comparisons within treatment levels revealed significantly higher prey densities in 2012−13 at sites outside of the no−fishing zone. There were also significant temporal differences in prey density: 2011 had the lowest fish density and 2012 the highest. In addition, comparison of the indices of mean crowding revealed significant changes in the distribution of the prey population along reefs, with more clumping of prey in 2012 and 2013. This initial assessment of variation in prey resources at GRNMS suggests that abundance and patchiness can provide a useful indicator for the presence of top predators on reefs and potentially aid in the management of such ecosystems.

91.1 GAGLIARDI, SF*; COMBES, SA; Harvard University; *sgagliardi@fas.harvard.edu*

Fuel efficiency and flight endurance of bumblebees (Bombus impatiens) carrying nectar loads

Bumblebees forage widely for floral resources, often carrying immense loads of pollen or nectar over long distances. Their endogenous fuel reserves are minimal, so bees burn a portion of the nectar they have collected to fuel their return journey to the hive. Despite the critical role that resource collection plays in hive growth and fitness, little data exists on the fuel efficiency of bumblebees carrying loads, or on the limits of their flight endurance. We expected that bees would use more fuel per unit time while carrying heavier loads of nectar, and that their fuel efficiency would improve as nectar load diminishes, resulting in an exponential decline in total body mass. To test this prediction, we starved bumblebees (*Bombus impatiens*) for several hours and then allowed them to sate themselves with 1 g/ml sugar solution. We developed an apparatus in which bees must hover constantly, and flew bees until exhaustion, weighing them every 10 minutes. Surprisingly, total body mass did not decline exponentially, but rather linearly, suggesting that bumblebee flight metabolism is less sensitive to the addition of extra loads than predicted. Bees typically consumed 50−65% of their body mass in nectar and were able to fly for 2−3 hours, burning approximately 2−4 mg of nectar per minute. The underlying causes of individual variability and potential effects of environmental factors on fuel efficiency warrant further investigation, as these could have important consequences for hive growth and survival.

55.4 GALASKA, M.P.*; MAHON, A.R.; SANDS, C.J.; HALANYCH, K.M.; Auburn University, Central Michigan University, British Antarctic Survey; *mpg0009@auburn.edu*

Genetic Connectivity of Antarctic Circumpolar Brittle Stars Ophionotus victoraie and Astrotoma agassizii

The Southern Ocean is home to highly endemic benthic fauna. Ophiouroids are a highly abundant and conspicuous member of Antarctica's benthic assemblages, comprising large percentages of the biomass in many areas. As an important member of the benthic ecosystem, we present data on two supposedly circumpolar ophiuroids (*Ophionotus victoriae* and *Astrotoma agassizii*) in an attempt to reveal genetic structure and identify open ocean barriers to dispersal such as depth or geographic distance. *O. victoriae* has feeding planktotrophic larvae while *A. agassizii* was thought to brood its young but is now known in its Southern Ocean clade to in part broadcast lecithotrophic larvae. Both of these reproductive strategies could help explain a circumpolar distribution as they provide a means for long dispersal. We utilized two mitochondrial markers, 16S & COI for *O. victoriae* and 16S & COII for *A. agassizii*. These genes were amplified for 253 *O. victoriae* and 188 *A. agassizii* that ranged from the Ross Sea into the Weddell Sea, a distance of over 5,000 kilometers. Preliminary results have yielded two very different genetic structures. *A. agassizii* appears to be genetically homogenous within its Southern Ocean clade, while *O. victoriae* appears to have a more distinct structure through its geographic range. As these initial results depend on just two mitochondrial markers, the use of 2b−RAD genotyping will provide more resolution to the genetic connectivity of both species. This technique has been shown to reveal detailed population structure where traditional markers failed.

114.5 GALLAGHER, A/J*; HAMMERSCHLAG, N; University of Miami; *gallagher.austin@gmail.com*

Urbanized sharks are happier than their rural counterparts

The role of serotonin in driving social interactions, dominance hierarchies, aggression, and state of mind has been well−documented in a number of species, ranging from invertebrates to humans. The majority of previous work assaying serotonin to understand happiness or stress in animals has been limited to model organisms or smaller study species which can be kept and maintained under laboratory conditions. It is unsurprising, then, that we generally know much less about the role of serotonin in predator−prey interactions, particularly for large and mobile species which often experience a diversity of changing environments across their life history. We assayed plasma serotonin levels, a proxy for "happiness," in two species of predatory sharks sampled in urban and rural environments in southern Florida. Bull sharks resident to the Bay of Miami had significantly higher plasma serotonin levels than bull sharks sampled in the Everglades National Park, where there is less human−impact. There were no significant differences in plasma serotonin between blacktip sharks sampled across urban and rural habitats, but their levels were significantly lower than bull sharks. Our results suggest that shark species which are hunted by larger species experience higher chronic stress and lower serotonin levels, whereas the benefits of urbanized living may be tracked neurologically and function to alter the ecological roles of sympatric top predators.

P2.186 GALLOWAY, K/A*; SUMMERS, A/P; University of Rhode Island, Friday Harbor Laboratories at University of Washington; *kategalloway12@my.uri.edu*

Ontogeny of tooth performance of Ophiodon elongatus during puncture and draw

The teeth of fishes have several roles; they serve in prey capture, retention, and processing. The link between tooth shape and function in prey capture and processing is reasonably well understood, at least in the context of the oral and pharyngeal jaws. Many lineages of fishes have teeth on cranial bones that do not have obvious opposing teeth, the vomer and palatine for example. In this study we investigate the puncture and draw performance of vomerine teeth and compare to the premaxillary teeth of the piscivorous ling cod, *Ophiodon elongatus*. We measured the force to pierce prey and to remove prey from embedded teeth across a size range from 205 to 836mm SL. Smaller ling cod required proportionally less force than larger fish for vomerine teeth to pierce their prey, and premaxilary teeth showed the opposite trend. The force to remove a prey item from the grasp of the teeth showed the same trend as puncture force across the size range. These data suggest that as the lingcod grows there is some shift in function from vomerine to premaxillary teeth. Smaller ling cod are likely to use vomerine teeth during capture, while larger ling cod are likely to use premaxillary teeth during capture. It can be inferred that premaxillary teeth in smaller ling cod are used for grasping and processing of prey because a large force that was required for the prey to tear away from the premaxillary teeth. Larger ling cod use vomerine teeth to process prey because a larger force that was required for the prey to tear away from the vomerine teeth.

89.2 GARB, J.E.*; GENDREAU, K.L.; SCHWAGER, E.E.; HANEY, R.A.; University of Massachusetts Lowell, Oxford Brookes University; *Jessica_Garb@uml.edu*

Genomic investigations of black widow and house spider venoms suggest rapid evolution of extremely potent neurotoxins

Black widow spiders (genus *Latrodectus*) are infamous for their exceptionally potent venom, which in addition to insect toxins contains the vertebrate neurotoxin ±−latrotoxin. ±−Latrotoxin is an unusual metazoan toxin because it forms exogenous calcium channels in vertebrate neurons, triggering massive neurotransmitter release in injected victims. However, ±−latrotoxin is just one of at least 20 latrotoxin paralogs, all of which are strongly and specifically expressed in the venom glands of the Western black widow (*L. hesperus*). Interestingly, the phylogenetic distribution of the large latrotoxin family is extremely narrow, being limited to a few genera of the same family (Theridiidae), suggesting its recent origin. In addition to latrotoxins, black widow venom also contains other classes of toxins, some of which may be unique to theridiids. Here we present analyses of newly sequenced spider genomes, including a genome from the house spider (*Parasteatoda tepidariorum*), a close relative of black widows that produces far less toxic venom. Bioinformatic surveys of toxin genes in the house spider genome, along with gene expression (RNA−Seq) studies of venom glands from multiple species suggest large differences in venom protein composition among closely related species. Moreover, phylogenetic analyses of latrotoxins and other toxin families suggest extensive and recent lineage−specific evolution of venom genes, along with substantial shifts in tissue specific expression among species. We will discuss these findings in terms of their adaptive significance for black widow ecology, and for deciphering the physiological activities and biomedical utility of black widow venom.

17.7 GARCIA, MJ*; MARSON, K; SVENDSEN, JC; EARLEY, RL; Salisbury University, University of Alabama, University of Minnesota; *mjgarcia@salisbury.edu*

Sex Differences in the Costs of Reproduction in a Sex Changing Fish, the Mangrove Rivulus (Kryptolebias marmoratus)

Reproduction is associated with significant sex−specific costs. To accommodate these costs and maximize reproductive success, many animal species have evolved a flexible sexual strategy − functional sex change. Theory predicts that transitions between sexes should occur when the fitness payoff of maintaining the current sex is exceeded by the fitness of switching to the opposite sex. In this study we sought to examine sex−specific costs of reproduction in a sex−changing vertebrate, the mangrove rivulus fish (*Kryptolebias marmoratus*). Rivulus are androdioecious; populations consist of self−fertilizing hermaphrodites and males. Hermaphrodites transition into males as they age or when exposed to elevated ambient temperatures. We generated 40 male−hermaphrodite pairs and quantified baseline steroid hormone levels, behavioral traits (aggression and risk−taking), metabolic rates, and anatomical traits (organ masses). We found significant differences in anatomical, physiological, and behavioral traits between the sexes. Hermaphrodites had larger gonadosomatic indices, higher maximum metabolic rates, were more aggressive, and were more risk−aversive relative to males. Males had greater body masses, possessed considerable fat stores, and had higher androgen and estrogen levels relative to hermaphrodites. Our findings suggest that hermaphrodites invest more heavily in gonadal tissue than males, maintain elevated metabolic rates, and sacrifice somatic growth to accommodate this investment. Our study provides support for future research investigating how external conditions (e.g. ambient temperature) influence internal conditions (e.g. metabolism), the impact that changes in internal conditions have on reproductive investment and, ultimately, how these changes dictate the point of transition between sexes.

P3.30 GARCIA, D.E.*; DRAZEN, J.C.; WENG, K.C.; DICKSON, K.D.; Univ. of Hawaii, Honolulu, California State University, Fullerton; *degarcia@hawaii.edu*

Metabolic Enzymes Activities in the fast−glycolytic locomotor muscle of Shark Species representing a Broad Range of Depths and Activity Levels.

Enzyme activity can be used as an index of aerobic or anaerobic capacity when it is difficult or impossible to measure metabolic rate or maximal activity directly, as with large sharks. The purpose of this study was to compare the activities of key metabolic enzymes in the fast−glycolytic locomotor muscles of shark species from a range of depths and predicted levels of locomotor activity. Four previously unstudied shark species, and additional individuals of two other species, were sampled, and combined with comparable published data. Interspecific comparisons using this combined database allowed more robust tests of hypotheses concerning relationships among enzyme activity, phylogeny, fish activity level, and depth of occurrence. For this study, sharks were collected using long lines, and muscle was sampled with an 8mm biopsy needle, frozen in liquid nitrogen aboard ship, and stored at −80°C for up to 12 months prior to analysis. Spectrophotometric assays were used to quantify the maximal activity (at saturating substrate concentrations) of four enzymes that catalyze reactions in the metabolic pathways for both aerobic and anaerobic ATP production: citrate synthase, malate dehydrogenase pyruvate kinase, and lactate dehydrogenase. There was a much wider range in enzyme activities in the shallow−living species than in the deep−water species, and the highest activities were found in regional endotherms and active swimmers. Activities of all four enzymes generally decreased with depth, corresponding with differences between shallow− and deep−water elasmobranch in locomotor capacity and ecological strategies. These findings parallel results for teleost fishes and cephalopods.

P3.96 GARCIA, S. M.*; GEMMELL, B. J.; BUSKEY, E. J. ; Univ. of Texas at Austin; *brad.gemmell@utexas.edu*

Sublethal Effects of Crude Oil and Chemical Dispersants on Swimming Behavior of Barnacle Nauplii

Meroplankton are often the only motile phase during the life history of many marine species. Thus, investigating the sublethal effects of crude oil and dispersants on molality is an important consideration. In this study we examine and quantify the swimming behavior of barnacle nauplii (*Balanus improvises*) when exposed to emulsified crude oil, dispersant (Corexit 9500) and a combination applied at 20:1 oil to dispersant ratio. Four exposure durations were tested; 6, 12, 18 and 24 hours at two realistic oil concentrations; 5 uL L^{-1} and 10 uL L^{-1}. High resolution videography and motion analysis software was used to quantify swimming kinematics of barnacle nauplii under the different conditions. Results show a significant decline in swimming velocity for nauplii exposed to crude oil after only 12 hours at both concentrations tested. At the concentrations tested, Corexit alone does not have a significant influence on nauplii swimming behavior but when combined with oil, it appears to exacerbate reductions in swimming speed. Exposure to commonly applied water accommodated fraction (WAF) and chemically enhanced water accommodated fraction (CEWAF) methods reveal a more significant impact on swimming behavior and mortality. These findings aid our understanding of sublethal effects of crude oil toxicity to marine zooplankton and our ability to predict how exposure to dispersive larval stages may impact the ability to maintain position in the water column and find suitable habitat.

P2.103 GARCIA, S.M.*; GOLLER, F.; University of Utah; *sarah.garcia@utah.edu*

Contributions of syringeal muscles to acoustic parameters of song in suboscines and oscines

The avian vocal organ, the syrinx, gives rise to highly complex acoustic behavior, and acoustic features of song are thought to be controlled by syringeal musculature. The syringes of suboscines and oscines feature prominent intrinsic syringeal muscles. These groups therefore provide an ideal frame work in which to study the roles of neural control in generating vocal diversity. Oscines, unlike suboscines, exhibit vocal learning, and it is unclear to what degree this difference is reflected in the use of syringeal musculature during song. Previous data from the great kiskadee (*Pitangus sulphuratus*), a suboscine, suggest syringeal denervation does not appreciably change vocalizations (Amador et al., 2008, J. Neurophysiol., 99(5):2383−9). In this study, we compare the effects of syringeal nerve cuts in western kingbirds (*Tyrannus verticalis*), a suboscine, and two emberizine oscines (green−tailed towhee, *Pipilo chlorurus*; fox sparrow, *Passerella iliaca*), to assess the varying contributions of syringeal control to acoustic properties. Consistent with data from great kiskadees, the frequency of vocalizations of western kingbirds was unaffected by nerve cuts, suggesting syringeal neural control is not required for frequency modulation. In contrast, nerve cuts in both emberizines resulted in a significant reduction of frequency range of the ipsilaterally contributed sounds. The surprising lack of an effect of denervation of syringeal muscles in tyrannids suggests that they modulate frequency by adjusting respiratory pressure, similar to the kiskadee. Thus, syringeal muscles do not contribute to expanding the frequency range of the song repertoire as is seen in oscines (Goller & Riede, 2013, J. Physiol. Paris, 107(3):230−42). Relying on respiratory modulation to adjust frequency severely limits the frequency range of an individual vocal repertoire.

S10.6 GARDINER, Jayne; New Colleg of Florida; *jgardiner@ncf.edu*

Finding food, finding home: the chemical ecology of sharks

In the natural environment, animals use multiple sensory cues simultaneously to perform complex behaviors. Chemicals can be mixed in nearly limitless combinations, allowing animals and even specific locations to have unique chemical signatures. Sharks have a renowned sense of smell and odor plays a major role in identifying important resources, such as prey, detecting the presence of predators, and recognizing critical habitats, such as nursery areas. Carried by flow, odor disperses over large distances in water and is often the first sensory cue encountered by a shark searching for food. For some shark species, odor is critical for prey detection, while other species can recognize prey either visually or by smell. Recent evidence also suggests that olfaction plays a major role in another important behavior: homing. Blacktip sharks migrate over hundreds of kilometers to return seasonally to their natal nurseries. While other cues, possibly geomagnetic, guide navigation over the broad scale, olfactory cues are required for recognizing their specific home range. To locate odor sources, sharks initially orient to chemical cues based on the timing of odor arrival at the nostrils, turning to the nostril that receives the signal first. This bilateral odor information aids in steering into patches of odor. Animals with more widely−spaced nostrils would be expected to be capable of resolving smaller angles of attack, which may have contributed to the evolution of the cephalofoil of hammerhead sharks. To follow an odor plume, however, sharks cannot use chemical cues alone due to the spatially and temporally chaotic nature of turbulent odor plumes. These animals require a directional vector, provided by flowing water. The direction of flow can be perceived using the lateral line or visual systems, or, in benthic species, using tactile cues, allowing sharks to follow odors to their source.

5.1 GARRETT, J*; SOCHA, JJ; Virginia Tech; *jfg@vt.edu*

The Madagascar hissing cockroach modulates abdominal pump frequency and spiracle phasing to compensate for hypoxia

All insects use pressure gradients produced by metabolism to move gas diffusively through an internal tracheal system. Some species augment this gas exchange using tracheal compression, a volume displacement of the tracheal tubes that generates bulk flow of air. At least three distinct behaviors are thought to affect such flow: abdominal pumping, collapse of internal tracheal tubes, and active opening and closing of spiracles. The specific coordination of these events should influence internal and external airflow patterns, and therefore may vary with changing metabolic requirements, including oxygen availability in the air. Due to its large size and viewable spiracles, the Madagascar hissing cockroach (*G. portentosa*) is a useful model for studying the coordination of respiratory behaviors. We used these roaches to study how the animal modifies its respiratory behavior to compensate for a reduced availability of oxygen. N adult specimens, both males and females, were exposed to 15%, 10%, 5%, and 0% oxygen. The Advanced Photon Source at Argonne National Lab was used to capture x−ray video of internal abdominal structures, while the abdomen and abdominal spiracles were recorded using separate visible−light video cameras. As oxygen concentration decreased, abdominal pumping frequency increased, along with tracheal collapse. Furthermore, spiracles opened more rapidly, spent more time open during each abdominal pump event, and fluttered less between events. At sub−critical oxygen concentrations (<5%), pumping ceased entirely and the spiracles remained fully open. By understanding how the hissing cockroach modulates its respiratory behavior in response to changing flow requirements, we have improved our knowledge of the network characteristics of actively−ventilating insects. Supported by NSF 0938047.

P1.78 GARZA, SP*; TISHCLER, L; NGUYEN, T; MARTINEZ ACOSTA, VG; WOOD, BF; DAVIS, J; SIKAZWE, D; Biology Dept., Univ. of the Incarnate Word, Feik School of Pharmacy, Univ. of the Incarnate Word, Chemistry Dept., Univ. of the Incarnate Word, Chemistry Dept., Univ. of the Incarnate Word; *vgmartin@uiwtx.edu*

Putative acetylcholinesterase inhibitor significanly reduces segmental regenration in Lumbriculus variegatus.

Studies of neurodegenerative disorders such as Alzheimers disease (AD) have long identified the cholinergic neurons as a site of dysfunction. Reduction in cortical acetylcholine (AChE) activity has been documented in patients with mild to moderate AD (Sabbagh and Cummings, 2011). Cholinergic abnormalities seen in AD also provide physiological targets that can be addressed with currently approved treatment options. In a collaborative effort with students of our summer Welch Program, we have designed putative acetylcholinesterase inhibitors whose efficacy are being tested using the regenerating model system, *Lumbriculus variegatus*. Acetylcholineesterase may also contribute to regeneration through its role in regulation of cell proliferation, differentiation, apoptosis and survival in non−neuronal cells (Fossati et al., 2013). Thus, the possible use of the cholinergic system during regeneration is intriguing. We have carried out initial studies to determine the effects of AChE on neural regeneration and recovery of function in our worm model system. We have determined the fission concentration where 50% of the population develops fission plans (FC50) and the lethal concentration where 50% of the population die (FC5) to be 0.0679mM and 2.3377mM respectively. Initial data suggests that this putative acetylcholinesterase inhibitor significantly reduces segmental regeneration in both the anterior and posterior regenerating worm fragments. It is therefore possible that acetylcholine may negatively regulate segmental regeneration *L.variegatus*.

P2.49 GATLEY, C.M.*; DETTY, M.R.; HOLM, E.; University at Buffalo, New York, NSWCCD, Washinton, D.C.; *cgatley@buffalo.edu*

A Multivariate Analysis of the Attachment of Biofouling Organisms in Response to Surface Properties

Previous investigations suggest that variation in surface properties affects the attachment of biofouling organisms. It is not possible, however, to combine the results of these investigations to produce a comprehensive view of how surface properties determine patterns of attachment. We have addressed this problem by exposing several types of biofouling organisms to a library of xerogel coatings, spanning a wide range of surface properties. Xerogels are economically and environmentally friendly coatings that provide smooth, reproducible, optically clear surfaces. The surfaces were characterized using a variety of techniques. Results from the surface characterization and biological assays were analyzed separately and in combination using multivariate statistical methods. Initial analyses using 10 different surface characterization variables and the results of attachment assays with larvae of the barnacles *Balanus amphitrite* and *B. improvisus*, and the bryozoan *Bugula neritina*, indicated that the surface characterization and the organismal response grouped the coatings differently. In particular, the biofouling organisms were able to distinguish four coatings that were not differentiable by their surface properties. We used canonical analysis of principal coordinates (CAP) to identify important materials properties governing attachment across all 3 species. The CAP pointed to surface energy and surface charge as important drivers of patterns in attachment, but also suggested that differentiation of the surfaces was influenced to a comparable or greater extent by the dispersion component of surface energy.

P1.135 GE, Z*; JOHNSON, J.D; COBINE, P.A; MCGRAW, K.J; GARCIA, R; HILL, G.E; Auburn University, Arizona State University; *zzg0008@auburn.edu*

High concentrations of ketocarotenoids in the hepatic mitochondria of a molting red songbird

Many species of fish, reptiles, and birds have carotenoid−based integumentary coloration. No vertebrate species can synthesize carotenoids de novo; they must ingest carotenoid pigments. Once ingested, some carotenoid pigments can be modified via enzyme−supported redox reactions.Such redox reactions can change the fundamental hue of carotenoids, including transformations of yellow dietary hydroxycarotenoids (e.g. lutein) to red ketocarotenoids (e.g. 3−hydroxy−echinenone).Some songbirds use dietary pigments directly. Some songbirds ketolate dietary pigments producing red ketocarotenoids, and ketolation of yellow dietary pigments is the primary source of red coloration in songbirds(Order Passeriformes).However,the site of carotenoid metabolism in red songbirds remains uncertain and contentious.Here, we studied pigment accumulation in the livers of male house finches (*Haemorhous mexicanus*) that were undergoing molt and hence synthesizing ketocarotenoids from dietary carotenoids.Our goal was, to describe the specific subcellular locations of carotenoids in a putative site for production of ornamental red pigments.We collected wild male house finches that were molting red,ketocarotenoid−containing feathers and analyzed the carotenoid content of cellular fractions of homogenized liver. We found the highest concentration of ketocarotenoids in the mitochondrial fraction. And further Western blot also confirmed the positive correlation between carotenoids and mitochondria. These observations are consistent with the hypothesis that carotenoid pigments are oxidized on or within hepatic mitochondria, esterified, and then transported to the cis−face of the Golgi apparatus for secretory processing.

47.5 GEHMAN, A. M. ; University of Georgia; *gehmana@uga.edu*

Cost of infectetion − host and parasite mortality across a range of temperatures and multiple stages of rhizocephalan infection

In most host−parasite systems it would be difficult or impossible to decouple the cost of parasite reproduction from the cost of the parasites presence within its host. However, rhizocephalans have a stage within their reproductive cycle, the virgin externa, which decouples infection from reproduction. The virgin externa is produced by a female parasite that has developed an internal network of tissue but is not yet reproductively mature. The virgin externa must have a male parasite recruit, and then it matures into a reproductive externa. Most infections are perpetrated by a single parasite with a single externa, but multiple externa are found. Multiple externa can either be a single interna with multiple reproductive organs or two interna each with its own externa. Either will lead to an increase in reproductive burden. I examined survival rate of crabs parasitized with either a virgin externa, a reproductive single externa, or a double externa of the rhizocephalan *Loxothylacus panopaei* which infects the mud crab *Eurypanopeus depressus* in Savannah, Georgia. Crabs were exposed to a range of temperature experienced in the field; 5, 10, 15, 20, 25, 30 and 35° C for 110 days. Parasite and host mortality occurred simultaneously for each parasitized crab. Double externa had significantly lower survival rates at extreme temperatures. There was high survival at intermediate temperatures, but double externa still had a trend towards lower survival. Surprisingly, there was no significant difference in survival rate between the immature virgin externa and mature single infections at any temperature. This suggests that the increase in mortality at extreme temperatures is driven by the mere physical presence of the parasite within the host.

111.3 GEMMELL, B. J.*; BUSKEY, E. J. ; Univ. of Texas at Austin; *brad.gemmell@utexas.edu*

New approach to small−scale PIV reveals secrets to the powerful escape swimming of the copepod

As one of the most numerous animal groups and a key link in aquatic food webs, copepods have developed numerous anti−predator strategies. One of the most effective is the escape response. Copepods are capable of reaching speeds over 500 body lengths per second and can respond to a hydrodynamic disturbance is as little as 2−3 ms. The pereiopods or swimming legs' generate propulsive thrust for escape swimming but compared to other animals, the force per gram of muscle controlling the pereiopods, is exceptionally powerful and fast. How copepods achieve such force has remained undetermined. In this study we employ a new approach to micro−scale particle image velocimetry (µPIV) to visualize fluid motion created by free−swimming copepods. Our results show that the both the antennae and telson contribute significantly to thrust generation during escape swimming. Antennae motion acts both to re−orient the animal as well as provide initial thrust prior to initiation of the swimming legs. The telson creates a substantial jet of fluid which can even overwhelm the one produced by the pereiopods. During the recovery stroke the telson can create secondary positive thrust which coincides with the resetting the pereiopods for the next stroke. This appears to aid in offsetting any negative thrust from the recovery stroke and prevents copepods from moving backwards. These results help to address the uncertainty of copepod force production during swimming and aid our understanding small−scale fluid dynamics that govern efficient animal locomotion and aquatic predator−prey interactions.

P3.72 GENTRY, K.M.*; JAWOR, J.M.; Univ. of Southern Mississippi, Hattiesburg; *kaylee.gentry@eagles.usm.edu*

Dear Enemies or Nasty Neighbors: Who is the bigger threat? Seasonal responses to territorial intrusions in Northern Cardinals

Several defensive theories explaining variation in territory protection exist. Two prevailing theories include the "dear enemy" and the "nasty neighbor" hypotheses where strangers or neighbors, respectively, are considered more of a territory threat. Northern Cardinals *(Cardinalis cardinalis)* are a year−round territorial species that do not move between breeding and non−breeding territories, however they have not had a territorial strategy defined. This research reports on two seasons of simulated territory intrusions where territory holders were presented with song from a known neighbor (recorded from cardinals from contiguous territories) or outside population individuals (same geographic region). These intrusions were preformed in and out of the breeding season (spring and fall 2014). During the breeding season there is behavioral support for the "nasty neighbor" hypothesis. Territory holders exhibited more aggressive, longer lasting reactions to perceived neighbors than to that of strangers. At this time, data from the non−breeding season has not yet been collected. Potentially, as the structure of the population changes (e.g., more juvenile birds looking for territories in the fall) behavioral strategies may change as well in year−round territorial species that possess general use territories.

41.6 GEORGE, M.N.*; CARRINGTON, E; Univ. of Washington; *mngeorge@uw.edu*

The impact of environment and physiological condition on the strength of a biological adhesive

Mussels (*Mytilus spp.*) possess the remarkable ability to adhere to a wide variety of surfaces in one of the most dynamic environments on the planet. To accomplish this, mussels produce a biological glue that is made up of several identified proteins which they mix together, deposit on a surface, and allow to cure within the environment. Even more impressive is that mussels accomplish this task while immersed in seawater, a medium which is thought to compete with traditional adhesion mechanisms of epoxies. Recently, researchers have begun to explore the role that the environment plays in the determination of attachment strength of mussel adhesive, with the goal of both emulating the processes involved and explaining seasonal trends in weakened attachment that have been reported in coastal habitats and aquaculture operations. In this study we had mussels from three different species adhere to materials with vastly different surface characteristics in the presence of seawater with ecologically relevant oxygen concentrations, CO_2 partial pressures (pCO_2), and hydrogen ion concentrations (pH). We then allowed mussels to live in these conditions for up to 3 months, testing the material strength of adhesive as a function of the exposure time of the animal. With this methodology we aimed to separate any direct effect that seawater conditions have on adhesive function from any indirect effects on the material that results from changes in an organism's physiology.

P2.125 GERACE, M.E.*; FICKLIN, J.A.; RAND, M.S.; Carleton College; *mrand@carleton.edu*

Physiological Mechanisms of Dorsal Crest Erections in Anole Lizards

Males in the lizard genus *Anolis* erect a ridge of tissue along the dorsum, which increases their lateral profile during agonistic encounters. Though noted in behavioral studies, little attention has focused on the physiological regulation of these crests. We tested the physiological and behavioral conditions under which males erect crests. The ²−adrenergic receptor agonist isoproterenol (ISO) initiated crest erections within 2−3 minutes of injection. Prior to histological examination, we hypothesized that vascular changes mediated crest erection through ²− and ±−receptor stimulation. Alpha−adrenergic receptor agonists failed to inhibit crest erections and the ²−receptor antagonist propranolol (PRO) delayed, but did not inhibit the onset of ISO−induced crests. We used mirrors to simulate male aggressive encounters and initiate dorsal crest development. Under these conditions, crest erections occurred in a time frame similar to the ISO−induced crests. However, injection of PRO prior to the mirror encounter completely inhibited crest erections, though all other agonistic behaviors (dewlap pulsing, lateral display, approach, etc.) were intact. Histological examination of the erect crest tissue indicated that an increase in extracellular fluid caused the increase in tissue volume, suggesting an inflammatory−like response. In separate experiments we used indomethacin (a prostaglandin synthesis inhibitor) or Na−cromolyn (a mast cell inhibitor) to inhibit ISO−induced crest erections. Neither approach inhibited the crest erections nor did we find evidence that leukocytes invaded the tissue 30, 300, or 600 minutes following crest induction. These lizards appear to use a mechanism for crest erection previously not described in a social signaling context.

P1.153 GERMAN, DP*; CHAABANI, F; GEVORGYAN, D; SUNG, A; FAWCETT, C; University of California, Irvine, Mission Viejo High School; *dgerman@uci.edu*

A test of the temperature constraint hypothesis: little variation in the digestive biochemistry of prickleback fishes (family Stichaeidae) from California (35° N latitude) and Washington (48° N latitude)

The temperature constraint hypothesis suggests that herbivorous fish species are depauperate at higher latitudes because of a temperature constraint on digestive biochemistry. However, some herbivorous and omnivorous fishes, like *Xiphister mucosus* (herbivore) and *Xiphister atropurpureus* (omnivore), extend to the Aleutian Islands (52° N latitude), and can digest algal compounds at lower temperatures. We compared the activities of six different digestive enzymes in both species of *Xiphister*, as well as in the carnivorous, *Anoplarchus purpurescens*, collected from California (35° N latitude) and Washington (48° N latitude). Enzyme activities were measured at 15°C (California), and 10°C (Washington), which reflect the summer temperatures of each locale. Few differences in activity levels were observed. Because amylase digests algal starches, these findings suggest potential biochemical adaptation of amylases toward temperature. We, therefore, examined the electrophoretic patterns of amylases, only finding different allelic patterns in carnivorous *A. purpurescens* from CA and WA. Amylase genetic sequences were identical in *X. mucosus* collected from both locations, further supporting the lack of variation in amylases in these species. Therefore, despite different ambient temperatures, *Xiphister* species are able to digest algal starches without different amylase isoforms suited for different temperatures and may achieve elevated activities under cooler conditions by increased expression levels of amylase genes.

P2.165 GERRINGER, M E*; YANCEY, P H; JAMIESON, A J; LINLEY, T D; SUMMERS, A P; University of Hawaii, Whitman College, University of Aberdeen , University of Aberdeen, University of Washington; *mgerring@hawaii.edu*

Gelatinous tissue in the hadal snailfish: Proximate chemical composition and implications for swimming performance

Some deep−dwelling fishes have a gelatinous layer either directly below the skin or around the spine in the caudal region. We investigated the composition and potential function of this gelatinous tissue. Gel samples from eight deep−water species were analyzed for water content (97.14 ± 1.19%), ionic composition, and osmolality, bulk protein (0.4 ± 0.2 %), lipid (0.93 ± 0.01 %), and carbohydrate (0.6 ± 0.28%). These suggest that the gel is mostly extracellular fluid. These analyses do not support the hypotheses that this tissue plays a role in nutrient storage in an energy−limited environment or buoyancy in a high−pressure one. The gelatinous layer is most prominent in the hadal snailfish *Notoliparis kermadecensis*, one of the planet's deepest−living fishes, making it an interesting model organism to investigate gel function. The authors propose that the gelatinous tissue may act as an energetically inexpensive method of increasing swimming efficiency by fairing the transition from trunk to tail. Swimming performance in the gelatinous hadal snailfish was compared to swimming performance in the tidal snailfish, *Liparis florae*, which have similar morphology, but no subcutaneous gel. Video analyses show that *Liparis florae* swam more body lengths per second than their hadal counterparts. A robotic snailfish model was also used to analyze the impacts of the gelatinous layer on locomotory performance. The model swam faster with a water layer, representing gel, around the silicone tail than with the silicone tail alone. Data from these three analyses suggest that the gelatinous layer may aid hadal snailfish locomotion at a low energetic cost.

P3.141 GERRY, SP; BRODEUR, LK*; BELDEN, J; ELLERBY, DJ; Fairfield University, Wellesley College; *lauren.brodeur@student.fairfield.edu*

Variation in the morphology and fast−start response of juvenile bluegill

Adult bluegill show variation in their morphology and swimming performance based on habitat. The littoral form has a deeper body with fins located farther from the center of mass to aid in maneuvering among the vegetation. Pelagic bluegill have a streamlined, fusiform body shape associated with efficient steady−swimming. This body shape is also associated with greater fast−start performance based on peak velocity, acceleration and turning rates. This is significant since fish that perform faster−starts should have greater fitness because they are better able to evade predators. Juvenile bluegill of both body forms hatch in the littoral habitat and remain there until they are less susceptible to predation in the open water. It is not known if there is any variation in morphology and performance in the juveniles, similar to the relationship seen in adults. Therefore, we quantified a total of 95 fish from three size classes (<50 mm, 50−80 mm, 80−120 mm TL). We measured functionally relevant morphological variables including fin areas, body area and body depth and analyzed fast−start performance from high−speed video recordings. Juvenile bluegill show variation in their morphology among each size class. Relative body depth increases from a streamlined body shape in the smallest juveniles to a relatively deeper shape in the subadult group. Juveniles also show variation in their fast−start performance. The smallest juveniles have the highest relative velocity and travel the farthest distance during the fast−start. This group is likely the most vulnerable to predation, therefore, their increased fast−start performance would increase fitness. Future studies of steady−swimming and maneuverability are needed to determine if juveniles show the same pattern of divergence in swimming performance as the adults.

P3.167 GERTH, CJ*; MAIA, A; Eastern Illinois University; *cjgerth@eiu.edu*

Shape Analysis of the Jaws in Two Minnow Species over Ontogeny

The complex niche of a fish species is difficult to define, but morphological traits are useful indicators of niche dimensions. Fish morphology partly reflects the evolutionary history and the influence of environmental conditions, such as prey selectivity and availability. This study compares two closely related species, sand shiner (*Notropis stramineus*) and silver jaw (*Notropis bucatus*) minnows, in terms of the morphological shape changes of the upper, lower, and pharyngeal jaws over ontogeny. These two species of minnows feed on small invertebrates and mostly midge larvae. The fish were collected locally in Kickapoo Creek, IL. We measured and photographed 40 individuals of each species binned in two different size classes (large and small). The traditional morphometrics measured, standard length, snout−to−vent length, eye diameter, upper jaw length, lower jaw length, and gape, were regressed onto total length to test for allometry. Digital pictures were processed with tpsDig and further analyzed with MorphoJ with a regular geometric morphometrics procedure using principle component analyses. We found that jaw variables show a positive allometric relationship with increasing body length. This is most likely related to a prey shift, from midge larvae to small invertebrates, as the fish grows due to gape limitations. In proportion to body size, the eyes of the small individuals are much larger than that of the larger individuals in both species. This is expected as smaller fish tend to rely on their eyes more for feeding and escaping predators. Geometric morphometrics revealed shortening and bulking of the anterior jaw elements and elongation of the pharyngeal elements with ontogeny. An increased reliability on the pharyngeal apparatus could be driving this shift.

109.4 GERVASI, S.S.*; BINGHAM, A.; BURGAN, S.; UNNASCH, T.; MARTIN, L.B.; University of South Florida; *steph.gervasi@gmail.com*

Age−dependency of avian responses to West Nile virus

Ontogenetic variation in traits related to survival can result in age−structured heterogeneity in natural populations. For example, the ability to cope with infectious disease is driven by immunological responses of hosts, which can vary with age and in the context of competing energetic demands. Very young and very old individuals often suffer disproportionately from disease because they are immunologically naive or undergoing immunosenescence. Yet, age−specific responses can be difficult to predict, since differential allocation of resources towards growth, reproduction, and anti−pathogen responses changes throughout an organism's life. Growing evidence indicates that different age−classes of hosts can contribute uniquely to epidemiological dynamics. Heterogeneity in traits such as susceptibility, vulnerability, and infectiousness can affect whether a pathogen spreads and persists in a host population. Whether age−specific host contributions to disease dynamics arise from variation in exposure or variation in responses to exposure has been difficult to disentangle in observational studies in natural systems. Here, we controlled for variation in exposure by challenging different age cohorts of avian hosts under identical conditions to a standardized dose of an emerging zoonotic pathogen, West Nile virus. We hypothesized that fledged (1−2 month old), recently matured (8−10 month old), and old−aged (> 2−3 year old) Zebra finches (*Taeniopygia guttata*) would differ in their responses to the virus. More specifically, we predicted that rates of infection, magnitude and duration of viremia, viral shedding, neutralizing antibody responses, and post−infection behavior would depend on age−class affiliation and be mediated via changes in immunity. Age−structure of enzootic hosts in natural populations varies in space and time and may be a key driver of pathogen transmission dynamics and disease risk to humans and wildlife.

30.7 GIBB, A.C.*; STAAB, K.L.; FERRY, L.A.; Northern Arizona University, McDaniel College, Arizona State University, West; *alice.gibb@nau.edu*

Do these fish suck? The intramandibular joint, suction feeding, and functional convergence in teleost fishes

Most teleosts possess a lower jaw composed of three fused bones; however, a release of fusion has evolved independently many times, each time creating an intramandibular joint (IMJ) that facilitates contact between the jaw and substrate during food capture. The IMJ may expand the functional repertoire of fishes that possess it; alternatively, an increased ability to exploit a new trophic resource may be accompanied by a decrease in suction−feeding ability. We predict that IMJ−bearing taxa share a reduced reliance on suction−based food capture as well as key functional characteristics of the feeding apparatus. To test this hypothesis, we examined three taxa that have independently evolved an IMJ: *Girella*, *Helostoma*, and *Poecilia*. All three IMJ−possessing taxa have reduced suction performance relative to sister species and share a handful of functional traits (e.g., all exhibit fusion of the cranial bones, relative to non−IMJ bearing sister species). However, each taxon is distinct in certain aspects of food−capture kinematics and mechanics: (1) the IMJ of *Girella* increases the lower jaw's mechanical advantage as food is removed from the substrate; (2) in *Helostoma*, the IMJ allows the formation of a circular gape that makes contact with the substrate at all points simultaneously during scraping; (3) the IMJ of *Poecilia* generates a large range of motion of the lower jaw, relative to other IMJ−bearing species. We conclude that the movements and mechanical properties of the lower jaw are distinct in each IMJ−bearing lineage, and that differences among taxa are a consequence of different plesiomorphic building blocks in each lineage and/or adaptations to a particular food resource.

30.5 GIDMARK, NJ; Unibersity of Washington, Friday Harbor Laboratories; *gidmark@uw.edu*

On the importance of the gape:muscle length relationship in feeding biomechanics

Skulls are astoundingly diverse, and anatomy, kinematics, and muscle physiology collectively determine the biomechanical implications of this diversity. An often−overlooked variable is physiological muscle length: force declines as muscle is stretched or shortened and force is optimal at an intermediate length, so jaw−closing force is dictated by the adductor muscle's length. Recent empirical data support the notion that muscle length is important for understanding function. Snail size, for example, dictates gape in the molluscivorous black carp (*Mylopharyngodon piceus*); since gape dictates muscle length, which dictates muscle force, prey size has an overriding effect on the force available for crushing, and thus crushing performance. Jaw movement patterns dictate the gape:muscle length relationship; grass carp (*Ctenopharyngodon idella*) use more jaw rotation than black carp when chewing, and the high muscle strains that drive this rotation result in muscle force loss of up to 80%. The gape:muscle length relationship also changes through ontogeny; since muscle force and suction volume scale differently with size, larger fish face a force deficit when closing the mouth around an engulfed volume of water. In great sculpin (*Myoxacephalus polyacanthocephalus*), this deficit is counteracted by ontogenetic changes in jaw lever ratio, resulting in lower gear ratios (jaw movement/muscle length change) at larger sizes. Across species of sculpin, gape:muscle length relationships co−evolve with changes in fiber length, so that muscle strain magnitude remains relatively constant and low across phylogeny. The simple relationship between muscle length and gape distills important aspects of anatomy, *in vivo* kinematics, and muscle physiology that provide vital insight into the functional diversity of feeding mechanisms.

P1.14 GIFFORD, M.E.; Univ. of Central Arkansas; *megifford@uca.edu*

The influence of incubation temperature on morphology, thermal performance, and fitness in Sceloporus consobrinus.

Incubation temperature can have important effects on organismal phenotypes and ultimately fitness. Despite numerous studies on these effects, few studies have examined the influence of incubation temperature on thermal sensitivity of performance traits. In this study I tested whether incubation temperature had a measurable influence on offspring phenotypes, including the thermal sensitivity of sprinting performance. Subsequently, I released hatchlings on replicate islands in a local reservoir to examine the fitness consequences on phenotypic variation. I collected eggs from 18 female *Sceloporus consobrinus*, split each clutch and assigned eggs to one of two incubation treatments. Half of the eggs were incubated at 27 degrees and the other half at 30 degrees. I measured all hatchlings within 24 hours of hatching, and measured thermal performance of sprinting speed within one week of hatching. All hatchlings were re−measured and released within 10 days of hatching. Islands were populated at a similar (natural) density with an equivalent number of hatchlings from each incubation treatment on each island. I visited each island at one−month intervals to estimate growth rates and survival throughout the first growing season.

92.4 GIGNAC, PM; Oklahoma State University Center for Health Sciences; *paul.gignac@okstate.edu*

Evolutionary−developmental parallels of the crocodylomorph feeding apparatus

Crocodylomorph taxa are represented today by members of the crown clade Crocodylia, adults of which typically have exceptional bite forces, bone−crushing teeth, and robust if elongate jaws. These features allow mature individuals to be particularly adept at capturing and subduing large, elusive prey. Neonatal forms, on the other hand, hatch with unremarkable bite−force capacities, delicate dentitions, and unusually short snouts for jaw prehension but reach the adult configuration within a few years of growth. These developmental patterns appear to broadly mirror the increasing size and robustness of the crocodylomorph jaw system during its 230 million year diversification. Such evolutionary shifts are presumed to relate to changes in the feeding biology of these animals at cladogenic events, analogous to feeding niche shifts undertaken by their modern counterparts during ontogeny. To formally investigate this relationship, I identified functionally important aspects of the crocodylomorph feeding system through ontogenetic bite−force experimentation, musculoskeletal modeling, examination of fossil material, and drawing from the literature to correlate developmental and evolutionary character changes in the feeding apparatus. I tested the hypothesis that shifts in the cranial osteology of fossil crocodylomorphs match those documented during the ontogeny of their living descendants. Results demonstrated functional similarities between basal crocodylomorph adults and modern crocodylian hatchlings, whose evolutionary and developmental histories indicate comparable modifications for augmenting maximum bite forces and increasing skull strength. These findings suggest developmental and evolutionary conservation of the jaw system and point towards potentially long−standing constraints on the embryonic craniofacial bau plan of crocodylomorphs that are released post hatching via strongly allometric growth.

48.3 GILBERT, R.*; KARP, R.; UETZ, GW; University of Cincinnati; *gilberrl@mail.uc.edu*
Investigating the relationship between multimodal sexual signaling and immune function in Schizocosa ocreata wolf spiders
Ground−active wolf spiders must combat constant exposure to soil−dwelling parasites and pathogens, as well as the potential for exposure from food and water sources. As a consequence, these spiders have developed an effective innate immune system. In this study, we evaluate the relationship between immune function and multimodal sexual signaling in a terrestrial wolf spider species, *Schizocosa ocreata*. This species has energetically costly multimodal courtship, which has been shown previously to be negatively impacted by bacterial infection as a juvenile. We found that males who had been previously exposed to a bacterial pathogen *Pseudomonas aeruginosa* in the laboratory as juveniles had significantly higher adult immune function than those who had not been previously exposed to a pathogen. In addition, adult tuft size (secondary sexual character) was significantly correlated with adult immune function within males who had not previously been exposed to a pathogen. We also found that energetically costly courtship behavior significantly reduced male immune response, and that males with relatively larger tufts are better able to sustain an immune response after courtship. Lastly, we found that infection as a juvenile significantly reduced courtship behavior and mating success, but that infection as an adult has the potential to increase courtship and mating success. This supports the assumption that secondary sex characters enforce signal honesty by being good indicators of overall male health.

46.3 GILBERT, A.L.*; MILES, D.B.; Ohio University; *anthony.gilbert09@gmail.com*
Examining the ecological plasticity of thermal performance for a color−polymorphic lizard
The use of thermal performance curves (TPC)'s to estimate lizard responses to climate warming has become common. Examining performance at varying ambient temperatures allows for comparisons of organismal performance dependent on current available temperatures and can extrapolate to predicted temperature ranges. However, integrating more than one effect of climate change on ecological and physiological performance can provide a more reasonable estimation of these responses. One such effect is limited prey abundance due either to a trophic cascade or community reorganization. In this present study, we quantified whether thermal performance curves were affected by food limitation. We experimentally limited access to food resources to one group of *Urosaurus ornatus*, and kept another group on a normal ration. We then estimated TPCs for each group to examine the change in temperature−dependent locomotor performance as a consequence of food availability. Our results demonstrate that whole organism performance and the preferred range of temperatures declines with limited food rations. Furthermore, the optimal temperature for performance declines as well. The heights and shapes of these curves are distinct, indicating that thermal performance is ecologically−dependent. Predictions of lizard responses to climate warming, therefore, should be placed within an appropriate ecological setting which incorporates predator−prey or other community dynamics.

25.5 GILBERT, C*; PERKINS, M.Q.; ZUREK, D.B.; Cornell University, University of Pittsburgh; *cg23@cornell.edu*
Target image expansion and contraction during visually−guided pursuit of prey induce jaw opening and closing by tiger beetles
In dynamic locomotory contexts, visual cues often trigger adaptive behavior by the viewer, yet studies investigating how animals determine impending collisions typically employ either stationary viewers or objects. Here we describe a dynamic situation of visually−guided prey pursuit in which both impending prey contact and escape elicit observable adaptive behaviors in the pursuer, a predatory tiger beetle. We investigated which visual cues independently control both opening and closing of the beetle's jaws during chases of prey dummies. Jaw opening and closing typically occur when prey is within the 60° field of binocular vision, but not at a specific distance, angular size, expansion rate or time−to−collision. We show that a change in the sign of the expansion rate of the target image induces adaptive jaw movements. When the target image changes from contracting to expanding, indicating that the beetle is gaining on the target independent of the velocity of either, jaws open within about 15ms. When the image changes from expanding to contracting, indicating that the prey is getting away the jaws close after about 35ms. These values are close to the 28ms lag time we have recently determined for the beetle's visual guidance system that controls whole body orientation during pursuit of prey. We discuss the "sloppiness" of the variation in the lag of the behavioral response, especially jaw closing, as an adaptation to uncertainty about target position due to degradation of the target image by motion blur from the fast running beetle.

P3.126 GILCHRIST, SL; New College of Florida; *gilchrist@ncf.edu*
Integrated system of shell use between land and marine hermit crabs: The role of octopuses in the supply chain
A seven year study of the shell acquisition and use by both land and marine hermit crabs at Cayos Cochinos, Honduras has revealed that shells from octopus middens are integral to the supply chain for the system. Two species (*Octopus vulgaris* and *O. briareus*) found in the area contribute to the resource pool. In two years, birds which forage in the intertidal were observed redistributing the shells away from the shoreline, making empty shells available over a broader area.

S5.7 GILLETTE, R; University of Illinois at Urbana−Champaign; *rhanor@illinois.edu*

Specialists of Simplicity: Soft Bodies, Little Brains, and Low Cunning

How and why did complex brain and behavior evolve? Clues to the evolution of complexity emerge from comparative analyses of animals with complex brains and those with simple morphology, nervous system and behavioral economics. The brains of vertebrates, arthropods and some annelids have highly derived executive structures and function that control downstream central pattern generators (CPGs) for locomotion, behavioral choice and reproduction. For the vertebrates, these structures − basal ganglia, cortex and hypothalamus − integrate somatotopically mapped sensory inputs with motivation and memory to transmit complex motor commands to relay stations controlling CPG outputs. Similar computations occur in the central complex and mushroom bodies of the arthropods, and in mammals these interactions structure subjective thought and socially based valuations. The simplest model systems available for comparison are opisthobranch molluscs, which have avoided selective pressure for complex bodies, brain and behavior through potent chemical defenses. In particular, in the sea−slug *Pleurobranchaea californica* the functions of hypothalamus, basal ganglia, cortex and hindbrain are all combined in the feeding motor network and its direct interactions with CPGs for agonist and antagonist behaviors. I will evaluate the unavoidably combined contributions of sexuality, reproductive strategy, nutritional storage, and skeletons to brain evolution.

8.3 GILLOOLY, J.F. ; University of Florida; *gillooly@ufl.edu*

Could Fick's Law of Diffusion Explain the Body Mass and Temperature Dependence of Metabolic Rate?

Metabolic rate sets the pace of life, so explaining the observed body size and temperature dependence of metabolism has remained a focus in physiology for over a century. Many complex models have been proposed, and much debate has ensued. Here I examine the extent to which Fick's law of passive diffusion can predict the body size and temperature dependence of vertebrate metabolic rates, a model which depends in part on the ratio of respiratory surface area to respiratory surface thickness. I find that the model performs remarkably well based on comparisons of model predictions to extensive data from ectothermic and endothermic vertebrates. I conclude by discussing why the utility of this relatively simple model may have been overlooked as a general explanation in metabolic scaling theory.

P1.169 GIRDHAR, K*; FENG, R; SHUKLA, S; BENITEZ, MJ; GRUEBELE, M; CHEMLA, Y; Univ. of Illinois, Urbana−Champaign, Indian institute of technology, Kanpur, Univ, of New Mexico, Alberquerque; *girdhar3@illinois.edu*

The behavioral space and neural model of locomotion repertoire of zebrafish

How does one describe quantitatively the complex motion of vertebrates? To answer this question, we investigated a model system for vertebrate locomotion: zebrafish swimming. We performed a quantitative analysis of all stereotyped behavioral swimming patterns of zebrafish larvae: spontaneous swimming, escape response to stimulus, and prey tracking. Previous attempts to analyze zebrafish swimming motion quantitatively have imposed many arbitrary parameters. Here, we instead used a parameter independent method that produces an orthogonal set of ``eigen−shapes'' of fish backbones to describe swimming motion in a low−dimensional space. We show that a linear combination of only three such ``eigen−shapes'' is sufficient to describe 97% of zebrafish shapes. Moreover, stereotyped swimming behaviors fall on two low−dimensional attractors embedded in this three dimensional behavioral space. We also show using a two−dimensional correlation analysis that ``scoots'' and ``R−turns,'' which were previously described as discrete behavioral states, in fact represent extrema in a continuum in this low−dimensional behavioral space. To understand the neural basis of the behavior, we have also developed a neural network model of spontaneous swimming of fish larvae. We present a set of neural parameters such as synaptic conductance, stimulus amplitude that produces swimming behavior and reconstructed the low−dimensional behavioral space obtained from experimental results.

103.3 GLAZER, L*; ALURU, N; HAHN, ME; Woods Hole Oceanographic Institution; *lglazer@whoi.edu*

Delayed effects of embryonic exposure to low levels of PCB−126 on adult zebrafish behavior

Human and wildlife exposure to anthropogenic environmental contaminants such as dioxin−like compounds has been documented worldwide. PCB−126 (3,3',4,4',5−pentachlorobiphenyl) is the most toxic dioxin−like PCB congener, causing toxicity through the aryl hydrocarbon receptor pathway. There is detailed understanding of the effects and the associated mechanisms following acute exposure of adults as well as embryos to PCB−126. However, when considering the developing embryo, the levels of chemical exposure leading to delayed effects can be below those causing overt effects. Yet, the full potential for later−life health effects that result from early−life low level exposure to dioxin−like compounds is not well understood. Zebrafish are excellent tools for studying later life effects of embryonic exposure for several reasons; their short generation time is ideal for full embryo−to−adult experiments in relevant time−scales, their ex utero development and transparent embryos allow for easy evaluation of exposure levels that do not cause immediate overt effects, their easy maintenance and breeding and high fecundity allow high throughput experimentation with many biological replicates. We exposed zebrafish embryos to either DMSO (vehicle control) or a low concentration of PCB−126 (0.3 nM) starting from 4−5 hours post fertilization (hpf) until 24 hpf, and reared them to adulthood. We compared the behavior of DMSO− and PCB−126−exposed fish at several juvenile stages (6, 7 and 14 days post fertilization) and after reaching adulthood. Our study shows that early, embryonic exposure to PCB−126 causes adult behavioral changes that are not apparent at the juvenile stages.

P3.170 GLENN, Z.D.*; FOSTER, A.D.; YOUNG, J.W.; SMITH, G.A.; BUTCHER, M.T.; Youngstown State University, NEOMED, University of Akron; *zdglenn@student.ysu.edu*

Ontogeny of locomotor performance in Eastern cottontail rabbits: Muscle architecture and fiber type of the vertebral extensor muscles

Rabbits have hindlimb extensor muscles that allow them to accelerate rapidly during locomotion, and our previous analyses indicate that juveniles have certain performance advantages that could increase their survival to reproductive maturity. Specifically, we found that extension at the lumbosacral joint provides the most work of acceleration, thus emphasizing the importance of the vertebral extensor muscles to the mechanics of their half−bound gait. To further investigate the ontogeny of force and power capacity in these muscles, muscle architectural properties and myosin heavy chain (MHC) isoform content are being quantified in both juvenile and adult cottontail rabbits (*Sylvilagus floridanus*). Muscle architectural properties including muscle moment arm, mass, belly length, fascicle length, pennation angle, and physiological cross−sectional area (PSCA) were measured and used to provide functional estimates of maximum isometric force, joint torque, and power. MHC isoform distribution will be determined by SDS−PAGE and densitometry techniques. Preliminary results from dissection and measurement indicate the m. longissimus dorsi and m. sacrospinalis of juveniles are massive, and together they are capable of higher force and power than any of their hindlimb extensor muscles. The results will be used to test the hypothesis that the hindlimb and vertebral column extensor muscles of juveniles are capable of performing similar amounts of mechanical work and power to those of adult rabbits. Supported by NSF IOS−1146916.

S3.4 GLENN, T.C.*; FAIRCLOTH, B.C.; MCCORMACK, J.E.; RAY, D.A.; BRAUN, E.L.; GREEN, R.E.; Univ. of Georgia, Athens, Louisiana State Univ., Baton Rouge, Occidental College, Los Angeles, CA, Texas Tech Univ., Lubbock, Univ. of Florida, Gainesville, Univ. of California, Santa Cruz; *travis.glenn@gmail.com*

Ultraconserved Elements Provide Orthologous Portals into Tetrapod Genomes Illuminating the Remarkably Slow Evolution of Crocodilian Genomes

The first phase of the crocodilian genome project has been completed. We sequenced and assembled the genomes of the American alligator, Saltwater crocodile, and Indian gharial. One striking feature of the crocodilian genomes is that they seem to evolve very slowly. To test the hypothesis of slow molecular evolution in crocodilians, we wanted to compare a relatively large number of single−copy orthologous loci from species throughout the tetrapod tree of life. Previously, we had used ultraconserved elements (UCEs) to obtain such loci for phylogenetic studies by extracting UCEs from sequenced genomes or by using sequence capture probes to amniote UCEs. In this study, we used UCEs to directly compare the rates of molecular evolution of crocodilians to all other major groups of tetrapods. We found that crocodilians do have slow rates of molecular evolution at UCE loci (i.e., the UCEs plus flanking DNA) and that analyses of other portions of the genome reveal similar results. Because unique sets of UCEs are known in many broad phylogenetic groups containing thousands of species (tetrapods, fish, and hymenoptera), and are likely in many other such groups, UCEs represent unique portals into the genomes of the diverse array of organisms studied by SICB members.

P2.75 GMUCA, N V*; KUHN, C E; DICKERSON, B; LIWANAG, H E M; Adelphi University, National Marine Mammal Laboratory, Alaska Fisheries Science Center, NOAA; *nataliagmuca@mail.adelphi.edu*

Effects of electronic instrumentation on thermoregulation in northern fur seals

The tracking of marine mammals with electronic devices enables researchers to gain a better understanding of their movements and at−sea behavior, thereby facilitating conservation efforts. In pinnipeds (seals and sea lions), electronic instruments are typically glued to the animal's fur, either directly to the pelage or on a neoprene patch. When instruments are recovered for data collection, they are retrieved either by cutting the fur or by cutting through the neoprene patch and leaving the bottom layer of neoprene attached to the animal. It is thought that the cut fur will be restored or the neoprene patch shed during the molt, but this has never been explicitly investigated. This study examined the effects of instrument attachment and retrieval on thermoregulation in northern fur seals. Northern fur seals rely primarily on their fur for insulation in water, and are thus ideal for determining the long term impacts of instrumentation on pelage function and recovery. To assess the thermoregulatory consequences of instrumentation, we measured the thermal conductivity of northern fur seal pelts in water for (a) instruments glued directly to the fur (N=30) and (b) instruments glued to the fur with a neoprene base (N=30). For each attachment method, we measured the thermal conductivity of the pelt (a) unmodified, (b) with instrument attached, and (c) with instrument removed. Using a hyperbaric chamber, we also measured the extent to which water is able to penetrate the air layer during diving, for both unmodified and modified pelts. This is the first study to measure the thermoregulatory consequences of instrumentation in fur seals and will help determine which method of instrument attachment best minimizes those consequences.

S8.9 GODWIN, J*; LAMM, MA; LIU, H; GEMMELL, N; North Carolina State University, University of Otago, University of Otago; *John_Godwin@ncsu.edu*

The need for speed: Neuroendocrine regulation of socially controlled sex change

Socially controlled functional sex change in fishes is a dramatic example of adaptive reproductive plasticity. Functional gonadal sex change can occur in less than a week while behavioral sex change can begin within minutes. Significant progress has been made in understanding the neuroendocrine bases of this phenomenon at both the gonadal and neurobiological levels, but a detailed mechanistic understanding remains elusive. We are working with sex changing wrasses to identify evolutionarily conserved neuroendocrine pathways underlying this reproductive adaptation. One key model is the bluehead wrasse, where sex change is well studied at the behavioral, ecological, and neuroendocrine levels. Bluehead wrasses show rapid increases in aggressive and courtship behavior with sex change that do not depend on the presence of gonads. The display of male behavior is correlated with AVT expression and experiments support a role for this neuropeptide. Estrogen synthesis is also critical in the process. Female bluehead wrasses have higher aromatase mRNA in the brain and gonads and estrogen implants block behavioral sex change. While established methods have advanced our understanding of sex change, a full understanding will require new approaches and perspectives. First, contributions of other neuroendocrine systems should be better characterized, particularly glucocorticoid and thyroid signaling. Second, advances in genomics for non−traditional model species should allow conserved mechanisms to be identified with a key next step being manipulative tests of these mechanisms. Finally, advances in genomics now also allow study of the role of epigenetic modifications and other regulatory mechanisms in the dramatic alterations across the sex change process.

P1.93 GOEPPNER, SR*; BEATY, LE; LUTTBEG, B; University of Massachusetts at Dartmouth, Oklahoma State University; *sgoeppner@umassd.edu*

Impact of Phenotypic Plasticity and Transgenerational Effects on the Anti−Predator Behavior of freshwater snails

In this experiment, we studied how lifelong exposure to predators affects the anti−predator behavior and survival of freshwater snails (*Physa acuta*) and their offspring. We exposed F1 snails to either a "predator treatment" (P) consisting of non−lethal crayfish cues or a "control treatment" (C) consisting of dechlorinated water. We divided the offspring (F2 snails) from each F1 snail treatment into predator and control treatments, resulting in four possible parent−offspring treatment combinations (CC, CP, PC, PP). The treatments were applied for four weeks. We measured how snails from each treatment responded to predators by placing them individually in deli cups and recording their movement around the cup in the presence and absence of crayfish cue. F1 and F2 snails reacted to the predator condition by moving up towards the waterline or out of the water, regardless of treatment. Throughout the behavioral assay, F1 and F2 snails from the predator treatment spent less time out of the water than control treatment snails. The amount of time the F2 snails spent out of the water was not affected by their parent's treatment. We measured the survival of snails in the presence of a lethal predator by placing mixed treatment groups of snails into an arena with a live crayfish and recording survival for each treatment. F1 snails from the predator treatment were killed faster than snails from the control treatment during survival tests. The survival time of F2 snails was not effected by their parent's treatment. Overall, lifelong exposure to predator cue may have important effects on the anti−predator behavior and survival of individuals exposed to predators, but not their offspring.

P2.32 GOESSLING, JM*; MENDONCA, MT; GUYER, C; Auburn University; *goessling@auburn.edu*

Seasonal Acclimation of Immune Parameters in Gopher Tortoises, Gopherus polyphemus

Wildlife diseases are of increasing importance as many vertebrate taxa have experienced recent and devastating disease outbreaks. Several hypotheses have been generated to explain why the frequency of disease in ectothermic vertebrates has increased as a result of recent patterns of climate change. Herein, we used baseline immunological parameters in Gopher Tortoises to test the seasonal acclimation hypothesis. Immune responses we quantified included bacterial lysis ability, total circulating leukocyte counts, and relative leukocyte counts. Additionally, we assayed baseline corticosterone as a covariate of the immune parameters. We found seasonal variation in bacterial lysis ability (ANOVA: $F = 8.659$, $P <0.0001$) and relative differential leukocyte counts (ANOVA: $F = 25.42$, $P < 0.0001$). Results from this study support the seasonal acclimation hypothesis to explain patterns of seasonal variation in disease susceptibility in this species.

79.2 GOLDBOGEN, J.A.*; CADE, D.A.; FRIEDLAENDER, A.S.; CALAMBOKIDIS, J.; STIMPERT, A.S.; JENSEN, M.M.; REYES, P.M.; POTVIN, J.; LIEBSCH, N.; Stanford University, Stanford Univ, Oregon State Univ, Cascadia Research Collective, Moss Landing Marine Labratories, St Louis Univ, Customized Animal Tracking Solutions; *jergold@stanford.edu*

Insights into the underwater behavior, species interactions, and biomechanics of baleen whales using integrated video and inertial sensors

Biologging approaches to study the biology of free−ranging animals have focused on either movement or video, but rarely are these two data sets integrated. We developed a tag system to measure the fine−scale kinematics of cetaceans while simultaneously recording video from dual cameras. The movement sensors included a pressure transducer, tri−axial inertial sensors (accelerometers, magnetometers, gyroscopes), and a paddle−wheel speed sensor. The cameras were pointed anteriorly 45 degrees to the right and left of the long axis of the tag, together generating a 180−degree view in the horizontal plane. We deployed these tags on 5 blue whales and 8 humpback whales off the coast of California in the summer of 2014. For the first time, we observed a wide−range of behaviors of the tagged whale, conspecifics, and parasites. These included interactions between whale lice, aggregations of prey (krill, anchovies) and non−prey (siphonophores) species, remora swimming and attachment behaviors, echelon swimming of conspecifics, and cooperative feeding with both whales and sea lions. We also observed how the movements of flippers and flukes were involved in facilitating different maneuvers, including lunge feeding. When the tags were pointed perpendicularly to the long axis of the whale's body, we could detect simultaneous movement of flipper and fluke, highlighting the fine−scale body control and varied use of different propulsion and control surfaces. By combining video and kinematic data, this tag design serves as an important tool for understanding the biomechanics and behavioral ecology of large aquatic vertebrates.

P2.16 GOMEZ, C.*; MOOI, R.; Skyline College, San Bruno, CA, California Academy of Sciences, San Francisco, CA; *rmooi@calacademy.org*

New fossil and extant species of Fibularia illuminate evolution of the most highly miniaturized "sand dollars"

The Clypeasteroida is a diverse clade of sea urchins commonly known as sand dollars. The largely Indo−Pacific clypeasteroid genus *Fibularia* is significant among these because of extreme miniaturization (hence, "micro−echinoids") −− the smallest known extant echinoid is a *Fibularia*. Here, we greatly expand a dataset containing morphometry and morphological information on all known extant and fossil species of *Fibularia*. Graphical representations of several crucial parameters reassess relationships among all the known extant taxa of *Fibularia*, including new material from recent Philippine expeditions. These analyses reveal two new living species as well as previously unrecognized cases of sexual dimorphism among several taxa, underscoring unusual, unstudied, and therefore enigmatic life history traits. Fossil material sent to us by colleagues working in Australia, New Zealand, and Madagascar expands knowledge of the diversity of Oligocene and Eocene *Fibularia*. Among these localities, there are at least three new species. With this new knowledge of diversity within *Fibularia*, we attempt to derive phylogenetic relationships that illuminate evolution of significant features within *Fibularia*. However, extreme paedomorphic reduction (truncation of ontogenetic trajectories leading to loss of terminally−added apomorphies) among these micro−echinoids continues to make phylogenetic work challenging. Nevertheless, present results indicate that sexual dimorphism evolved more than once within the group, that brooding behavior has evolved at least once, and that there is a taxonomically confused subset (though possibly not monophyletic) of *Fibularia* in the Eocene of the western Indian Ocean, including Madagascar. [Supported by NSF BIO REU grant 1358680 to Mooi]

43.3 GONZALEZ, L.A.*; BELL, C.D.; University of Florida, University of New Orleans; *lag117@gmail.com*

Phylogenetics and Mating System Evolution in the Southern South American Radiation of Valeriana (Valerianaceae)

Valerianaceae, containing ~300 species, occupy a variety of habitat types across the world, and shows multiple shifts in mating systems. The basal lineages, Patrinia and Nardostachys, are exclusively hermaphroditic, but there was a shift to dioecy early within the clade. Previous studies have shown that dioecy, gynodioecy, and polygamodioecy have evolved independently multiple times. Nowhere is this more apparent than in the southern South American (i.e., Patagonia) radiation of Valeriana. This clade is made up of 40 species, occurring in a wide ecological as well as elevational gradient. For this study, we inferred a phylogeny for this clade based on 5 nuclear regions (accD, Agt1, Chlp, Hmgs, ITS) and 7 chloroplast regions (matK, ndhJ, trnD, trnG, trnK, trnL, ycf5) for 31 of the 40 species. We used BayesTraits to explore a variety of morphological evolutionary hypotheses. We found that the rate of evolution towards a mixed mating system was three times that going from a mixed mating system to an exclusively hermaphroditic system. Likewise, we found no evidence for gynodioecy being an intermediate step to dioecy. We also explore the potential correlation in the evolution of mixed mating systems with several morphological characters (inflorescense, seed morphology) and ecological attributes (elevation, temperature).

94.4 GONZALEZ, B.C.*; PETERSEN, H.C.; MARTINEZ, A; WORSAAE, K; University of Copenhagen, Denmark; *brett.gonzalez@bio.ku.dk*

Colonization and adaptation of scale worms to interstitial and anchialine habitats (Aphroditiformia, Annelida)

Scale worms (Aphroditiformia) are one of the most diverse families of annelids (<1200) found in all marine habitats including many extremes such as anchialine caves, the interstitial environment, whale falls, and hydrothermal vents. The wide range of habitat colonization reflects a complex evolutionary history, yielding a vast array of adaptations and life history traits. Here we present the most diverse phylogeny of scale worms, including several undersampled lineages using four molecular markers and morphological data with both character and habitat reconstructions. Our dataset includes 50 newly sequenced taxa analyzed using probabilistic methods; including 8 anchialine cave endemics and 17 exclusively interstitial from throughout the world. Two independent interstitial colonizations events are traced within the Sigalionidae−Pholoididae clade, i) origin of the clade *Pisione−Pisionidens*, characterized by an elongation of the body and loss of elytra; ii) and the clade *Laubierpholoe*, characterized by a reduction in the number of segments and elytra brooding. Amongst the Polynoidae, a single colonization event to anchialine caves is represented by the anfiatlantic *Gesiella* and *Pelagomacellicephala* lineages. This clade exhibits stygobitic features, including reduction of eyes and pigmentation, elongation of sensory appendages, and evolution of pelagic swimming behavior. Our analysis also supports a relationship between cave Macellicephalinae and Gesiellinae and deep−sea clades. Adaptations amongst Aphroditiformia, especially the elytra morphology related to these colonization events is briefly presented, combining SEM, CLSM and observations of live specimens.

6.6 GONZALEZ, P*; LOWE, CJ; Stanford University; *paulgzlz@stanford.edu*

Comparing axial patterning across divergent life histories: data from the indirect−developing hemichordate Schizocardium

How do patterning mechanisms evolve when life cycles become more or less complex? Most marine invertebrates have a biphasic life cycle that includes a planktotrophic larval stage (indirect developers), while others develop directly into a small−scale version of the adult (direct developers). Little is known about how mechanisms that regulate early development are modified when evolutionary transitions between these two life history strategies occur. As a result, interpreting comparative developmental data from animals that have both distinct body plans and different life cycles is difficult. It is not uncommon for closely related species with morphologically similar adult stages to have contrasting life history strategies. These organisms give us an opportunity to determine whether axial patterning mechanisms differ between direct and indirect developers, independent of their adult body plan. Enteropneust hemichordates are divided into two clades. One of them comprises exclusively direct developers that form an adult without intervening larval stages. The other comprises indirect developers that develop through a tornaria larva with an extended planktonic period. Here we describe axial patterning mechanisms in an indirect−developing hemichordate from the genus *Schizocardium*. We show the expression patterns of transcription factors with known function in anteroposterior (AP) patterning in other deuterostomes, as well as preliminary data on the function of some of the main signaling pathways that establish AP and dorso−ventral polarity. We test whether these mechanisms are more similar to the direct−developing hemichordate *Saccoglossus*, which has a similar adult body plan but an abbreviated life cycle, or to echinoderms, which have highly derived adult body plans but similar larvae.

P1.10 GONZáLEZ−GóMEZ, PL*; ARAYA−SALAS, M; BASSI, A; MACCORMACK, J; Instituto de Filosofía y Ciencias de la Complejidad (IFICC), Department of Biology, New Mexico State University,, Occidental College; *plgonzalezgomez@gmail.com*

The role of habitat structure in the evolution sexually selected traits

The two main processes encompassed in the concept of sexual selection, male−male competition and female choice, can act as powerful selective pressure driving the development of traits as ornaments or weapons with direct effect of fitness. In turn, both processes −inter and intra sexual selection− can interplay and be influenced by environmental variables as landscape configuration fixing limits and constrains in their expression. We studied the role of habitat structure in the evolution of plumage coloration and bill daggers in hummingbirds. We collected reflectance spectrophotometry and stereomicroscope images of bill morphology from museum specimens (Moore Lab of Zoology, Occidental College) from 63 species representing each clade in the hummingbird phylogeny. In addition, we collected data from habitat use from bibliographic sources. We found a relation between habitat types and reflectance of gorgette and belly and the contrast between both patches. Species inhabiting open habitats tend to exhibit brighter plumage than species in closer habitats. We also found bill daggers more likely to develop in species inhabiting closer that open habitats. Our results suggest that physical properties of the environment where the sexual signals are emitted are relevant factors influencing the evolution of animal signaling by shaping their expression and limits.

P2.136 GOODELL, E.F.; ELLESTAD, L.E.; CHAMBERS, I.G.*; STEVENS, K.; VILLENEUVE, D.L.; ORLANDO, E.F.; University of Maryland, College Park, USEPA, Mid−Continent Ecology Division, Duluth MN; *eorlando@umd.edu*

Cloning, Initial Characterization, and Ontogenic Expression of Membrane Progesterone Receptors in the Fathead Minnow, Pimephales promelas

Teleost fish progestogens play important roles in reproduction, including initiating oocyte maturation, sperm maturation and motility, and functioning as pheromones in some species. Teleost progestogens activate progesterone receptors and function through genomic pathways via nuclear receptors and non−genomic pathways via membrane progesterone receptors (mPR±, mPR^{2}, mPR^{3} −1, and mPR^{3} −2) and progesterone receptor membrane component 1 (PGRMC1). Here, we cloned the complete ORFs of the four mPRs and provide initial characterization of protein architecture and molecular phylogeny. We also studied the ontogenic expression of mPRs in whole embryos, larvae, and young juveniles and in tissues collected from older juvenile to adult life history stages. The expression of the mPRs was measured with quantitative PCR using SYBR green chemistry. Tissue types included juvenile head, juvenile trunk; and brain, pituitary, gonad, liver, intestine, heart, skeletal muscle, trunk kidney, and gill in subadult to adults. Fathead minnow mPRs appear structurally similar to mPRs in other species and for each receptor, appropriately cluster with closely related species in the phylogenetic analysis. Expression patterns of the mPRs were relatively broad, but there were interesting life stage and sex differences suggesting specific roles for those mPRs in the regulation of some physiological processes. To the best of our knowledge, this study is the first sequence information for fathead minnow mPRs and the most comprehensive examination of the developmental expression of mPR genes in a teleost fish. Funding Source: Morris Animal Foundation grants to EFO and LEE (D12ZO−046) and EFO (D14ZO−010).

105.7 GOODRICH, KR*; COUGHLIN, DJ; Widener University; *kgoodrich@widener.edu*

Biomechanical properties of distal woody twigs in pawpaw (Asimina triloba)

Distal woody twigs and their associated foliage are at risk of mechanical damage during storm events, largely due to high and fluctuating wind loads. Distal twigs of pawpaw (*Asimina triloba*) exhibit an unusual phenomenon during/following storm events, whereby the twig "twists" so that distal leaves are held in an upside−down orientation. Twigs then re−orient to an upright position typically within 24 hours of the storm event. Immediately following a storm event, a "twisted" twig will hold its upside−down orientation even when manually flipped to its normal orientation. We hypothesize that this "twisting" twig behavior might minimize storm damage of distal woody twigs and associated foliage. We have measured flexural stiffness (EI), torsional stiffness (GJ), and viscoelastic creep in first year's growth and second year's growth for twigs of pawpaw and two co−occurring species which do not exhibit this "flipping" phenomenon. Pawpaw maintains low GJ values across a range of twig diameters relative to other species in our study, and only pawpaw demonstrates viscoelastic creep (and relaxation from creep). We present video of this flipping phenomenon in the field, and provide preliminary data on leaf/twig re−orientation for distal twigs in high winds. We are currently studying cross−sectional tissue composition for twigs of pawpaw and the other study species to identify potential composition/structural differences which may contribute to the different biomechanical properties recorded.

P1.80 GOODSON, N.B.*; BROCKHOFF, B.L.; HUSTON, J.P.; SPIELER, R.E.; NOVA Southeastern University, Heinrich−Heine Universität Düsseldorf; *ng586@nova.edu*

Caffeine elicits time−dependent bidirectional response of functional recovery in Carassius auratus lesion model

Caffeine works through a variety of complex mechanisms to exert an often bidirectional set of functional and structural neurological changes in vertebrates. We investigated the effects of chronic caffeine exposure on functional recovery of the dorsal light reflex (DLR) in hemilabyrinthectomized common goldfish, *Carassius auratus*. In this lesion model, the unilateral removal of the vestibular organs results in temporary loss of gravitationally modulated postural control which is quantifiable via the DLR. We compared the functional recovery over 24 days of post−surgery goldfish perpetually held in a caffeine solution of 2.5 mg/L (n=10), 5.0 mg/L (n=10), 10.0 mg/L (n=11), or 0.0 mg/L control (n=9). Comparison to a sham surgery group (n=11) indicated statistically significant changes in the DLR of all hemilabyrinthectomized fish on day 1. The control group recovered over the study period and approached but did not reach sham surgery DLR. The 2.5 and 5.0 mg/L groups initiated postural recovery similar to controls but then returned to a stronger DLR. Beginning on day 10, the 5.0 and 10.0 mg/L caffeine groups diverged from the control and all three caffeine groups were statistically different from the control on days 15−24. Results suggest caffeine exposure at first is benign but prolonged exposure hinders functional recovery. Further studies are planned to elucidate the mechanism of action of caffeine on the DLR goldfish model.

10.2 GOOS, J.M.*; COTHRAN, R.D.; JEYASINGH, P.D.; Oklahoma State University, Southwestern Oklahoma State University; *jared.goos@okstate.edu*

An elemental perspective on the expression and evolution of condition−dependent traits

Condition dependence of sexual traits has been proposed as an important mechanism that maintains trait honesty. In this context, condition is defined as the pool of resources allocable to traits. However, the operational definition of condition has varied widely. Often, studies have manipulated the *supply* of total energy or a few molecular resources, implicitly assuming shifts in the amount of allocable resources to condition−dependent traits. Ecological supply of energy carrying molecules, or specific molecular resources is heterogeneous, and covaries with other important energy sources and molecules. It is difficult to quantify all the energetic and molecular resources while maintaining ecological relevance. Nonetheless, such obstacles hinder robust testing of the condition−dependence hypothesis. Examining condition dependence at the elemental level has the potential to overcome these obstacles. Complexity in environmental supply of resources and an individual's composition can be reduced to about 25 biologically active elements, or the ionome. We posit that measuring ionomic profiles of resources in the environment, the individual, and traits of individuals will reveal the elemental signatures of condition dependence. Specifically, we predict that the expression of a condition−dependent trait is more sensitive than non−sexual traits to the element that has the greatest physiological demand and in least ecological supply. It follows that higher condition is a function of not only the genomic capacity of a genotype to acquire, assimilate, and allocate this element, but also the ecological supply of the limiting element. Understanding the elemental signatures of condition dependence has the potential to reveal fundamental rules underlying the evolution of condition dependent traits in all taxa with unrivaled ecological rigor.

78.6 GORA, EM*; YANOVIAK, SP; University of Louisville; *evan.gora@louisville.edu*

Lightning impacts forest ecology

Patterns of tree mortality determine how forest composition and structure change over time. Lightning directly and indirectly causes 70% of annual tree mortality in some forests, and interspecific differences in the electrical properties of trees likely influence the likelihood or severity of lightning damage. We hypothesized that the distribution of lightning damage is associated with specific tree characteristics (e.g., emergent status, slope position), and that biotic damage is associated with lightning damage. We also hypothesized that electrical resistivity differs among tree and vine species. We surveyed tree damage along 9 transects in old−growth forest in Michigan and classified damage on 309 focal trees. Although none of these trees exhibited evidence of lightning, associated meander surveys identified 14 cases of unambiguous lightning damage. We also measured the electrical resistivity of 8 tree species and 3 vine species. Lightning damage was more commonly associated with emergent stature (50% of struck trees) and higher rates of biotic damage (50%) than the surrounding tree community (22% emergent status and 21% incidence of biotic damage). Nearly all (93%) of the lightning damaged trees were conifers, suggesting that their interaction with lightning has a phylogenetic basis. Resistivity differed significantly among species and was ca. 200% higher in trees than vines. Accurate quantification of lightning−induced tree mortality will improve forest turnover models and improve predictions of future forest structure under conditions of increased lightning frequency.

P2.194 GOULD, F.D.H.*; LAMMERS, A.; OHLEMACHER, J.; GERMAN, R.Z.; NEOMED, Cleveland State University; *fgould@neomed.edu*

High level neuromuscular coordination in infant mammal sucking kinematics

Sucking, a mammalian synapomorphy for infant feeding, requires multiple sensory inputs to facilitate coordination of multiple oropharyngeal structures. The recurrent laryngeal nerve (RLN) provides sensation for the lower vocal tract, and motor to intrinsic muscles of the larynx. It is critical for normal swallowing but is not thought to be involved in sucking. We tested the hypothesis that, as high levels of sensorimotor integration are essential for all stages of feeding, disruption of this pathway would influence sucking. We implanted radiopaque markers in the tongue, palate, hyoid, thyroid and epiglottis of infant pigs. Using digital videofluroscopy at 100 fps we recorded the animals feeding before and after unilateral RLN lesion. RLN lesion affected the position and movements of the tongue and hyoid. The location of structures differed between treatments, with tongue, hyoid and thyroid being held more cranially, and the epiglottis more caudally in lesioned animals. Ranges of movements differed, as well as relative expansion and contraction within the tongue. Variation in between cycle movements was less in the lesioned animals. In general, lesions resulted in cranial displacement of hyo−laryngeal structures, associated with modified and highly stereotyped tongue and hyoid kinematics. These changes affect structures that are critical in both sucking and airway protection. This suggests that a high level of coordination among several cranial nerves providing sensorimotor innervation for the entire oropharyngeal complex occurs in the brainstem, including sensory fields outside of the immediate functional area.

S10.4 GOYRET, J*; YUAN, M; Univ. of Tennessee, Martin, Archbold Biological Station; *jgoyret@utm.edu*

Olfaction and Vision in the Innate Recognition of Nectar Sources Under Different Illuminances

Nectar foraging is a goal−directed behavior. Nevertheless, its goal − nectar − is not its causal principle. Rather, this goal−directedness is achieved by an inherited, innate program resulting from selective pressures acting on the efficiency with which foraging is performed. For this, it is fundamental that the animal can extract meaningful information from its uncertain environment. Lacking an explicit representation of what a nectar source (flower) is, pollinators control their foraging movements using multiple floral signals that increase their probabilities of nectar encounter. The use of these signals is not rigid, but user−specific (species, experience, learning) and context−dependent (spatiotemporal patterns of stimulation, signal availability, multimodal integration). In this study we evaluated the use of two important floral signals, visual display and odor, in naïve *Manduca sexta* hawkmoths under different illuminance conditions. We offered moths two artificial feeders (a white one and a blue one) against a dark−green background. Both feeders were either scented or unscented. Under conditions resembling starlight and crescent moonlight, a small proportion of moths (~30%) recognized unscented feeders as potential nectar sources and probed on them, but these proportions were doubled when feeders were scented. Under brighter conditions (quarter−moonlight and gibbous−moon light) moths showed equally high levels of responsiveness (60%), regardless of whether feeders were scented or unscented. Additionally, we found that moths showed a bias for white over blue feeders in dim light, which disappeared under brighter illumination. We would like to discuss the role of olfactory and visual signals, and multimodal integration, in "telling a naïve moth what a flower is".

44.2 GRABAR, R.G*; GILMAN, C; IRSCHICK , D.J; University of Massachusetts Amherst ; *rgrabar@umass.edu*

Effects of Surface Diameter on Jumping in Two Gecko Species

We tested the hypothesis that surface diameter influenced the jumping ability of two gecko species. We hypnotized that narrower diameter dowels would negatively affect the maximum distance geckos can jump, as well as other kinematic variables. Our experimental data included dowels of varying diameter between 1 cm and 5 cm, and we were able to record 3−4 good jumps per animal. In all, we were able to obtain data from nine lizards form these two species,all of which were marked on their body using nontoxic paint. We used a custom−made jumping apparatus. Two sides of the structure were secured with Plexiglas walls to prevent the gecko from escaping and the other sides allowed us to place the gecko on the dowel.Each gecko was placed on one of the two dowels and was encouraged to jump by a tap on the base of their tail. Each jump was recorded at 500 f/s with a Photron 1280 PCI high−speed video camera. We calculated several variables:(1)jump distance, the distance traveled of a mark labeled on the gecko from rest to landing;(2)takeoff angle, the angle between the shoulder and pelvis girdle and the horizon just after the feet left the dowel,(3)landing angle, the angle between the same line and the horizon when any of the gecko's feet first touch the landing surface;and(4)takeoff speed, speed traveled during the last five frames of takeoff. We found no significant effect of dowel size on jump distance within species. Further, there seemed to be little impact of dowel size on takeoff or landing angle. However, we found some effects of dowel diameter on takeoff duration within gargoyle geckos.The two species also displayed some differences in their jumping performance.

P2.86 GRACE, MS*; MCLAMB, WT; EMER, SA; ZACHARIAH, T; Florida Inst. of Technology, Melbourne FL, Brevard Zoo, Melbourne FL; *mgrace@fit.edu*

Functional Magnetic Resonance Imaging (fMRI) of Python molurus Brain Demonstrates TRP Channel Mediation of Infrared Imaging

Neuronatomy and electrophysiology indicate that trigeminal sensory neurons innervating python pit organs project to the ipsilateral brainstem nucleus of the lateral descending trigeminal tract (nLTTD), from which information is routed to the contralateral optic tectum, where visual and thermal maps of space are integrated. Previous functional analyses of sensory function in the snake brain involved technically difficult, invasive procedures in heavily sedated snakes. Here we set out to develop functional magnetic resonance imaging for large snakes, and to use it to measure brain response when pit organs were presented with physiologically relevant thermal stimuli and agents designed to elucidate the mechanisms of thermosensory signal transduction. Sedated snakes exposed unilaterally to thermal stimulation of pit organs exhibited differential blood−oxygenation−level−dependent (BOLD) response in the optic tecta and nLTTD. Heat applied to the left labial pits elicited an average intensity increase of 14% and 13.75% in ipsilateral nLTTD and contralateral optic tectum, when compared to corresponding control nLTTD and optic tectum (contralateral and ipsilateral, respectively) in the same snakes. Topical application of the TRPA1−channel antagonist A−967079 negated responses to heat (average differences in heat−induced voxel intensity in nLTTD and tectum were 3.5% and 0.5%, respectively). These results provide the first in vivo physiological demonstration of TRPA1 channels as molecular thermosensors in any infrared−imaging snake species, validate fMRI for physiological assessment of brain function in live snakes, and provide the first imaging−based confirmation of the infrared pathway in the snake brain.

50.4 GRACE, MS*; TAYLOR, SM; LOEW, ER; Florida Inst. of Technology, Melbourne FL, Cornell U., Ithaca NY; *mgrace@fit.edu*

Comparative Analysis of the Elopomorph Fish Retina: Dramatic, Ecology−Specific Changes Through Development

Unlike the mammalian retina, the teleost fish retina undergoes persistent neurogenesis from intrinsic stem cells. To understand retinal development in the unusual elopomorph superorder, retinal characteristics were analyzed over the course of development in three ecologically distinct elopomorph fishes ladyfish (*Elops saurus*), bonefish (*Albula vulpes*), and speckled worm eel (*Myrophis punctatus*). Photoreceptor morphologies, distributions and spectral absorption were studied at larval, juvenile and adult stages. All pre−metamorphic elopomorph retinas are rod−dominated (unlike most teleost fish species), while later retinal characteristics closely correlated with post−metamorphic ecology. Adult *E. saurus* has high rod densities, grouped photoreceptors, a reflective tapetum, and longer−wavelength photopigments, supporting vision in turbid, low−light conditions. *A. vulpes* has higher cone densities, lower rod densities and shorter−wavelength photopigments, supporting diurnal vision in shallow, clear water. *M. punctatus* loses cones during metamorphosis, develops new cones after settlement, and maintains high rod but low cone densities, supporting primarily nocturnal vision. Thus, the retina changes in dramatic ways over the course of development, and these changes support ecology of each species and developmental stage.

P1.26 GRAHAM, AM*; PRESNELL, JS; University of Miami; *graham.allie@gmail.com*

Into Thin Air: Hypoxia Inducible Factor (HIF) gene family diversification, and evolution

Hypoxia inducible factor (HIF) transcription factor genes are known to play a key role in cellular response to low oxygen tension in a variety of organisms, and are frequently associated with adaptations to high altitude and other oxygen limited environments. The HIF gene products encode alpha (HIF−1± , HIF−2± , HIF−3±) and beta (ARNT, ARNT2, ARNTL) subunits that form functional heterodimers to regulate transcription. All HIF genes are characterized by the presence of two domains, the bHLH DNA binding domain and the oxygen sensing PAS domain. HIF−1± and HIF−2±/EPAS are additionally characterized by the presence of the HIF−C−terminal domain (HIF−CTAD). Despite their important role in oxygen sensing, very few studies have focused on the evolutionary history of the HIF gene family, with virtually no analyses outside of the vertebrate lineage. We have assessed the expansion and diversification of the HIF gene family in 39 eukaryotic genomes. We have also investigated the separate evolutionary histories, and selective pressures of each of the three domains that characterize the HIF family. Our results suggest that (1) the HIF−CTAD domain evolved de novo in the Bilaterian stem lineage, and is specific to a subset of the HIF genes, (2) the appearance of the HIF−2±/EPAS domain architecture is correlated with the evolution of closed−circulatory system endothelial vasculature, (3) the HIF transcription factor family is heavily constrained in the Vertebrate lineage, with the exception of HIF−3± and that (4) Pancrustacea have substantially divergent HIF genes.

P3.56 GRAHAM, J.L.*; KUCERA, A.C.; GREIVES, T.J.; CRESPI, E.J.; Washington State Univ., North Dakota State Univ.; *jessica.l.graham@ndsu.edu*

Does age influence maternal care behaviors in brooding red−backed salamanders?

Life history theory predicts that there is a trade−off between investment in current reproductive success and future reproductive opportunities. Therefore, for iteroparous species with maternal care, older mothers should expend more energy in ensuring the survival of her current clutch than younger mothers that likely have future reproductive opportunities. To test this hypothesis, we measured aggression of female red−backed salamanders (*Plethodon cinereus*) toward intruding conspecifics in relation to maternal age. Red−backed salamanders guard their eggs for approximately two months until hatching. In the presence of an intruder, a female can engage in aggressive behaviors to increase the likelihood of clutch survival at the risk of injury to the female that may cost future reproductive opportunities. To test for an association between maternal aggression and age, we exposed female salamanders with broods that were 5, 20, or 45 days old to a non−reproductive, conspecific female intruder and recorded all behaviors for 3 hours. We also observed females 24 hrs prior to the trial to assess baseline behaviors at each time point. At the end of the trial, we sacrificed females to measure circulating corticosterone and testosterone, and we used skeletochronology to estimate female age. We predicted that older females will spend more time with their eggs and display greater aggression when faced with an intruder, and if these behaviors are mediated by corticosterone or testosterone, we expect that age will be correlated with circulating hormone levels. These data will shed light on how age may affect behavioral patterns during the maternal care period.

72.1 GRAVISH, N*; CRALL, JD; MOUNTCASTLE, AD; WOOD, RJ; COMBES, S; Harvard University; *gravish@seas.harvard.edu*
Data driven study of flight in aerial clutter
Flying insects are frequently confronted with spatially and temporally complex aerial environments. Avoiding collisions, predation, or excessive energy expenditure in such environments may require robust navigation and control behaviors. The study of flight mechanics and control in cluttered aerial environments will thus shed light on the behaviors and physical limitations of animal flight in natural environments, and possibly translate into advances in robotic design and control laws for flying micro−aerial vehicles. Control and maneuvering within complex structured airspace is especially important for pollinating insects such as the bumblebee (*Bombus impatiens*). Foraging bumblebees fly many foraging flights per day in which they navigate between tens to hundreds of flowers on a single foraging bout. Here we describe an experimental methodology to observe the flight of freely behaving bumblebee workers challenged to maneuver through a cluttered aerial environment. We challenge bumblebee colony members to fly through an array of randomly placed posts situated at the nest entrance which have a characteristic mean−free path length scale of 4.1±2.0 cm and which enforces sinuous flight paths through the observation arena. Flight recordings are triggered through motion detected in the observation arena and are tracked at 300Hz, converted to 3D coordinates, and archived. Flight tracking is triggered automatically and between June and August we observed 7,105 flights through the arena. Median speed was 26.7 cm/s consistent with previous observations of maneuvering flight by bumblebees. We observed that collision avoidance maneuvers were initiated in response to oncoming obstacles and we discuss obstacle avoidance strategies in free flight.

19.1 GREEN, P.A.*; PATEK, S.N.; Duke University; *patrick.a.green@duke.edu*
Ultrafast weapons in mantis shrimp: winners of fights strike more frequently, not with greater force
The extreme impact forces and dramatic displays delivered by fighting mantis shrimp (Stomatopoda) are an exceptionally dynamic example of weapon use. While knowledge of weapon systems is based mainly on weapons that exert low peak forces over milliseconds, mantis shrimp strikes exert high peak forces over microseconds. Classic predictions of weapon systems − that weapon morphology correlates with weapon force, weapon displays reliably signal weapon force, and winners of fights have greater weapon force − have yet to be tested in the ultrafast, high−peak force weapons of mantis shrimp. We tested these predictions by studying sex− and size−matched fights in *Neogonodactylus bredini*. Weapon morphology did not correlate strongly with maximum strike force. Additionally, the meral spread' weapon display of *N. bredini* was not more common than other behaviors, and few fights were concluded by meral spreads alone. Winners of fights did not have greater maximum strike force than losers; instead, winners struck a greater number of times during fights than losers. While most fights escalated to striking, strikes were often delivered onto the armored tailplate (telson) of competitors and caused no significant damage. Our results indicate that meral spreads in *N. bredini* do not communicate maximum strike force. Instead, we propose that telson striking may signal an individual's aggressive persistence or energetic capabilities during a fight. By testing classic weapon predictions in an ultrafast weapon system, we show that what is commonly known as combat (exerting force onto competitors) may not be damaging, but instead may signal another aspect of fighting ability.

82.2 GRIECO, T.M.*; WONG, A.C.; RICHMAN, J.M.; University of British Columbia; *griecotm@dentistry.ubc.ca*
Periodicity and dynamics of tooth replacement from a longitudinal study of leopard geckos
Many reptiles replace their teeth continuously, providing an opportunity to understand the process of tooth renewal. We present preliminary data from a longitudinal study of tooth replacement in adult leopard geckos (*Eublepharis macularius*). Upper jaw wax impressions revealed dynamic patterns of tooth shedding and limited midline symmetry. Typically, a tooth is shed in one week and replaced by a functional tooth within the next week. Across all tooth positions during the 14 week control period, the average replacement frequency is once every 6.5 weeks with a range of never replacing to immediate replacement after one week. The cycle of replacement for a given tooth position was not constant over time, but spatial and temporal data show some periodicity. Although the periodic spacing of shed teeth within a functional tooth row differs between individuals, there is a pattern across the row over time that individuals share and may reflect mechanisms of physiological or developmental control within the tooth row. These waves of replacement occur along the jaw and usually last for 5−6 replacements. Replacement in *E. macularius* shows more rapid turnover than similar patterns reported for *Iguana iguana* and *Alligator mississippiensis*. The regularity of the observed patterns suggest emergent replacement phenomena that may result from the order of tooth initiation between tooth families, local inhibitory influences within the jaw, and the rates of development within tooth families. Studies are currently underway to assess the influence of each of these factors. As such, the leopard gecko serves as an ideal model to investigate the molecular underpinnings of classical hypotheses such as the Zahnreihen and local inhibition models for reptilian tooth replacement.

P1.113 GRIFFIS, S.M.*; JENNINGS, D.H.; Southern Illinois University − Edwardsville; *dajenni@siue.edu*
Sequence comparisons of Insulin−like Growth Factor−1 genes in closely related Anolis (Sauria, Iguanidae) lizards of differing body size.
In vertebrates, body size is primarily regulated through the actions of growth hormone (GH), Insulin−like growth factors, and their receptors. The current work compares the coding region of insulin−like growth factor−1 (IGF−1) sequences among three closely related *Anolis* lizards varying in body size. Two species, *Anolis sagrei* and *A. carolinensis*, are relatively small bodied anoles with similar snout−vent lengths and IGF−1 sequence data for both species is available through GenBank. The third species, *A. equestris*, is a large−body anole for which IGF−1 sequences have not been reported. For all three species total liver RNA was extracted and reverse transcribed to cDNA and then amplified using IGF−1 specific primers. In both *A. sagrei* and *A. carolinensis*, a single PCR product of appropriate length was generated. In *A. equestris*, two products were detected; one similar in size to that of the other anole species, and one longer. The functional significance of the two IGF−1 isoforms observed in *A. equestris* is unknown, but raises the possibility that evolutionary changes in body size in this species result from differential expression or regulation of IGF−1.

S9.10 GROSS, Louis J.; Univ. of Tennessee, Knoxville;
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Preparing "Fearless" Biologists: Quantitative components for undergraduate life scientists

Many national reports have noted the growing importance of quantitative approaches in biology and encouraged the development of undergraduate curricula that incorporate quantitative methods. The major formal quantitative education that undergraduates receive is through math, stat and computer courses, mostly not linked to the quantitative conceptual foundations useful in biology. Calculus still reigns as often the only math component of undergraduate biology requirements, despite the fact that comprehension of the theoretical underpinnings of biology requires understanding of probability and discrete math. Concepts such as equilibrium and stability are typically not even mentioned in these calculus−oriented courses. There is little connection to observation and data in math courses specifically designed for biology students, so students see these courses as divorced in context from their laboratory and field−oriented biology courses. To supplement quantitative education initiatives such as those in Vision and Change, colleagues and I have developed a pedagogy and text based upon the "rule−of−five" which utilizes a mixture of approaches (symbolic, graphical, numerical, verbal analogy, and data) to relate key concepts accounting for the diverse learning styles of students. I will demonstrate how data on photosynthetic rates is used to build a large portion of standard calculus concepts, how landscape change based on Google Earth is used to encourage hypothesis formulation and testing and allows students to derive the basic rules of matrix multiplication, and discover the relationship between eigenvectors and landscape equilibrium. Computational tools Matlab and R allow students to more readily apply quantitative methods to data, while building comprehension of basic coding that goes beyond the use of a "black−box".

43.4 GROSSNICKLE, D.M.; University of Chicago;
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Evolution of lower jaw morphology within early mammalian clades

The lower jaws of major mammaliaform clades of the Mesozoic Era (252−66 million years ago) have shown disparate morphologies. It is expected that such major differences would be correlated with differences in biomechanical functions in the mandible and middle ear evolution. Here, I present a geometric morphometric analysis of jaw morphology to examine early jaw adaptations within Mesozoic mammals. Utilizing fossil jaw images belonging to 105 premamammalian cynodont and mammaliaform taxa, shapes of the angular process and the coronoid process were analyzed, and the elevation of the mandibular condyle was measured. For both the angular process and coronoid process, shapes were quantified and compared using semilandmark outlines subjected to two−dimensional geometric morphometric techniques. To assess broad evolutionary trends, average shapes of the jaw processes for mammalian groups were considered in a phylogenetic context. Results indicate convergent jaw changes within three long−lived groups: cimolodontan multituberculates, the stem lineage of monotremes, and the clade that includes therians (placentals and marsupials) and their close relatives. These groups develop an elevated condyle, a posteriorly−positioned angular process, and a lower and more inclined coronoid process. The jaw changes arose only after the evolutionary detachment of postdentary bones and Meckel's cartilage within these lineages, which may have freed the jaw for musculoskeletal remodeling. In addition, the jaw changes may have co−evolved with increased grinding function of the molars, allowing for a diet consisting of increased plant matter. Therefore, the adaptations of the jaw and molars appear to be correlated for masticatory efficiency in omnivorous/herbivorous clades, contributing to the long−term survivals of these clades.

S4.8 GUIDETTI, Roberto*; VECCHI, Matteo; CESARI, Michele; ALTIERO, Tiziana; BERTOLANI, Roberto; REBECCHI, Lorena; Univ. of Modena and Reggio Emilia (Italy);
roberto.guidetti@unimore.it

Pharyngeal structures and piercing stylets in tardigrades: their evolution and relationships with the feeding habits

Tardigrade feeding apparatus is a complex cuticular structure with considerable taxonomic significance. It can be schematically divided into four parts: buccal ring, buccal tube, stylet system, and muscular pharynx. Basically it functions as a sucking organ in which the two piercing stylets are used to detach food from substrates and to penetrate plant cell or animal walls, while the pharynx sucks the organic matter via a cylindrical tube. This kind of feeding apparatus represents an autapomorphy of Tardigrada, but its origin is still unknown. Tardigrades belong to Panarthropoda, even though their feeding apparatuses share some characters with those of some Cycloneuralia. Our aim was to study the possible evolutionary origin and transformation of the feeding apparatuses of tardigrades. We compared new data on buccal−pharyngeal apparatus morphology obtained by SEM, CLSM, and energy−dispersive X−ray spectroscopy analyses with previous data. In addition, using software for evolutionary biology analyses, we traced back the characteristics of the feeding apparatus structures along the tardigrade phylogenetic tree obtained by molecular analyses. Although several tardigrade taxa are poorly studied (especially the marine Arthrotardigrada that generally seem to present a higher number of plesiomorphies), with the present analyses we were able to identify the possible plesiomorphic and homoplastic traits of tardigrade feeding apparatuses, and to find convergent characters among different evolutionary lineages. This analysis allowed also to establish a more specific relationship between tardigrade diet and feeding apparatus anatomy.

P1.108 GUISE, EG*; O'BRIEN, S; Radford University, Radford VA;
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Trouble with trenbolone? Examining the influence of a common run−off pollutant on Gambusia holbrooki development and behavior.

Trenbolone is a relatively new endocrine disrupting chemical that acts as a testosterone mimic, and is considered to be one of the most powerful anabolic steroids in use (Saaristo 2013). Trenbolone has three times the bonding affinity of testosterone and has a half−life of ¾ a year (Orlando 2004). With extensive usage in the beef cattle industry as a growth promoter, trenbolone has been found to appear in animal waste and runoff from cattle feed lots (Bartelt−Hunt 2012). Such a stable and potent molecule being released into the environment could potentially cause devastating effects on freshwater environments. As a potent androgen, trenbolone could increase masculine traits in freshwater species, and may disrupt reproductive processes. Here we explore the effects of ecologically relevant levels of trenbolone, as determined by sampling, on the freshwater fish species, *Gambusia holbrooki*. We elucidate influences on morphological, breeding, and behavioral characteristics in the fish and their subsequent offspring.

35.6 GUNDERSON, AR*; STILLMAN, JH; San Francisco State University; *alexrgunderson@gmail.com*

A global analysis of plasticity in the thermal tolerance of ectotherms

Two broad (and non−mutually exclusive) hypotheses have been proposed to explain diversity in the plasticity of thermal physiology. The first is adaptive, and proposes that greater plasticity should evolve in more variable thermal environments. The second is based on evolutionary constraints, and says that adaptation to more extreme thermal environments leads to a decrease in plasticity. We tested these hypotheses by calculating acclimation flexibility of the Critical Thermal Maximum (CTmax) and Critical Thermal Minimum (CTmin) for hundreds of ectotherms in five major clades from published studies. For the environmental variability hypothesis, we tested for an association between flexibility and latitude. For the evolutionary constraint hypothesis, we tested for associations between flexibility and species highest thermal tolerance limits. We found little support for either hypothesis. However, we did find that flexibility tends to vary by habitat type and clade, which may have important implications with respect to broad patterns of vulnerability to climate change.

81.7 GUTIERREZ, E*; LENTINK, D; Stanford University; *eguti007@stanford.edu*

Predicting Weight Support Based on Wake Measurements of a Flying Bird in Still Air

The wake development of a freely flying Pacific Parrotlet (*Forpus coelestis*) was examined in still air. The bird was trained to fly from perch to perch through a laser sheet while wearing custom−made laser safety goggles. This enabled a detailed study of the evolution of the vortices shed in its wake using high−speed particle image velocimetry at 1000 Hz in the plane transverse to the flight path. The measurement started when the bird was a wingbeat in front of the laser sheet and stopped after it traveled a few wingbeats beyond the laser sheet. The instantaneous lift force that supports body weight was calculated based on the velocity field, using both the Kutta−Joukowski and the actuator disk quasi−steady model. During the first few flaps, both models predict an instantaneous lift that is reasonably close to the weight of the bird. Several flaps away from the laser sheet, however, the models predict that the lift steadily declines to about 50% of the weight of the bird. In contrast to earlier reports for bat wakes in wind tunnels, these findings for bird wakes in still air suggest that the predictive strength of quasi−steady force calculations depends on the distance between the animal and the laser sheet.

P2.187 GUTZWILLER, S.C.*; HUNTER, J.P.; The Ohio State University, Columbus, The Ohio State University, Newark; *gutzwiller.5@osu.edu*

The Functional Implications of Talon Expansion in Microbats

The convergent evolution of the talon, the distolingual extension of the tribosphenic upper molar, and additional features forming on the talon, such as the hypocone cusp, have been well documented across therian mammals. Exactly how the addition of this novel structure influences molar function is not completely understood. The present case study examines the crushing and shearing function of the talon within the dietarily diverse suborder Microchiroptera, in order to explore the adaptive implications of talon expansion in therian mammals. Crushing and shearing function was estimated using Relief Index (RFI), a measure of the degree of relief in the crown surface, attained from three−dimensional computer models of microcomputed tomography (microCT) scanned upper first molars. RFI of the entire molar was found to be sufficient in distinguishing dietary groups, including frugivores with low molar relief and a crushing−dominated molar function, and insectivores with high molar relief and a shearing−dominated molar function. However across dietary groups, the relief of the talon itself was consistently low, suggesting that it primarily performs a crushing function. The increased occlusal area dedicated to crushing provided by the expansion of the talon would be an adaptive benefit to a frugivorous microbat that relies on crushing for food breakdown. However, the adaptive benefit of a talon to other dietary groups, including insectivores that rely more heavily upon shearing for food breakdown, is not fully understood. Possible explanations are discussed.

P3.135 GUZMAN, R/M*; MCCUE, M/D; POLLOCK, E/D; MCCUE, K/E; St. Mary's Univ, Univ Arkansas, UTHSCSA; *mmccue1@stmarytx.edu*

Prolonged fasting causes systematic changes in rats: $^{13}CO_2$ breath testing and small molecule metabolomics

Measurements of the $\delta^{13}CO_2$ in animal tissues are routinely used to make inferences about the extent to which C3 plants and C4 plants contribute to the diets of animals. However a fasting animal's diet is its own tissues. Interestingly, the body lipids contain measurably lower amounts of ^{13}C than lean tissues (e.g., carbohydrates and proteins). We postulated that changes in the $\delta^{13}CO_2$ in the exhaled CO_2 of rats would reflect the timing of fasting−induced changes in oxidative substrates and expected the breath would initially become isotopically lighter with increased reliance on lipid oxidation and then heavier during prolonged−starvation. We further tested whether differences in the $\delta^{13}C$ of the bulk diet would influence the fasting−induced changes $\delta^{13}C$ in the breath. We raised rats (n=23) on diets derived from rice (C3) or corn (C4) for 8 weeks. Rats were fasted for 11 days. Breath samples were collected every 6h and urine was collected daily. We measured the $\delta^{13}C$ in tissues from a subset of rats before and after fasting. The breath of prefasting rats resembled that of their lean tissues, and then fell by >2.5 per mil during the first 2 days, almost reaching the values of the body lipids as carbohydrate stores were consumed. After 7 days the $\delta^{13}C$ of the breath began to gradually increase with an increased reliance on protein oxidation but never returned to the prefasting values suggesting a balance of lipid and protein catabolism. The isotopic composition of the bulk diet had no effect on the fasting−induced changes in the $\delta^{13}C$ of the breath. NMR−based metabolomics also detected systematic changes in the urine metabolites indicative of fasting−induced changes in oxidative substrates. We conclude the ^{13}C−breath testing and urine metabolomics may be useful methods to noninvasively track the physiological progression of fasting.

P2.176 HACKMANN, A*; SIMKINS, A; FEDERLE, W; University of Cambridge, UK; *ah685@cam.ac.uk*

Mechanisms to cope with leg contamination when walking on water

Pond skaters (Gerridae) are a group of insects which permanently live on the surface of lentic waters. Each of their tarsi is equipped with dense arrays of hydrophobic hairs, which enable them to use surface tension to walk on water. Although these mechanisms have been studied in detail, it is still unclear how pond skaters maintain and clean their hydrophobic hairs. By measuring the shadows of the dimples generated by the pond skaters' legs after contamination with hydrophilic microparticles (sodium aluminum silicate), we showed that the contact size of the pond skaters' legs with the water surface decreased. Moreover, the bodies of contaminated pond skaters touched the water surface, which is not normally observed for uncontaminated individuals. The contact of the body with the water surface reduced the distance covered per rowing stroke. By contaminating pond skater legs with fluorescent particles, we showed that they possess self−cleaning properties, which come into play during each rowing stride cycle on the water surface and resemble the contact self−cleaning of adhesive footpads in geckos and insects. Even after multiple leg strides, we observed that contaminated pond skaters performed active grooming movements with specialized cleaning structures on their front and middle legs in order to clean the hairs on their tarsi. Further understanding of the underlying principles of insect cleaning might inspire the development of artificial devices for surface cleaning on the micro− or nanoscale.

60.6 HAGEY, T/J; University of Idaho; *tjhagey@uidaho.edu*

Using FEA Simulations to Investigate the Gecko Adhesive System

Gecko lizards can be found using arboreal, terrestrial, and rocky microhabitats with the assistance of their adhesive toe pads. Gecko adhesive pads are composed of modified ventral scales called scansors, each containing millions of microscopic hair−like structures called setae. Working in unison, setae cling to a substrate using van der Waals interactions to produce strong frictional and adhesive forces. To properly function, gecko setae are subject to multiple requirements, including self−cleaning, resisting clinging together, and performing on wet and dry irregular surfaces. Geckos must also efficiently detach their feet during locomotion. All of these requirements likely dictate gecko adhesive morphology, yet we find morphology to be highly variable within and between species with setal length varying 10−fold across species and nearly four−fold within individuals. Previous studies have used mathematical models to investigate setal mechanics with limited success likely due to intra−individual variation. As a result, we will use micro computed−tomography to build 3D reconstructions of the gecko adhesive system. These reconstructions will be used to conduct finite element simulations, digitally replicating setal behavior during attachment and detachment. With this approach, we can investigate the causal relationships between setal morphology and performance. These new techniques will allow us to build upon previous biomechanical models of gecko adhesion while incorporating aspects of variation never previously included. This project also highlights how interdisciplinary approaches can be used to strengthen our understanding of animal biomechanics, patterns of evolution and adaptation, and synthetic adhesives.

S5.2 HALANYCH, K. M.*; KOCOT, K. M.; WHELAN, N. V.; Auburn University, University of Queensland; *ken@auburn.edu*

Early animal relationships: Alternative hypotheses and character inference

Early evolution of animals has long been a mystery. The fossil record of the earliest metazoan forms is very limited and there has been disagreement between various molecular phylogenetic analyses as to which extant lineage is sister to all other animals. Phylogenomic evidence suggests that ctenophores branched off from other animals earlier than sponges. Here we will review how data support and conflict with alternative hypotheses about the base of the animal tree. Strengths and pitfalls of recent studies will be examined with attention paid to the sponge−first versus ctenophore−first topologies. These alternative hypotheses imply different scenarios about the evolution of tissue types and organ systems. In particular, muscular and neural systems vary greatly among basal animal lineages unlike bilaterian animals where construction and organization of these systems seem to follow set rules. Importantly, the long held assumption that sponges are basal animals has constrained which features and characters we have focused on as evolutionarily important. In order to understand evolutionary history of morphological features, we must explore complex pathways and gene systems that allow features, such as nerves and muscles, to function in an integrated capacity. Placement of ctenophores at the base of the animal tree implies that metazoan nervous systems evolved twice, moreover functional and genomic evidence shows that ctenophore neural systems are very unlike those of other animals regardless of inferred tree topology. Discussion will focus on the interplay between inferred tree topologies and interpretation of morphological features (muscles and neural systems) in early animals.

P1.130 HALL, EMILY*; PODOLSKY, ROBERT; SUNY College of Environmental Science and Forestry, College of Charleston; *hallemily691@gmail.com*

A Test of Genetic Variation for Resistance to Effects of Seawater Acidification on the Skeletal Development of Sea Urchin Larvae

Rising levels of atmospheric CO_2 are altering global ocean chemistry, including a decline in the pH of surface waters. Under more acidified conditions, marine organisms that build shells and skeletons are under increasing risk of a reduction in their ability to deposit calcium carbonate. Relatively little is known about genetic variation in the capacity of organisms to respond to such effects. We examined skeletal growth in larval sea urchins to examine genetic variation in their sensitivity to elevated CO_2 under exposure at two life history stages: at fertilization, and during larval development. Using gametes of the purple−spined sea urchin (*Arbacia puncutlata*), we carried out single−pair crosses in blocks of 3 males x 3 females for a total of 9 sibships, repeated over 7 blocks. Fertilizations were done in seawater saturated at either current (392 ppm) or 2.5x−current (980 ppm) CO_2, and the resulting embryos from each cross were reared over 3 days to four−arm larvae under each of the same two CO_2 conditions. Nine landmarks on larvae were used to calculate both skeletal and soft body measurements. Exposure to elevated CO_2 during larval development significantly reduced the length of the postoral arms and body rods and increased postoral arm asymmetry. Surprisingly, exposure to elevated CO_2 during fertilization also reduced the subsequent growth of anterolateral arms, body rods, and body length. We found significant additive and non−additive genetic variation for growth of certain characters but no evidence of genetic variation for the effects of elevated CO_2 on growth. These results suggest that this population may not have the genetic capacity for an evolutionary response to elevated CO_2 under predicted near−future conditions.

P1.114 HALL, C.A.*; BAILEY, A.M.; DEMAS, G.E.; Univ. of North Carolina, Pembroke, Indiana University; *cah028@bravemail.uncp.edu*

Food availability as a cue for seasonal reproduction: Delayed reproductive development in juvenile Siberian hamsters

Seasonally breeding animals maximize reproductive success by reproducing only when there are sufficient resources available; when resources are scarce, reproduction is not energetically supported. Similarly, delayed reproductive development in response to undernutrition is a well−demonstrated phenomenon in mammals. The peptide hormone kisspeptin is known to both coordinate reproductive development and to play a role in triggering seasonal reproductive activity. A lack of kisspeptin action is associated with undernutrition during development; therefore, we hypothesized that seasonally breeding animals that experience a nutritional challenge early in life may exhibit altered seasonal responses as adults as a result of modified kisspeptin activity. We delayed reproductive development in male and female Siberian hamsters (*Phodopus sungorus*) by providing restricted food (70% of *ad libitum* intake) during a period from weaning until early adulthood. We assessed changes in body mass, timing of puberty, and reproductive masses at postnatal day 60. Food−restricted animals exhibited delays in development compared to *ad lib.*−fed animals; this effect was more dramatic in females than in males. Ongoing work is aimed at examining underlying differences in mRNA expression of kisspeptin and its receptor in relevant brain areas, as well as circulating reproductive hormones. The results of this study complement similar studies of reproductive development in mammals while contributing to our knowledge of the mechanisms of seasonal reproduction.

P1.131 HALL, E.M.*; BRADY, S.P.; CRESPI, E.J.; Washington State University, Dartmouth College; *emily.m.hall@wsu.edu*

Mapping the susceptibility landscape: the crossroads of physiology and disease dynamics

Roads are a major anthropogenic disturbance covering around 1% of the area of the US and affecting nearly one fifth. Northern states routinely apply de−icing salts which is associated with chronic salinitization of wetlands. We hypothesized increased salinity (an osmoregulatory stressor) in roadside ponds affects energy available for growth and immune function in amphibian larvae and will decrease performance and susceptibility to disease. Roads can affect disease susceptibility of amphibians in two ways, by increasing transmission of pathogens or by decreasing host resistance to infection. We examined the effects of wood frog (*Rana sylvatica*) tadpoles living adjacent to roads with high salinity on growth and development in a reciprocal transplant experiment, and susceptibility to ranavirus (FV3) infection in a dose response exposure experiment. We found tadpoles in roadside ponds had lower survival, a slower growth rate, and a transgenerational effect on development rate in roadside originating tadpoles. Furthermore, ranavirus associated die offs were more likely to occur near roads and the prevalence of infection was higher in roadside ponds. Survival to ranavirus exposure in the lab differed across ponds of varying distances from the road. Specifically, the dose response of roadside tadpoles was flatter than woodland tadpoles. Overall, roads may contribute to population declines by decreasing performance of tadpoles and as a source of ranavirus propagation in this matrix of ponds.

P1.165 HALSEY, LG*; COWARD, SRL; University of Roehampton; *l.halsey@roehampton.ac.uk*

Energy expended during horizontal jumping: investigating the effects of surface compliance

Locomotion energy costs can be affected by the substrate underfoot and the mechanics of movement. For example, in some cases substrate properties can exacerbate energy expenditure while in other instances those properties, if skilfully exploited, such as by arboreal primates, can attenuate transport costs. We present the first data on metabolic costs of horizontal jumping in humans, and interpret the differing costs of jumping between two distinct substrates in terms of kinematic alterations. The substrates were either firm' or compliant' and jumps over two distances were measured: 1.2 and 1.8 m. Participants jumped at 0.2 Hz, back and forth between surfaces, wearing a portable respiratory gas analyser, and metabolism remained aerobic. The cost for a human to jump horizontally is, per unit distance, around 18−fold the cost to walk and around 12−fold the cost to run. The main findings concerning the effects of substrate properties on jumping energy costs were: (1) for long jumps, jumping from a compliant surface is energetically less costly than jumping from a firm surface; (2) the difference in energy costs associated with a compliant versus firm take−off surface is not present at shorter jumping distances. Kinematic analysis indicates possible explanations for these findings. Firstly, the calf muscle is likely used more, and the thigh muscles less, to take−off from a firm springboard during 1.8 m jumps, which may result in the power required to take−off being produced less efficiently. Secondly, the angle of take−off from the compliant surface during 1.8 m jumps is closer to the optimal for energetic efficiency (45°); possible due to the impulse provided by the surface as it returns stored energy during the final stages of the take−off. The theoretical effect on energy costs due to a different take−off angle for jumps of only 1.2 m is close to negligible.

S1.3 HALSEY, LG; University of Roehampton; *l.halsey@roehampton.ac.uk*

Animal locomotion: What factors shape the energy costs?

The net cost of pedestrian transport on the flat (NCOT; energy expended kg−1 m−1) is lower for larger animals while smaller animals gain an energetic advantage uphill. Other factors so far investigated describe NCOT at best weakly: number of limbs is not predictive while there is some suggestion of a negative effect of temperature and of a waddling gait. Furthermore, although moving faster along the ground requires a higher rate of energy expenditure, for most terrestrial species this rate scales linearly with speed on the flat and thus NCOT is invariant of speed. Therefore, total transport costs, at least for terrestrial animals, appear to be explained mainly by the physical costs of raising and moving the body a given distance, which is broadly described by mass. However, in certain terrestrial species, and in flying and swimming species, the NCOT−speed relationship is not a constant. From an energetics perspective, when minimising energy expenditure is the priority, presumably the default speed of locomotion for such species minimises NCOT. However, this speed may vary with factors such as substrate properties, substrate angle, load carrying and weather conditions (e.g. wind), and furthermore these factors may interact with each other and body mass. Together, these factors create an animal's energy landscape'. Additionally, the energy cost of locomotion associated with changing direction can be substantial and have implications for an animal seeking to minimise NCOT; their default direction of movement should be to continue in a straight line. Animals should be expected to adapt their speeds and movement patterns to their energy landscape, to attenuate the effects of the environment and other factors on their transport costs. Thus the energy landscape should influence, in predictable ways, not only an animal's speed of locomotion but also the routes that it takes while travelling through its environment.

P2.39 HAMDEN, JE*; DAVIS, J; CAUGHRON, J; Radford University; *jhamden2@radford.edu*

Measuring immunocompetence of free living, non−model passarines using a novel BKA

Being able to accurately measure the immunocompetence of free living, non−model animals would be of great value; making it possible to make comparisons across species, niche, sex, and life−history stage. However, currently it is very difficult to measure even just one aspect of immunocompetence. The methods currently used for determining innate immune capacity (phytohemagglutinin assay (PHA) and bacteria killing assays (BKA)) are problematic and often don't work for non−model species (Martin et. al., 2004). We have developed a variation on a more traditional BKA technique that can accurately and efficiently assess immune capabilities of birds by exposing static bacteria to the antibodies and complement contained in blood plasma and then observing bacterial growth using a spectrophotometer. Previous BKA techniques either did not factor in bacterial growth rate or life stages, leading to an increase in overall variance of results or utilized to great a quantity of plasma to be of use in small vertabrates. Our assay overcomes this problem by ensuring all bacteria are at the same point in growth at the time of inoculation with plasma as well as not allowing for microbial growth while plasma mediated killing is occurring. In principle, the greater the cell death caused by plasma, the longer it will take to observe log growth in the E. coli population following exposure to complement in bird plasma. This variation on the BKA takes a relatively short amount of time to conduct, is cost effective, and utilizes a minimal amount of plasma making it useful for small vertebrates and potentially even invertebrates. Here we present results utilizing this technique to determine complement mediated killing in various passerine groups, in comparison with heterophil:lymphocyte ratio. The use of the heterophil:lymphocyte ratio technique was used to validate the data observed in the use of our novel BKA.

P3.177 HAMEDI SHAHRAKI, M.; KHODABANDEH, S.*; SEYFABADI, J.; HEMMATI, S.; Tarbiat Modares University; *surp78@gmail.com*

Effects of sea anemone, Stichodactyla hadoni , mucal proteins on the embryonic development of zebra fish, Danio rerio

Numerous toxins have been detected in sea anemones mucus. In the present study, the effects of *S. hadoni* mucal proteins on the different stages of embryo in zebra fish, as a model, were examined. Zebra fish is an excellent model for ecotoxicological studies and their embryo has some properties such as small size, rapid development and transparent cover. The sea carpet samples were collected from the inter−tidal areas of the eastern part of the Hormuz Island (Persian Gulf), and were frozen in −160 °C. The total mucal protein concentration, extracted with 100% methanol, was measured by ELISA, and then three concentrations of protein (2.1, 3.7 and 7.4 mg/ml distil water) was made. 2 ml from each concentration was added to the micro plates containing 150 zebra fish eggs with 2 replications. The sterile water was considered as control group with 2 replications. The eggs were incubated for 72 h and the process of embryonic development was performed every 6 to 12 hours. Results showed normal embryonic development in the control groups, while the eggs treated with 3/7 and 7/4 mg/ml of sea anemones mucal proteins degenerated and blackened in less than 12 hours. Also a delay in the phase of growth was observed in 1.2 mg/ml groups. Our results showed that the mucal proteins from this sea anemone can affect embryonic development rapidly. At low concentration these proteins can cause delayed growth, and in high concentrations cause cell lysis and degeneration. No similar studies have been conducted to compare with our results, but some anomalies such as eye hypo−pigmentation, pericardial oedema and swim bladder have been reported as the result of fish exposure to p−tert− buthylphenol, 2, 4−Dimethylphenol and 2% ethanol.

26.1 HAMEL, JA*; MILLER, CW; Elon University, University of Florida; *jhamel2@elon.edu*

Are female mating decisions adaptive when environments vary? A test using natural resource variation

Female mate choice can vary according to environmental context. Few studies have examined whether context−dependent mate choice is adaptive, and, if adaptive, whether fitness benefits are direct or indirect. Leaf−footed cactus bugs (*Narnia femorata*) provided an opportunity to test if context−dependent female mate choice results in direct or indirect fitness benefits. In this species, males defend high− or low−quality cactus territories where offspring develop: territories with or without cactus fruit, a high−quality nutritional resource. Females discriminate against males when males are reared without fruit, but only when they encounter those males in territories with fruit. We examined the direct and indirect fitness consequences of female mate choice across contexts. We found that mating context (high− or low−quality cactus territory) and male diet (reared with or without fruit) influenced both female fecundity and female reproductive success. In contrast, we found that offspring diet, but not sire diet, influenced offspring adult body size. Our findings suggest that for female *N. femorata*, context−dependent mate choice is adaptive, and results in direct, but not indirect fitness benefits.

P2.17 HAMIDI, H.M.*; CARDENAS, P.; THACKER, R.W.; Univ. of Alabama at Birmingham, Uppsala Univ.; *dr.bob.thacker@gmail.com*

Diversification and Correlated Trait Evolution in Astrophorid Sponges (Porifera: Demospongiae)

Although sponges (phylum Porifera) are basal metazoans with relatively simple body plans, some groups of sponges possess a wide diversity of siliceous spicules that form a mineralized skeleton. Recent investigations of the Order Astrophorida have established a molecular phylogeny based on gene sequences encoding the large (28S) subunit of nuclear ribosomal RNA and subunit I of mitochondrial cytochrome oxidase (coxI). This molecular phylogeny conflicts with traditional arrangements of Astrophorida and suggests a novel pattern of gain and loss of morphological traits, including spicules. We expanded a previously published morphological character matrix of Astrophorida to include nested traits based on an ontology of morphological characters and modified the character matrix to include only the presence and absence of traits. We obtained 28S and cox1 sequences of Astrophorida from GenBank, aligned these sequences using MAFFT, and constructed a molecular phylogeny by implementing a relaxed clock model in MrBayes. We tested whether morphological traits were correlated with this phylogeny by calculating measures of phylogenetic signal implemented in the R−based software package 'arbor'. Of the 24 morphological traits examined, 14 displayed significant phylogenetic signal. Ongoing work examines phylogenetic correlations among these traits and their impact on the diversification of Astrophorida.

74.8 HAMMOND, T.T.*; BERG−KIRKPATRICK, T.; SPRINGTHORPE, D.; WALSH, R.E.; LACEY, E.A.; Univ. of California, Berkeley; *thammond@berkeley.edu*

Remote sensing accelerometers for detecting behaviors in two chipmunk (Tamias) species

Measuring behavioral activity budgets in small mammals is a difficult task due to its time−costliness, the difficulty of observing these animals in the wild, and the effects of observers on animal behaviors. In recent years tri−axial accelerometers have been increasingly employed to facilitate this task, however, their application in small mammals has been restricted, mainly due to weight limitations. Additionally, accelerometers engender a novel set of complications, due to the large datasets they produce and the need for a system that can reliably map acceleration patterns to specific behaviors. Using recently developed, tiny (1.5−2.0 g) accelerometers, we simultaneously collected filming and accelerometer data for two species of chipmunks (*Tamias alpinus* and *Tamias speciosus*) in a semi−naturalistic captive setting. We then manually labeled all films with behaviors in order to generate an accelerometer dataset annotated with specific behaviors. We then used techniques from machine learning to develop a system that can automatically label a novel stream of completely unprocessed accelerometer data with behavioral categories. Finally, we piloted this system in wild chipmunks, resulting in the collection and analysis of behavioral data from completely unobserved, free−living animals. This is a novel contribution to the field of remotely sensing behavioral activity budgets in small animals. Additionally, this study will open doors for an examination of behavioral differences in the focal species, which have divergently shifted their elevational ranges in response to the past century of climate change in Yosemite National Park, CA (Moritz *et al.*, 2008).

P1.127 HANAUER, RE*; KETTERSON, ED; Indiana University; *rhanauer@indiana.edu*

Does urbanization reduce the glucocorticoid response to an acute stressor?

Vertebrates respond to acute stressors by increasing glucocorticoid hormone levels. These increases in glucocorticoids affect many physiological processes, including energy storage, immune function, and behavior. Animals that colonize urban environments are faced with novel anthropogenic stressors, which might induce elevated levels of circulating glucocorticoids and changes in associated traits. Paradoxically, urban animals exhibit bold behavior, which is frequently correlated with low stress response. Thus, while urban environments could be initially stressful, selection for bold personality may lead to a reduced glucocorticoid response in urban animals. In still a third possibility urban animals may attenuate their response to stressors through habituation (learning over the course of the lifetime). Previous comparisons of urban and non−urban birds report differences in corticosterone (cort) response to acute stressors, but the direction of change from ancestral habitats to urban habitats has not been consistent, and no studies have examined multiple urban and non−urban populations of the same species. One urban population of our study species, the dark−eyed junco (*Junco hyemalis*), is known to have an attenuated stress response compared to a nearby ancestral population. We studied juncos from five cities and six non−urban sites in California from March to July 2014 and asked whether a lower cort response was consistently observed in urban juncos. We measured cort response to acute stress by taking blood samples from free−living juncos within 3 minutes of capture and again 30 minutes later. Results of this first study to compare replicate urban and non−urban populations of one species of bird are pending, and will provide valuable insights into the impact of urbanization on stress physiology.

P1.30 HANEY, W.A.; SCHUMACHER, E.L.*; ANDERSON, C.D.; REECE, J.S.; Valdosta State University; *elschumacher@valdosta.edu*

Population Genetics of the Federally Endangered Florida Grasshopper Sparrow

North America's most endangered bird, the Florida Grasshopper Sparrow (*Ammodramus savannarum floridanus*), is on the verge of extinction with fewer than 200 total individuals inhabiting three remaining geographic populations in south Florida. To aid in preserving this species and to assess its current genetic diversity relative to prior sampling periods (i.e., 1881−1939 and 1995−1998), 26 individuals from one of the remaining populations (Three Lakes WMA) were genotyped at each of the six microsatellite loci analyzed in prior studies. Despite continued decline in population census size, all loci remain highly polymorphic and there has been virtually no alteration in gene diversity, nor any strong evidence of system of mating inbreeding. The results of this study indicate that declines in population census size do not appear to be due to a loss in genetic variation associated with genetic drift, a result that has positive implications for the establishment of successful captive breeding programs. Ongoing research based on these samples includes the development of a PCR−based sex determination test, an analysis of the genome structure of the Florida Grasshopper Sparrow, and analyses of changes in mitochondrial DNA diversity over the same timeframe analyzed here.

38.2 HANEY, BR*; FEWELL, JH; Arizona State University; *brhaney@asu.edu*

The evolution and reproductive consequences of queen cooperation in a harvester ant

Primary polygyny, the cooperation of multiple unrelated queens in a social insect colony, has been documented in multiple taxa but is poorly understood as a behavioral phenomenon. The harvester ant *Pogonomyrmex californicus* has geographically distinct populations dominated by either monogynous (single queen) or polygynous colonies. Little is known about how cooperative queens divide reproduction or associated fecundity costs, but this information is vital to understand how this cooperative behavior has evolved. We examine primary polygyny by capturing entire mating flights of monogynous and polygynous *P.californicus* colonies and comparing their reproductive characteristics. Data from three annual mating flights indicate a lower per−queen reproductive output as well as a male biased sex investment in polygynous colonies, suggesting a considerable fecundity cost to queens that participate in primary polygyny. We also use microsatellite markers to determine per−queen reproductive and workforce contribution. Preliminary genetic data shows that some queens produce a larger proportion of the mating flight than they do the workforce, suggesting subtle conflict within the colony.

84.5 HANEY, RA*; CLARKE, TH; HAYASHI, CY; AYOUB , NA; GARB, JE; University of Massachusetts Lowell, Washington and Lee University, University of California Riverside; *robert.a.haney@gmail.com*

Evolutionary transcriptomics of the venom gland in widow spiders

The expansive spider Family Theridiidae currently contains close to 2400 species, several of medical importance due to human envenomations. Among these are the notorious black widows of the genus *Latrodectus* and the closely related false widows of the genus *Steatoda*. We identified sets of venom gland specific transcripts (VSTs) from three widow spider species (*L. hesperus*, *L. geometricus* and *S. grossa*) using RNA−Seq data from replicates of three tissue types. The three species share a toxic arsenal consisting of atypically large neurotoxins (latrotoxins), small inhibitory cystine knot (ICK) toxins, CRISPs, enzymes with toxic potential and putatively novel toxins. Venom gland transcriptome evolution may proceed by changes in the number of transcripts of a given type due to duplication of the encoding genes, or by changes in the primary sequence of expressed proteins including those driven by adaptive evolution, or via changes in the magnitude or spatial pattern of expression of its component transcripts through regulatory mechanisms. We explore each of these potential avenues. We test whether venom gland specific expression has led to increased orthogroup size. We explore to what extent transcripts exhibit conserved patterns of venom gland biased expression across species, or whether recruitment to venom gland specific expression is a dynamic process in widow spiders. We test whether orthogroups with VSTs are more rapidly evolving at the sequence level or undergo more positive selection than those with more broadly expressed genes. We define lineage specific orthogroups and transcripts and test for lineage specific upregulation of transcripts in the venom gland, all of which may contribute to species−specific venom phenotypes.

36.7 HANLON, SM*; KERBY, JL; PETERSON, B; MOORE, JE; United States Fish and Wildlife Service; *hanloc2107@gmail.com*

Agriculture−induced aquatic contamination as a predictor for disease dynamics in reptile populations

In recent years, anthropogenic stressors have drastically altered both terrestrial and aquatic ecosystems. One of the greatest threats to organismal health are agricultural pesticides that commonly run off or drift into wildlife habitats. A group of organisms that are particularly susceptible to the effects of pesticides are turtles, which are exposed to the chemicals in both aquatic and terrestrial landscapes. Another threat to turtle health are ranaviruses, a group of viruses with low host specificity; reptiles, amphibians, and even fish can be lethally or asymptomatically infected and can serve as reservoirs for other vulnerable species. While ranaviruses are extremely lethal and have been attributed to mass herpetofaunal die offs, ranaviruses may persist in populations without causing immediate die−offs. Working with the Wapanocca National Wildlife Refuge (WNWR), we tested the hypothesis that pesticides act as predictors for turtle species distributions and ranavirus occurrences in natural populations. In a year−long, ongoing effort, we have collected water samples, to test for residues of >90 pesticides, and assessed turtle distributions and ranavirus occurrences in populations that are either in relatively contaminant−free areas, or areas that are heavily contaminated through direct agricultural runoff. We found that habitat type, along with pesticide occurrence, are predictors of turtle diversity and abundance. Moreover, seasonality plays an important role in ranavirus occurrence due to flora change, water level, and amount and type of pesticide residues found in agricultural runoff. We conclude that agricultural contamination may play an important role in turtle diversity and distributions and may also affect disease dynamics in natural populations.

P1.183 HANSEN, S*; MINICOZZI, M; GIBB, A.C.; Northern Arizona University; *sh646@nau.edu*

How do fish with different terrestrial jumping abilities respond to being stranded on land?

Some teleosts will intentionally strand themselves on land to escape poor conditions, while others may become accidentally stranded. Do some species travel farther than others when stranded on land? Many small teleosts perform a tail−flip jump to move about on land. During this behavior, a fish rolls its head over the tail, extends the posterior body to push against the substrate, and launches into ballistic flight. We predicted that species with takeoff angles of approximately 45° ("good jumpers") would jump more frequently and travel a greater distance, relative to species with takeoff angles greater than 45° ("poor jumpers"). To test this prediction, we stranded six species with varying jumping abilities (*Gambusia affinis*, *Betta splendans*, *Umbra lima*, and *Oryzias latipes*, "good" jumpers vs. *Pseudomugil signifer* and *Danio rerio*, "poor" jumpers) on a moist surface for two minutes and the response to stranding was recorded from overhead with digital video. Trials were analyzed by overlapping before/after images of each jump and net displacement was measured with ImageJ. During the trials, "good" jumpers moved very little, jumping approximately five times in two minutes, while "poor" jumpers moved continuously, jumping approximately fifty times (10x more often). Because they jumped infrequently, "good" jumpers covered less distance during a trial, relative to so−called "poor" jumpers. We hypothesize that these responses are a consequence of the natural history of each species: good jumpers may be predisposed to jump out of the water and rest immobile until an aquatic threat is gone, whereas, poor jumpers are unlikely to voluntarily leave the water. Consequently, "poor" jumpers may jump repeatedly in an effort to return immediately to the aquatic environment when stranded on land.

P3.57 HANSER, JT*; CASTO, JM; Illinois State University; *jthanse@ilstu.edu*

The Effect of Ambient Temperature on Avian Incubation Behavior Prior to Clutch Completion

While the majority of incubation in birds occurs after the completion of egg laying, in some species, parents often begin incubation prior to clutch completion. Consequently, eggs within clutches typically develop and hatch asynchronously, often resulting in reduced rates of growth and survival among later−hatched nestlings. In many species, incubation prior to clutch completion and hatching asynchrony are associated with high ambient temperatures. Prolonged exposure to high, suboptimal temperatures can result in abnormal development and negatively affect the viability of eggs. Thus, when ambient temperatures are high, incubation prior to clutch completion may serve to minimize reductions in the hatching success of eggs by expediting the hatching of the earliest laid eggs. Here, we used information collected by automated data−loggers (iButtons) to model the effect of ambient temperatures on the incubation behavior of European starlings (*Sturnus vulgaris*), a cavity nestling species, prior to clutch completion. By placing data−loggers externally on the underside of each next box as well as within the cup of each nest, we were able to record ambient and nest temperatures for each nest over the course of the laying period. We found that, while nest cup temperature and the likelihood that eggs experience temperatures necessary for embryonic develop are strongly influenced by ambient temperature, nest attentiveness − inferred by comparing external and nest cup temperatures − appears to be unrelated to ambient temperature. Together these results suggest that while incubation prior to clutch completion and hatching asynchrony may be associated with high ambient temperatures, this relationship does not reflect a change in incubation behavior as a response to high ambient temperatures.

55.7 HARDER, A.M.*; HALANYCH, K.M.; MAHON, A.R.; Central Michigan University, Auburn University; *harde3am@cmich.edu*

Genetic diversity of Pallenopsis (Arthropoda: Pycnogonida) in the Western Antarctic

Pycnogonids, or sea spiders, are marine arthropods with cosmopolitan and eurybathic distribution. Of the approximately 1,300 pycnogonid species described worldwide, over 240 species occur in the Southern Ocean, and over half of those are endemic to the Antarctic. Morphological data suggest circumpolar distributions for multiple Antarctic species; however, recent molecular inquiries into the genetic structure of Antarctic benthic invertebrate populations have revealed varying patterns of genetic connectivity and, in many cases, cryptic speciation events that are incompatible with the previously hypothesized genetic homogeneity for Southern Ocean invertebrates. To date, little is known about genetic connectivity within Antarctic *Pallenopsis* species populations, and *Pallenopsis* phylogeny remains highly unresolved, with insufficient morphological data available to determine evolutionary relationships between *Pallenopsis* and other pycnogonid genera. This study describes genetic structure of *Pallenopsis* populations of western Antarctic coastal regions, the Scotia Arc, Falkland Islands, and Chilean coast. In this study, we present the results of analyses derived from the mitochondrial COI and 16S rRNA genes that show gene flow patterns between these populations, and provide a molecular basis for phylogenetic assessments of the genus *Pallenopsis*. Examination of genetic characters in conjunction with traditional morphological taxonomic procedures will provide increased resolution to the evolutionary history of *Pallenopsis*, and will lead to descriptions of multiple new species. Future sampling and analyses from other areas of the Antarctic coastline will provide a broader context for the phylogeny of *Pallenopsis*.

P3.120 HARMATA, K.L.*; PALES, A.R.; BLACKSTONE, N.W.; Northern Illinois University; *katieharmata@aol.com*

The Role of Symbiont Migration in Coral Bleaching

Although widely studied, aspects of coral bleaching remain poorly understood. It is generally agreed that perturbation causes the impairment of photosynthesis of symbionts (*Symbiodinium* spp.) and that this is the first step of bleaching. In what can be referred to as the canonical pathway, this is followed by an increase in reactive oxygen species, and cell and symbiont death. Alternatively, impaired photosynthesis also triggers a "non−canonical" pathway involving symbiont migration within the colony. In this pathway, damage to photosynthesis removes a major sink for carbon dioxide and bicarbonate, resulting in relatively higher levels of both. In some corals, gastrovascular flow and hence symbiont movement is driven mainly by cilia. In many systems, bicarbonate is known to activate ciliary action via soluble adenylyl cyclase (sAC) and cyclic adenosine monophosphate (cAMP). It remains an open question whether or not this pathway operates in corals. To test this, colonial octocorals were treated with bicarbonate and gastrovascular flow rates were calculated. When treated with a low concentration of bicarbonate for a short period of time there was little to no effect on flow rates. However, when treated with a higher concentration for a longer period of time flow rates were dramatically enhanced. To further examine this pathway, additional experiments will include treating corals with an inhibitor of sAC and assaying cAMP levels. These results for the first time connect basic coral physiology with carbon dioxide levels in the ocean. Greater migration of symbionts may result in more symbionts exiting the coral colony or reaching "safe zones" in a colony where they can survive perturbation.

61.2 HARPER, F. M.; Rollins College, Winter Park, FL; *fharper@rollins.edu*

Teaching Marine Biology: topics not covered in textbooks

The impacts of human activities on the health of marine ecosystems are increasingly evident and relevant for students studying marine biology. While topics such as oil spills and climate change are generally well−covered in marine biology textbooks, important problems such as plastic and noise pollution receive little mention. Given the paucity of information in textbooks on these issues, course curricula and instruction may be significantly impacted. Decisions as to whether to teach a topic can be driven by the content available in the course textbook. Instructors may lack the knowledge or comfort−level to adequately examine topics either not covered or only briefly mentioned. Yet the scientific literature abounds with current research on these topics that should be shared with marine biology students. Current research about three topics poorly covered in textbooks (plastic pollution, noise pollution, deep−sea mining) will be discussed. Techniques for supplementing student textbook readings with articles in the popular press will be shared, as will a laboratory exercise investigating the role of consumer choices in reducing plastic pollution.

P3.39 HARRIS, A*; MONDELUS, F; HARRISON, J; CARROLL, M,A; CATAPANE, E.J.; Medgar Evers College; *catapane@mec.cuny.edu*

Histamine Receptors in Gill of the Bivalve Crassostrea viginica and the Actions of Histamine at the Gill Interfilamental Junctions

Crassostrea virginica contain serotonin and dopamine, which mediate physiologic functions in gills and other organs. Histamine (HIS), a biogenic amine neurotransmitter in nervous systems and sensory receptors in invertebrates, has rarely been reported in bivalves. Recently, we showed in *C. virginica* HIS is involved in sensory reception in sensory−motor integration of gill lateral cell cilia beating. We used HPLC to quantify HIS and immunohistofluorescence to detect HIS and HIS H2 receptors in tissues including interfilamental junctions of gill. We hypothesize H2 receptors could be confirmed by Western Blot (WB) analysis, and HIS has a physiological action on interfilamental junctions. For WB gill lysate was prepared by polytron disruption in NP−40 detergent buffer containing protease inhibitor, then centrifuged to obtain supernatant of solubilized membrane proteins. Up to 30 µg of solubilized protein was subjected to SDS−PAGE with 10% acrylamide gels and electroblotted onto nitrocellulose. H2 receptor immunoreactivity was revealed with primary and HRP−conjugated secondary antibodies, and developed using CN/DAB substrate kit. Physiological effects of HIS at interfilamental junctions were observed with a Leica microscope. Responses of interfilamental junctions to HIS and the HIS antagonist famotidine were photographed. WB showed a strong band at 70 kD corresponding to H2 receptors. The physiology study showed HIS ($10^{-3} - 10^{-5}$ M) caused a dose−dependent contraction of interfilamental junctions. Famotidine ($10^{-3} - 10^{-5}$ M) blocked contractions. The study confirms previous immunohistofluorescence findings of the presence of H2 receptors in gill of *C. virginica* and identifies a specific physiological role of HIS in the gill.

P1.121 HARRIS, C.M.*; MADLIGER, C.L.; LOVE, O.P.; University of Windsor; *harris2c@uwindsor.ca*

The Application of Feather Corticosterone as an Indicator of Stress in the Wild

The measurement of stress is a key physiological tool used to investigate the mechanistic linkages of ecological and conservation problems. Glucocorticoids (i.e., corticosterone or cortisol) are a well−established measure of stress; however, measuring circulating levels in the blood can be difficult, invasive, and limited in scope. Measuring corticosterone levels in feathers is a recently proposed alternative which has quickly grown in popularity due to the ease of feather collection. However, a number of details of the method are not well understood, limiting the current interpretation and applications of this tool. Here we investigate how corticosterone levels in naturally moulted feathers respond to a long−term stressor in a wild population of tree swallows (*Tachycineta bicolor*). Our results provide important guidance on the measurement of stress in feathers and its use in assessing natural and anthropogenic impacts in the wild.

80.5 HARRISON, J.S.*; CROFTS, S.; Univ. of California, Santa Cruz, Univ. of Washington; *jasaharr@ucsc.edu*

The Ontogeny of Anti−Predator Defense Structures in the Great Sculpin (Myoxocephalus polyacanthocephalus)

Anti−predator defense is important for survival, especially for slow−moving benthic fishes who can't outrun larger predators. In cottoid fishes, preopercular spines are caudally oriented defensive structures with one or more sharp branches. In this study we examined the ontogeny and performance of preopercular spine in the Great Sculpin (*Myoxocephalus polyacanthocephalus*), a bottom dwelling piscivore that can reach 80cm TL. We sampled 15 *M. polyacanthocephalus* from 3 to 27 cm (SL) and found that spines grew isometrically in both length and width. To test performance we measured the ease with which spines were able to penetrate a synthetic proxy of predator's flesh. We used silicone rubber block and measured penetration force as the spines were inserted to 75 percent of spine length. Puncture force scaled negatively with length − as individuals get larger, their spines become more efficient at penetration. Another aspect of spine performance is resistance to breakage. We used finite elemental models of three *M. polyacanthocephalus* spines from three size bins (0−10 cm, 10−20 cm, 20−30 cm) to analyze Von Mises stress distribution and magnitude across a size gradient. We found that maximum Von Mises stress localized to the tips of the spines, and was higher in smaller spines than in larger spines, indicating that the spines of smaller fishes are more likely to break with a load proportional to their spine size. This may reflect a difference in predation pressure, with smaller fish relying on crypsis and larger ones on spines for defence.

S11.3 HARRISON, J.F.; Arizona State University; *j.harrison@asu.edu*

Oxygen Sensing and Handling Across the Pancrustacea

Most aspects of oxygen sensing including hypoxia−inducible factor (HIF), AMPK, and nitric oxide signaling are ancient pathways that occur throughout the Pancrustacea. Tracheal respiratory systems have evolved independently several times in terrestrial Arthropoda, including in the Hexapoda within the Pancustacea. Tracheal ventilation occurs primarily due to intersegmental muscles altering body volume, re−purposing muscles used primarily for posture and locomotion. However, some aquatic juvenile insects utilize appendage muscles for external ventilation as in crustaceans. Both crustaceans and insects respond to hypoxia with increasing ventilation driven by central pattern generators in the nerve cord. The response reflects the location of the primary constraints on gas exchange, with crustaceans increasing external and insects increasing internal ventilation. In contrast to most vertebrates, Pancrustaceans decrease rather than increase heart function in response to hypoxia. Tracheal systems and air−breathing allow hexapods to achieve higher rates of oxygen consumption than crustaceans, and hexapods are generally more able to support locomotion with aerobic metabolism. However, the two systems seem to have similar capabilities to support metabolism during hypoxia as critical P_{O2} values that limit aerobic metabolism and performance in crustaceans and insects appear similar. All Pancrustaceans examined so far exhibit suppression of metabolism, feeding and growth in mild hypoxia. Both air−breathing crustaceans and hexapods can achieve high internal P_{O2} levels, and both have relatively low internal P_{CO2} and bicarbonate levels relative to vertebrates. Secondary evolution of air−breathing in crustaceans and water−breathing in hexapods are beautiful examples of convergent function within the constraints of phylogenetic history. Partially supported by NSF IOS 1122157 and 1256745.

P2.41 HART, C.E.*; LEMA, S.C.; HARDY, K.M.; California Polytechnic University, San Luis Obispo; *cohart@calpoly.edu*

Impact of 4−nonylphenol on the gene−level immune response of the Pacific oyster, Crassostrea gigas, following bacterial infection

Endocrine disrupting compounds (EDC's) are chemicals that can interfere with hormone signaling pathways and are now recognized as pervasive in estuarine and marine waters. One emerging EDC in California's coastal waters is the xenoestrogen 4−nonylphenol (4−NP), which has been shown to impair reproduction, development and in some cases immune function of marine invertebrates. To further investigate effects of 4−NP on marine invertebrate immune function, we conducted molecular−level characterizations of gene transcript changes in the Pacific oyster (*C. gigas*) following bacterial exposure. To quantify these effects we exposed oysters to dissolved phase 4−NP at high (100 ¼g/L) or low (2 ¼g/L) concentrations for 7 days, and then experimentally infected (via injection into the adductor muscle) the oysters with the marine bacterium *Vibrio campbellii*. After 24 hours, tissues (gill, mantle and hemocyte) were dissected and flash frozen in liquid nitrogen. Quantitative real−time RT−PCR was used to measure relative transcript abundances for genes known to respond to bacterial challenge (BIGdef1−3, BPI, DefH1−2, galectin, lectin2, lysozyme, transglutaminase, and TIMP). Thus far we have determined that exposure to 4−NP has a significant effect ($p<0.06$) on relative mRNA levels of BPI and galectin in the gill tissue with the most substantial differences occurring in the low dose for both bacterially−infected and −naïve oysters. Furthermore, bacterial infection alone has effects ($p<0.06$) on relative mRNA levels of TIMP, transglutaminase, and lysozyme across all 4−NP concentrations evaluated. These results suggest that exposure to 4−NP can alter the transcriptional responses of immune−related genes to bacterial infection in *C. gigas*.

P2.203 HART, H*; EVANS, A; GELSLEICHTER, J; AHEARN, G; University of North Florida, Southern Mississippi Gulf Coast Research Lab; *hannahhart2009@gmail.com*

Molecular identification and functional characteristics of peptide transporter 1 in the bonnethead shark (Sphyrna tiburo)

Many elasmobranchs are considered top predators with worldwide distribution, and in general these fish play an important role in the transfer of energy from the lower to the upper trophic levels within the marine ecosystem. Despite this, little research regarding the rates of prey digestion and processes of energy and nutrient absorption have been explored. Specifically understudied is enzymatic digestion within the intestinal brush border that functions to breakdown macromolecules to smaller subunits for absorption across the gastrointestinal epithelium. Given their carnivorous diet, the present study sought to expand knowledge on nutrient intake in elasmobranchs by focusing on the uptake of products of protein metabolism. To accomplish this, Peptide Transporter 1 (PEPT1), a protein found within the brush border membrane of higher vertebrates that is responsible for the translocation and absorption of small peptides released during digestion by membrane− bound proteases, was molecularly identified in the bonnethead shark(Sphyrna tiburo) using degenerate primers based on conserved portions of known PEPT1 sequence. The transporter was localized by immunocytochemistry, and vesicle studies were used to identify the apparent affinity of the transporter, and to quantify the rate of uptake by its H+−dependent cotransporter properties, using 3H−glycylsarcosine as a model dipeptide. Such results provide insight into the rate and properties of food passage within S. tiburo, and can lead to topics like physiological regulation of protein metabolism and absorption, and how it may vary in elasmobranchs that exhibit different feeding strategies, thereby helping us assess different life history characteristics that contribute to elasmobranch vulnerability of overfishing.

P3.208 HARTLINE, D.K.*; LENZ, P.H.; RONCALLI, V.; Univ. of Hawaii at Manoa; *danh@pbrc.hawaii.edu*

Multiplicity of Nav1 Genes in a Crustacean Subclass, the Copepoda

Vertebrate voltage−gated sodium channels (Navs) are characterized by a multiplicity of isoforms, designated Nav1.1 through 1.9 in addition to the alternatively−spliced variants. These have been ascribed to multiple gene duplication events in the evolution of the line. In contrast, most invertebrates have only a single version of a clearly sodium−selective channel, homologous to the *Drosophila melanogaster* channel designated Dm−Nav1. A second channel, Dm−Nav2 appears to be permeable to calcium as well as sodium. However, the transcriptome of the calanoid copepod, *Calanus finmarchicus*, possesses at least three distinct channels of the Nav1 group as well as an Nav2. One *Calanus* Nav1 channel is distinctly more similar to Dm−Nav1 than the other two and includes a large number of splice variants. Analysis of the cladoceran *Daphnia pulex* genome confirms the presence of only a single Nav1 gene, suggesting that the multiplicity of Nav1 genes may have evolved in the copepod line. We mined public databases for other arthropods and invertebrates for sodium channel sequences homologous to those of the *Calanus* channels. Most crustaceans surveyed, including several copepods, possessed only sequences similar to the *Drosophila*−like Nav1 sequence. However the cyclopoid copepod *Eucyclops serrulatus* yielded a sequence homologous to a non−Dm−Nav1 isoform (Calfi−Nav1−III) but not one to Dm−Nav1.

P1.163 HARVEY, R*; BUSE, C; LOWE , J; ROSKILLY, K; HUBEL , TY; WILSON , AM; Royal Veterinary College; *rjharvey@rvc.ac.uk*

Determining speed, track and acceleration of free running animals from a low cost UAV platform

Unmanned aerial vehicles (UAVs), frequently referred to as drones have become more common and affordable and are a promising tool for providing position and speed data for free ranging wild animals. There are challenges however since the camera payload is small, the UAV does not remain in a fixed position even under autopilot control due to GPS position noise and the platform changes orientation when stabilising its position. We evaluated a modified Tarot UAV platform, a GoPro camera and Laser range finder to estimate speeds, acceleration and track of moving animals on the ground. In order to validate the accuracy of the system we determine distances between key visual marker positions on the ground using the UAV system and independently with a survey grade dual frequency GPS system. Furthermore we compared video tracked positions of a dog running in the target area wearing a high sample rate raw data GPS/IMU collar to measure the accuracy of data generated from tracking a manoeuvring target.

101.5 HATA, T*; DENNY, MW; Stanford University; *tomhata@stanford.edu*

High flows in low places: measuring sub−millimeter scale water motion in the intertidal zone

The hydrodynamic forces generated by breaking waves are one of the greatest environmental stressors experienced by organisms residing in the rocky intertidal zone of wave−swept shores. Although past studies have developed methods to measure water velocity in the field on the scale of centimeters a scale relevant to relatively large organisms such as barnacles and limpets measuring at finer scale has not been possible because the delicate laboratory instrumentation usually used for this purpose is unfit for the extreme physical conditions of the intertidal zone. Flow at sub−millimeter scales is important to characterize, however, as it affects the distribution of small benthic organisms as well as larvae and spores seeking to settle on new surfaces. We have designed a pressure block able to continuously measure flow 250 microns above the substrate. We are also able to manipulate the topography immediately surrounding the pressure block to determine the effectiveness of apparent hydrodynamic shelters (e.g., the inside of an empty barnacle test or the interstices of a mussel bed) at damping local water velocities. Data show that the flow environment across a flat plate at this height can exhibit extremely high velocities (greater than 5 m/s) with great frequency (several occurrences per minute). Local topography can reduce water velocities by up to 50%, so organisms within these hydrodynamic shelters would still be exposed to high flows. These measurements suggest that organisms of this size range can not hide from hydrodynamic forces by residing in the boundary layer.

83.4 HAVIRD, J.C.*; MITCHELL, R.T.; HENRY, R.P.; SANTOS, S.R.; Auburn Univ., MedStar Union Memorial Hospital; *jhavird@auburn.edu*

The evolution of alternative osmoregulatory responses in the Crustacea

Euryhaline crustaceans are thought to employ conserved adaptations resulting in hyper−osmoregulation in dilute waters, including a salinity−mediated increase in expression of osmoregulatory genes encoding for ion transport proteins and related enzymes in the gills. However, *Halocaridina rubra*, an atyid shrimp from the unusual anchialine ecosystem, apparently lacks this response. To further characterize osmoregulatory pathways among crustaceans, RNA−Seq of gill tissue was performed during salinity transfers for 5 additional anchialine shrimp species (Atyidae and Alpheidae). As a control, salinity−mediated RNA−Seq of both osmoregulatory and respiratory gills was performed in the blue crab, *Callinectes sapidus*, which has traditionally served crustacean osmoregulation model. While "classic" crustacean osmoregulatory genes were up−regulated as expected in *C. sapidus*, these same genes appear to be ubiquitously expressed in *H. rubra* at high levels (i.e., top 10% of expressed genes in the gill transcriptome) regardless of salinity. In contrast, *H. rubra* differentially expressed genes involved in oxygen transport, calcium binding, and mitochondrial genome maintenance during salinity transfer. This atypical pattern was not observed in the 4 other anchialine shrimp. For example, *Caridina rubella* exhibited a 13−fold increase in expression of Na^+/K^+−ATPase. This supports metabolic data indicating a trade−off for osmoregulatory function at the expense of gas exchange in the gills of *H. rubra* and implies a novel osmoregulatory strategy not shared with closely related anchialine crustaceans. Extending these studies to a wider ecological and taxonomic range of taxa will help determine if this strategy is unique among the crustaceans.

63.6 HAYFORD, H.A.*; CARRINGTON, E.; Friday Harbor Labs, Univ. of Washington; *hayford@uw.edu*

The best of both worlds: radio tracking and thermal mimics show thermoregulation in intertidal snails

Behavior can ameliorate exposure to increasing environmental temperatures, yet the capacity of an organism to thermoregulate is often overlooked when predicting the effects of climate change. Tidal cycles offer a predictable change in microclimate that intertidal animals may exploit to avoid stressful temperatures. In mesocosm studies the snail, *Nucella ostrina*, is selective in its foraging location, using both temporal and spatial variability to avoid potentially high temperatures. We hypothesized that free−range snails would select to forage on days and at times that would minimize their risk of exposure to extreme temperatures. We were interested in when during a tidal cycle snails moved into exposed high shore areas and whether these decisions shifted the distribution of temperatures the snails experienced. We used a combination of radio frequency identification (RFID) technology and thermal mimics to approximate body temperature of a mobile marine organism. We affixed passive integrated transponder (PIT) tags to snails and installed radio antenna at three discrete shore elevations in the rocky intertidal. Antennas detected the presence or absence of snails in exposed areas continuously for three months and temperatures were recorded every 15 minutes. This two−part technique is useful for animals that can't be implanted with thermal telemetry sensors. Snails chose a narrower range of temperatures than those available in the environment, disproportionately selecting intermediate temperatures and avoiding the highest environmental temperatures. This behavior may buffer warming air temperatures and should be considered in models of coastal population and community dynamics.

P1.1 HECK, MJ*; PEHLIVANOVIC, M; PURCELL, JU; HAHN, DA; HATLE, JD; Univ. of North Florida, Univ. of Florida; *jhatle@unf.edu*

Nutrient allocation and carbonyl accumulation upon dietary restriction are inconsistent with the disposable soma hypothesis

Dietary restriction extends lifespan and reduces reproduction in most animals. The disposable soma hypothesis attributes these effects to a shift in the allocation of ingested nutrients. It suggests longevity is the result of reduced investment in reproduction and increased investment to the soma, permitting an increase in cellular maintenance and in turn extending lifespan. To further investigate the role of nutrient allocation upon life−extending dietary restriction, tissue−specific allocation of ingested nitrogen was tracked in grasshoppers (*Romalea microptera*) upon a full or restricted diet. Carbonyl assays were performed in the same individuals to examine protein oxidation and tissue maintenance. To develop a labeled diet on which grasshoppers could thrive, hydroponically grown Romaine lettuce was enriched with ^{15}N. Each day, individual grasshoppers were fed appetizers' (either high ^{15}N or low ^{15}N lettuce) followed by a low ^{15}N full or restricted quantity meal'. This allowed quantification of the relative proportions of nitrogen distribution upon a normal or restricted diet (60%). There was a 50% decrease in reproductive investment upon dietary restriction. Correspondingly, while ovary sizes differed, *relative* allocation of ^{15}N to the ovary did not change. For somatic tissues (e.g., mandibular muscle, femur muscle, and hemolymph proteins), allocation was similar between restricted and full diet grasshoppers. Carbonyl assays of some somatic tissues revealed reduced protein oxidation in diet−restricted individuals. At present, the data suggests dietary restriction does not alter nutrient allocation but does reduce protein oxidation, a finding that is inconsistent with the disposable soma hypothesis.

P1.192 HEERS, A. M.*; HUTCHINSON, J. R.; American Museum of Natural History, Royal Veterinary College; *ashmheers@gmail.com*

Building a Bird: Ontogenetic and Evolutionary Construction of the Avian Body Plan

In the process of invading aerial media, birds and theropod dinosaurs have undertaken some of the most dramatic morphological and functional transformations in the history of vertebrates. Flight is the most physically demanding form of locomotion, and flight−capable adult birds possess many anatomical features that are presumably adaptations or exaptations for meeting such demands. Juvenile birds, like early winged dinosaurs, lack the hallmarks of advanced flight capacity. Instead of large wings they have small "protowings", and instead of the robust, interlocking forelimb skeleton associated with powerful and highly canalized flight strokes their limbs are more gracile and their joints less constrained. Such features are long assumed to have precluded early theropods from powered flight, yet immature birds with dinosaur−like anatomies engage their incipient wings to flap−run up slopes and even briefly fly. How is this accomplished? Using SIMM (Software for Interactive Musculoskeletal Modeling) and OpenSim, we constructed biomechanical models of a bird (*Alectoris chukar*) at different ontogenetic stages, to assess how changes in anatomy effect improvements in locomotor performance during posthatching development. Our results suggest that immature and adult birds with different skeletal morphologies can perform similar skeletal kinematics by producing and resisting different amounts of aerodynamic force during a given behavior. This type of work can help elucidate the ontogeny and evolution of avian locomotion by establishing how muscular and aerodynamic forces interface with the skeletal system to generate movement in morphing juvenile birds, and by using juveniles to inform biomechanical modeling of extinct theropods with similar anatomies.

P1.170 HEIM, SW*; AJALLOOEIAN, M; VESPIGNANI, M; ECKERT, P; IJSPEERT, A; ETH Zurich, EPF Lausanne; *heim.steve@gmail.com*

Simplifying Control through Active Tail Use

We're interested in the use of active tails for steady−state locomotion of legged systems. Building on the work of [Libby12] and [Johnson12] who thoroughly analysed active tail−use for body−pitch control during flight−phase, we focus on the stance phase through analysis of mathematical models, numerical optimisation as well as hardware testing on the cat−inspired robot Cheetah−Cub[Sproewitz13]. Starting with a SLIP−model [Blickhan89] augmented with an active flywheel, we find the main advantage of the additional control−input is in decoupling body−pitch stabilisation from the task of injecting energy into the system: all leg−actuators can thus be recruited for performing positive work on the body, while the flywheel maintains trunk stability. We hypothesise that this simplification of motor−control is also a key advantage when using a tail. However, in a more realistic model with a full tail, these control problems are coupled. We establish criteria for designing a tail that effectively decouples the two control problems and analyse their implications both analytically and through numerical optimisation. A long, light tail optimises these criteria and results from simulations and hardware tests match this prediction. We find that for small animals the main constraint is the range of displacement of the tail, similar to [Johnson12]. As we scale upwards the constraint becomes actuation power: the muscle−content of the tail necessary to keep up should scale at a power of 4/3s with body mass, which conflicts with the light−and−long design. Hence the effectiveness of a tail to decouple control becomes limited as we scale upwards. We match this with selected biological data [Alexander75] as well as abstract cases, and find that numerical optimisations generally match with the predictions.

93.2 HEINRICH, EH*; BRADLEY, TJ; University of California, Irvine; *eheinric@uci.edu*

Oxidative stress during disruption of gas exchange patterns in insects

Insects utilize an efficient gas exchange system made up of tracheal tubes which deliver oxygen directly to tissues. Since oxygen delivery bypasses the circulatory system and depends only on diffusion through air and some fluid filled tracheoles, it is possible for insects to have high tissue P_{O2} values. However, insects can maintain a low internal P_{O2} through the use of prolonged spiracle closures and micro−openings, also referred to as discontinuous gas exchange cycles. The oxidative damage hypothesis proposes that discontinuous gas exchange provides an adaptive advantage to insects by preventing excess oxidative damage during periods of low metabolic demand. We tested this hypothesis by disrupting the respiratory pattern of *Manduca sexta* pupae and *Drosophila melanogaster* adults by exposure to mild hypercapnia. Superoxide dismutase activity and oxidative damage of lipids and proteins were quantified in insects with disrupted respiratory patterns and compared to damage in insects with normal respiratory patterns. This study provides a direct tests of the oxidative damage hypothesis and may suggest a mechanism by which insects protect themselves from oxidative damage while maintaining a high metabolic scope.

P1.133.5 HELFRICH, L*; KARCHNER, S.I.; HAHN, M.E; ALURU, N; Biology Department, Woods Hole Oceanographic Institution; *naluru@whoi.edu*

Characterization of microRNAs in Atlantic killifish embryos from PCB−resistant and sensitive populations.

The Atlantic killifish (*Fundulus heteroclitus*) is an ideal model species to study physiological and toxicological adaptations to stressors. Killifish inhabiting the PCB−contaminated Superfund site in New Bedford Harbor, MA (NBH) have evolved resistance to toxicity and activation of the aryl hydrocarbon receptor (AHR) signaling pathway after exposure to PCBs and other AHR agonists. Until recently, a lack of genomic information has limited efforts to understand the molecular mechanisms underlying environmental adaptation to stressors. The advent of high throughput sequencing has facilitated an unbiased assessment of coding as well as non−coding RNAs in any species of interest. Among non−coding RNAs, microRNAs (miRNAs) are important regulators of gene expression. The objective of this study is to catalog the miRNAs in killifish and determine their expression patterns in the embryos from contaminated (NBH) and pristine (Scorton Creek, MA (SC)) sites. Embryos from NBH and SC were collected daily from 1 to 15 days post−fertilization and RNA from pooled samples from each site was sequenced using SOLiD sequencing. Analysis of the sequencing data identified 216 conserved mature miRNA sequences that are expressed during development. Using the draft killifish genome, we retrieved the miRNA precursor sequences. Based on the capacity of these putative precursor sequences to form the characteristic hairpin loop, we identified 197 conserved miRNA sequences in the genome. We also determined differentially expressed miRNAs between NBH and SC, and verified their expression using quantitative real−time PCR. (Supported in part by the WHOI Summer Student Fellow program, NIEHS grants P42ES007381 and R21ES017304, and National Science Foundation collaborative research grants DEB−1265282 and DEB−1120263.)

6.1 HELM, R/R*; DUNN, C/W; Brown University, Brown University ; *rebecca_helm@brown.edu*

Drug−Induced jellyfish formation in scyphozoa

Moon jellyfish (*Aurelia aurita*) polyps form jellyfish in response to the increase of a naturally occurring protein in polyp tissue, and in the presence of a drug with structural similarity called indomethacin. We wanted to know how widespread this drug−induced response is within the Scyphozoa, and by extension, gain insights into the evolution of strobilation induction. We tested indomethacin on eight Syphozoan species, one cubozoan and two hydrozoans. We found that indomethacin−induction of jellyfish formation is clade specific, with some species showing altered phenotypic responses not associated with jellyfish production. We also discovered that indomethacin permanently suppresses the polyp phenotype, so that animals continuously exposed to indomethacin do not regrow polyps. In one species, we tested the effects of indomethacin on planulae, and discovered indomethacin also suppresses planula metamorphosis. Together, these results suggest this drug, and possibly its naturally occurring structural counterpart, may be suppressing polyp morphology in a species−specific manner.

86.1 HENDERSON, L.J.*; HAHN, T.P.; University of California Davis; *lindsayhenderson@hotmail.com*

Male plumage coloration and the plumage coloration of his social group influences investment in song

The production of song for mate attraction can be costly. Thus, males should modulate its production according to its probable benefits. It is known that male birds increase song production based upon the proximity and reproductive competence of females. Further, males increase song production when exposed to high quality song of conspecific males. To date, the influence of other sexually−selected signals upon song production, such as plumage coloration, has not been investigated. House finches (*Carpodacus mexicanus*) are highly social and non−territorial, and females show a preference for both elaborate male song, and the intensity of red carotenoid−based plumage coloration. Therefore, it may be profitable for more colorful males to invest less in energetic song relative to less colorful birds, or vice versa. The social environment may also modify investment in song, for example less colorful males relative to their conspecifics may increase their song production to maximize their attractiveness to females. We tested these predictions with captive house finches by manipulating male plumage coloration through carotenoid supplementation during molt, so that 50% of birds had red plumage whereas the other 50% had yellow plumage. Males were then housed under 3 social environments, 1) all red, 2) all yellow or 3) a mixture of red/yellow birds. We then recorded male song after presentation of a female. To control for female attentiveness towards individual males, we also measured female behavior. Our results show that more colorful males invest more in song production regardless of their social environment. But when males are housed with more colorful conspecifics they invest more in song compared to those housed with equally un−colorful males. This study provides novel evidence that a male's feather coloration, and his social environment influences investment in song.

27.2 HENNIN, H.L.*; BERLIN, A.M.; BÊTY, J.; GILCHRIST, H.G.; FORBES, M.R.; LOVE, O.P.; University of Windsor, ON, Patuxent Wildlife Research Center, USGS, Laurel, MD, Université du Québec à Rimouski, QC, National Wildlife Research Centre, Environment Canada, Ottawa, ON, Carleton University, Ottawa, ON; *hennin@uwindsor.ca*

Physiological mechanisms mediating energetics in diving seaducks

Life history trade−offs result from individuals allocating a finite amount of resources to multiple life history stages. As such, energetic acquisition and management plays a fundamental role in regulating life history trade−offs, which can be measured through physiological traits. Baseline levels of glucocorticoids mediate energetics in vertebrate species, have been shown to influence foraging behaviour, and have been linked to fat deposition. Although there is a link between variation in baseline corticosterone (CORT; the primary avian glucocorticoid), foraging and fat stores, these links have not been tested experimentally. Working with a captive colony of white−winged scoters (*Melanitta fusca*) we aim to understand the mechanistic role that CORT plays in mediating body mass gain by manipulating CORT levels within a baseline range. We tested this by treating individuals in a repeated measures design with three different 21−day release pellets in a randomized order including: 1) control (15 mg placebo), 2) low dose of CORT (15 mg CORT pellet) and 3) moderate dose of CORT (35 mg CORT pellet). We tracked the release of the pellets by sampling for baseline plasma CORT once every 3 days, examined HPA axis feedback via ACTH injections and took the body mass of each individual across each of the three trials. Individuals with experimentally elevated CORT had higher body mass (and hence fat deposition rates) compared to control individuals within a wintering life history stage. These results provide insight into how glucocorticoids influence the ability of individuals to acquire fat stores, which will have downstream consequences for life history trade−offs.

P1.99 HENNIN, H.L.*; LEGAGNEUX, P.; BÊTY, J.; WILLIAMS, T.D.; GILCHRIST, H.G.; BAKER, T.M.; LOVE, O.P.; University of Windsor, ON, Université du Québec à Rimouski, QC, Simon Fraser University, Burnaby, BC, Environment Canada, Ottawa, ON; *hennin@uwindsor.ca*

Preparatory energetic management in a pre−breeding seaduck

Effective acquisition and management of energetics prior to reproduction should strongly influence reproductive decisions (timing of breeding and reproductive investment). However, because capturing individuals prior to investment is difficult, and because capture often leads to the abandonment of reproduction, we know little about the mechanisms mediating these life−history decisions. We examine physiological parameters predicted to influence energetic management by sampling individuals of a free−living colony of Arctic−nesting common eiders (*Somateria molissima*) up to three weeks prior to reproduction. We focused on baseline plasma corticosterone (CORT), very−low density lipoprotein (VLDL) and vitellogenin (VTG) for their respective roles in driving daily and annual energetic balance, rate of condition gain (fattening) and follicular investment. We found that baseline CORT increased significantly from arrival to the initiation of reproductive investment (period of rapid follicular growth − RFG), indicating that CORT may stimulate foraging behaviour to facilitate both lipid deposition to females and follicles. Supporting this, we found that plasma VLDL increased throughout the pre−breeding period, peaking as predicted during RFG. Female eiders exhibited unprecedentedly high levels of plasma VTG before their theoretical RFG period, a potential strategy for pre−emptively depositing available protein stores into follicles while females are simultaneously fattening. This study provides some of the first data available examining the temporal dynamics and interaction of the energetic mechanisms driving variation in reproductive decisions and success in diving seaducks.

P1.88 HENRY, E*; BUTLER, M; Univ. of Hawaii at Manoa; *erh@hawaii.edu*

Important Resources of an Endangered Hawaiian Damselfly

The blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) is a native Hawaiian damselfly that is endemic to upland streams on the island of Oahu. It is part of an ecologically diverse adaptive radiation that is spectacular in body color and ecological variation. Although a robust phylogeny has been done on this genus, very little is known about the natural history and behavior of any *Megalagrion* species. Recently, *M. n. nigrolineatum* has been added onto the Federal Endangered Species list based on concerns over habitat loss and invasive predators, this is based on limited data. In this study, *M. n. nigrolineatum* was observed in the field to describe its daily and seasonal activity patterns and to gain a deeper understanding of their behaviors, microhabitat selection, and habitat use. The seasonal differences in behavior that were observed include: higher abundance, more tandem pairs, and less male−male interactions in the spring than in the fall. Daily fluctuations in damselfly abundance and perch selection remained constant regardless of the season. *M. n. nigrolineatum* were significantly more likely to be facing away from the stream and would select perches that were in the shade as opposed to areas in the sun. However, males were more likely to defend territories in the sun. Knowledge about their activity patterns are important for future ecological studies and conservation efforts, and the differences in behavior found in *M. n. nigrolineatum* leads one to wonder what other unique behavioral attributes can be found among this extremely ecologically diverse genus.

3.3 HENSCHEN, A. E.*; WHITTINGHAM, L. A. ; DUNN, P. O.; Univ. of Wisconsin, Milwaukee; *hensche9@uwm.edu*

Oxidative stress, immune response and male ornaments in the common yellowthroat

Females are thought to choose mates based on the size or color of male ornaments because they are indicators of male quality. By choosing more ornamented males, females could potentially gain heritable benefits for their offspring, such as superior genes for parasite resistance. These genes might not only reduce the risk of infection, but also the oxidative damage caused during prolonged immune responses. In our study we tested the hypothesis that ornaments are honest indicators of the ability of males to manage oxidative stress. In our study population of common yellowthroats (*Geothlypis trichas*), females prefer to mate with males with larger black facial masks, and mask size is positively correlated with antibody production (IgG) and variation at the major histocompatibility complex (MHC). We induced an immune response in males with an injection of a bacterial membrane component and measured harmful pro−oxidants and protective antioxidants before and 24 hours after injection. Although immune response did not increase oxidative stress (change in oxidative stress was the same between treated and untreated individuals), males with larger masks experienced a larger decrease in glutathione, an important intracellular antioxidant, and a larger increase in reactive oxygen metabolites, an early marker of oxidative damage. Change in total antioxidant capacity (TAC) in the plasma was not related to mask size or treatment group. It is possible that exposure to a stressful environment, such as 24 hours in captivity, may have caused the change in oxidative stress in males with larger masks. In the future, we will investigate ornament size and additional indicators of stress.

96.3 HENSLEY, N.M.*; LEUNG, N.; TORRES, E.; OAKLEY, T.H.; Univ. of California, Santa Barbara, Cal. State Univ., Los Angeles; *hensley@lifesci.ucsb.edu*

Evolution of bioluminescent mating signals in cypridinid ostracods (Crustacea)

How new traits originate is a central question in evolutionary biology, but the molecular changes that lead to evolutionary novelty are often difficult to determine. Bioluminescence is a novel trait with a clear genetic basis, and within ostracods, is used for anti−predator displays and complex mating signals. We aim to identify the molecular changes that gave rise to bioluminescence in cypridinid ostracods. To address the origin of molecular function in bioluminescence, we first obtained sequences similar to known luciferases from Illumina transcriptomes of multiple luminescent and non−luminescent species. We characterized luciferase function from different species by expressing the proteins in cell culture and performing light reaction assays. To investigate the molecular origins of luciferase, we used hidden Markov models of the von Willebrand factor type D (VWD) protein domain to find luciferase−like genes and assembled gene trees. From these, we chose two other candidates, named soroluciferase(sluc) and dual−VWD−± (2VWD−±), to test for catalytic ability. Assay results indicate differences in enzyme activity between luciferases of different species, and between sluc and 2VWD−±. We hypothesize that the differential activity between luciferases is correlated with the species' differences in bioluminescent mating signals due to differences in enzyme kinetics. Together, these analyses support the origin of luciferase via VWD domain fusion and duplication.

S11.7 HENZE, M.J.; Lund University, Sweden; *miriam.henze@biol.lu.se*

The evolutionary history of pancrustacean eyes

Pancrustacea offer great opportunities to investigate the evolutionary history of vision because of a diversity of eye designs and life styles. Their most prominent photosensitive organs, two compound eyes, consist of individual photoreception units called ommatidia. Compound eyes can be split in dorsal and ventral halves, be disintegrated to few, loosely assembled ommatidia, transformed into camera−type eyes (lateral ocelli) or absent. The other main photosensitive organs of pancrustaceans are median eyes, named naupliar eyes in crustaceans and dorsal ocelli in insects. These three camera−type eyes are positioned dorso−frontally on the head and are sometimes joined together, partly reduced or absent. Homologies of pancrustacean eyes and photoreceptors have been inferred from morphological and developmental comparisons. On a finer time−scale, relationships can be resolved using opsin−based photopigments, the first components of the visual transduction cascade. Data on opsin phylogeny and expression pattern have accumulated in recent years, but there is a strong bias for the compound eyes of a few, derived taxa. In an attempt to draw general conclusions, I interpret results on both eye types in Orthoptera, a comparatively early branching insect lineage, in the context of data on other insect orders and crustaceans. The opsin phylogeny suggests that gene duplications, permitting differential opsin expression in insect ocelli and compound eyes, occurred independently more than once and recently compared to the origin of the eyes. While expression patterns in the compound eyes of two cricket species are strikingly similar, they differ from those in a locust and other insects. This illustrates that a connection between specific photoreceptors and opsin families in pancrustaceans exists, but switches allowing for functional adaptations can be observed regularly.

P3.70 HEPPARD, J.M.*; MURPHY, T.G.; Trinity University; *jheppard@trinity.edu*

Female Betta fish modulate their investment in aggression depending on resource value

Investment into aggressive behavior may depend on motivation to fight, and motivation can be highly influenced by the value an individual places on a contested resource. Female *Betta splendens* (hereafter bettas) are known to be aggressive towards other females, particularly when first establishing a hierarchy that allows predictable access to resources. We tested whether variation in resource value affects the level of aggression between female bettas. A dyad of female bettas were sequentially presented with low and high value resources of two types: either non mate−based resources (small food stimulus, large food stimulus), or mate−based resources (small male stimulus, large male stimulus). We monitored aggressive interactions between the dyad of females as they competed for access to these resources and compared aggressive behavior when faced with either a high−value or low−value resource. We found that aggressive behavior, particularly aggressive signaling interactions, were higher among females when competing for more food compared to less food. There was no significant difference in aggression when we varied male size. These results suggest that females modulate their investment in aggression based on a perceived quantity of food−resources weighed against potential negative costs of a fight. There was no detectable difference in female aggression based on stimulus male body size, indicating that females may not use male body size as an indication of resource value. While male aggression and dominance are well studied, we recommend that females should also be the subject of study, especially because females' aggressive phenotypes are likely to better reflect the effects of social selection for access to non−mate based resources.

95.5 HERDINA, AN*; PLENK JR., H; BENDA, PP; LINA, PHC; HERZIG−STRASCHIL, B; HILGERS, H; METSCHER, BD; University of Vienna, Austria, Medical University of Vienna, Austria, Charles University and National Museum, Prague, Czech Republic, Naturalis Biodiversity Center, Leiden, the Netherlands, Natural History Museum Vienna, Austria; *annanele.herdina@univie.ac.at*

Correlative 3D imaging of bat penis histomorphology for functional and developmental studies

Shape and size of the bat baculum (os penis) are established taxonomic characters, but micromorphology of baculum and penis have seldom been studied in bats. This study provides a foundation for further functional research by generating new data on 2D and 3D micromorphology of the *Pipistrellus pipistrellus* penis. Correlating 3D x−ray microtomography (microCT) imaging with serial, surface stained, undecalcified ground sections enables us to get a precise histomorphological evaluation of a larger number of samples and of other species. Ground sections of the penes of 4 bats (2 subadult) were compared with microCT images of the bacula and some iodine−stained penes of *P. pipistrellus* (adult n=30, subadult n=22), *P. pygmaeus* (n=24), *P. hanaki* (n=9), and *P. nathusii* (n=11). The baculum in the studied species consists of a proximal bifurcated base, a long, slender shaft, and a small, forked distal tip. The base consists of woven bone and contains a medullary cavity with fatty marrow. The shaft of the baculum consists of lamellar bone around a central vascular canal, surrounded by woven bone in a part of the shaft. Distally the shaft consists of woven bone. The urethra and corpus spongiosum lie ventral of the corpora cavernosa and the baculum. In the subadult bats, the baculum consisted of woven bone completely and its base was not fully developed. The combination with histomorphological techniques enabled a more precise interpretation of the histological structures shown in microCT images from all four *Pipistrellus* species.

P1.189 HERMANSON, J.C.*; WIEDENHOEFT, A.C.; USFS Forest Products Laboratory; *jhermans@wisc.edu*

Data−driven wood anatomy: Using machine vision for wood identification (and beyond)

Rapid, accurate, and inexpensive wood identification is an important factor in keeping illegal wood and wood products out of the supply chain, and thus combating illegal logging. U.S. enforcement of the Lacey Act and CITES treaty obligations have greatly increased the demand for wood identification expertise. Traditional human−mediated wood identifications, based upon pattern recognition of anatomical features, have proven too slow and too costly to meet the demands of law enforcement. To meet this demand, we have developed a portable machine vision system that can identify wood based upon an image of the transverse surface of an unknown specimen. Currently, the reference database includes 8000+ machine vision images of 160 species in 55 genera, a full order of magnitude greater taxonomic variation than any prior work. We capture a 2048− by 2048−pixel image of a 6.8− by 6.8−mm area of a transverse section of wood. Using this image, we compute discrete wavelet transform "energies" at 11 ($\log_2[2048]$) spatial scales within the image. Partial least squares discriminant analysis on these energies creates a classification system. The current system has a 60% success rate in identifying an unknown specimen, which is equal to or better than the average law enforcement officer with a week of training. Beyond wood identification, the plethora of images can be analyzed to explore anatomical characters at levels of quantitative detail hitherto not practical by traditional wood anatomy.

S12.10 HERNANDEZ, LP*; STAAB, KL; George Washington University, McDaniel College; *phernand@gwu.edu*

Cypriniform suction feeding: Evolving in and out of the ooze

While much of the functional work on suction feeding has involved members of Acanthopterygii, a much older cypriniform radiation led to almost 4000 species filling nearly every freshwater trophic niche. Within the great majority of acanthomorph clades that have been investigated suction feeding and the underlying morphology responsible for the generation of rapid suction have been largely conserved. This conserved feeding apparatus is primarily aimed at increasing the force experienced by the prey item thus making a strike more effective. Cypriniform feeding anatomy is comprised of a number of novelties used for benthic feeding, which characterized early members of this clade. The modified cypriniform structure of the oral jaws represents a case where a particular type of suction feeding allowed for probing the benthos with a more functionally maneuverable feeding anatomy. Requisite modifications included origin and elongation of a median kinethmoid, duplications of certain divisions of the adductor mandibulae muscles, and a dorsal muscular palatal organ. The elongated kinethmoid (coupled with modified adductor muscles) allowed for a type of premaxillary protrusion that decouples the upper and lower jaws, enables premaxillary protrusions with a closed mouth, and facilitates benthic sorting. This greatly modified benthic feeding morphology allowed for a degree of maneuverability and variation in kinematics not seen within most acanthomorphs. Later cypriniform radiations into piscivorous or planktivorous feeding guilds were associated with shortening of the kinethmoid and simplified adductor morphology. Although this suite of morphological novelties seemingly evolved for benthic feeding, with minimal modifications these anatomical features were later coopted during radiations into different functional niches.

72.3 HERREL, A*; VILLAROEL, B; CORNETTE, R; DECAMPS, T; DEBAT, V; CNRS/MNHN; *anthony.herrel@mnhn.fr*

Phenotypic plastiity and flight performance in relation to developmental temperature in the invasive species Drosophila suzukii.

Developmental temperature is known to influence the adult phenotype in many ectothermic organisms. Invasive species entering new climate zones are often faced with changes in temperature which may affect their adult phenotype and performance. Here we explore whether variation in developmental temperature affects wing shape and flight performance in the invasive *D. suzukii*currently moving towards the North of Europe. Our preliminary results show that developmental temperature has a strong effect on wing shape with animals raised at cooler temperatures having larger amd more elongate wings. Moreover, our results show that wing shape is significantly correlated to flight perforamnnce traits with animals with more elongate wings showing more direct flight paths. Although no direct effects of developmental temperature on flight performance at a standard temperature could be demonstrated ($p = 0.057$), our data suggest that the shapes induced by development at low temperature are similar to those of animals showing straighter flight trajectories. Thus, developmental plasticity appears intimately linked to flight performance in *D. suzukii* which may explain its evolutionary success in invading cold climate zones.

P1.182 HESSEL, AL*; TAHIR, U; PETAK, JL; LEMOYNE, RC; TESTER, J; NISHIKAWA, KC; Northern Arizona University; *alh385@nau.edu*

A Powered Ankle−Foot Prosthesis with a Neuromuscular Based Control Algorithm can Successfully Mimic Human Walking.

For a person with a trans−tibial amputation (PTTA), the iWalk BiOM is a commercially available powered ankle−foot prosthesis. The stock BiOM control algorithms use equations, not based upon muscle theory, to control the ankle torque output. In our research, we have developed a muscle model based on the winding filament hypothesis (WFH), which adds to the cross bridge theory and can explain the phenomena of force enhancement, force depression, and eccentric negative work. We developed a neuromuscular model control algorithm based on the WFH and incorporated it into the BiOM operating system to test whether human−style walking is attainable within a muscle−based control algorithm. We measured the metabolic cost of transport and walking gait characteristics of PTTA wearing a passive prosthesis, the BiOM with the original stock controller, and the BiOM with our WFH based controller. Our preliminary data indicate that the WFH−based BiOM is capable of producing a human−like ankle torque profile during walking that is lost in PTTA with a passive prosthesis, similar to the capability of the commercial BiOM. Further, while metabolic rates significantly decreased with the commercial BiOM, results were variable with the WFH BiOM, which we believe can be remedied with the next evolution of the WFH controller. Our future work will include testing on uneven terrain, ramps and stairs. We hope that this work will inspire bioengineers to create next−generation powered prostheses using control algorithms inspired by an understanding of muscle biology.

96.1 HEWS, DK*; PRUETT, JA; CAMPOS, SM; ZÚÑIGA−VEGA, JJ; VITAL, C; MARTINS, EP; Indiana State Univ., Indiana Univ., Univ. Autonoma de Ciudad Juarez, Mexico, Univ. Nacional Autónoma de México, Indiana Univ.; *diana.hews@indstate.edu*

Throat color morphs in male Sceloporus parvus lizards: morphology, mite loads and behavior

Researchers have documented within−population color morphs and found such color variation is associated with behavioral differences for a growing number of vertebrate species. Few throat morphs have been described for *Sceloporus* lizards, a genus for which we have a rich body of ecological and evolutionary research. Here we describe throat color variation in male *S. parvus* from Queretaro in central Mexico in late May and early June, and we assess whether other phenotypic traits covary with throat color. Males from two sites less than 5 km distant and 500 m different in elevation differed in morphology, including SVL−mass relationships, throat morph frequency, tail breakage status and mite abundance, and some traits differed between morphs. Overall SVL for the adult males we sampled ranged between 45 to 53 for each morph, suggesting throat colors were not due to simple ontogenetic variation. Focal male behavior in staged territorial intrusions at one site did not differ by morph, including broadcast displays (headbobs), aggressive display (headbob with dorsolateral flattening and static dorsolateral flattened postures) and chemosensory behaviors, although the Yellow−Blue throat morph (n=9 trials) tended to display more headbobs than the Blue−White throat morph (n= 5 trials). The higher elevation site had more human−associated disturbance in addition to different habitat structure and both differences could contribute to site−specific differences in the frequencies of the color morphs we captured.

99.3 HIERONYMUS, TL; Northeast Ohio Medical University; *thieronymus@neomed.edu*

Skeletal correlates of wingtip shape in land bird (rollers, woodpeckers, and allies)

Wingtip shape has several functional consequences in avian flapping flight, both in aerodynamic effects and in inertial costs. Although the shape and kinematics of the distal wing exert a strong influence on function, variability in the ligaments and skeleton that support the primary flight feathers of the distal wing segment is largely unexplored. This is especially true for the land birds' historically grouped as Coraciiformes and Piciformes (rollers, woodpeckers, and allies). Many of these taxa display odd bony features in the hand that have taxonomic utility, but only limited functional and anatomical context. This study addresses the question of whether variation in the hand skeleton is consistently associated with variation in wingtip shape, feeding ecology, or migration pattern. Skeletal morphology was summarized by 3D geometric morphometrics from microCT scans of alcoholic and skeletal specimens. Primary feather length measurements were taken from alcoholic and spread wing preparations to assess wingtip shape. Feeding and migration behaviors were scored as a series of binary variables from published accounts, then submitted to principal coordinate ordination to assess behavioral variability. The current sample includes n = 24 taxa, evenly distributed within the crown clade, with additional data collection to extend to ~10% of the 675 crown taxa. Preliminary comparisons suggest that interactions between migratory behavior, feeding ecology, and body size are associated with distinct wingtip shapes. While there are clade−specific skeletal morphologies associated with elongate middle primary feathers (VI−VIII), skeletal attachments of the distalmost primary feathers (IX−X) show consistent features associated with feather length across clades. The patterns seen within rollers, woodpeckers, and related taxa point to more general anatomical constraints on wing shape evolution within birds.

44.7 HIGHAM, T.E.*; BIRN−JEFFERY, A.; Univ. of California, Riverside; *thigham@ucr.edu*

Constraints and innovations in terrestrial locomotion: how geckos modulate adhesion and limb kinematics with changes in incline

Geckos, like other vertebrates, must move up and down inclines in their natural habitat. They often utilize an adhesive system to enhance traction, and this innovation allows them to occupy habitats that are inaccessible to many other animals. However, the employment of this directional adhesive system, which involves digital hyperextension to disengage the toes, likely constrains other limb movements. We used a generalist pad−bearing gecko (*Chondrodactylus bibronii*) to determine how geckos modulate forelimb and hind limb function in response to inclines, and whether geckos can take advantage of their directional adhesive system on downhill slopes . We quantified 3D limb kinematics of geckos moving up and down a variety of inclines (level, +/−10 and +/−45 degrees). The −45 degree treatment induced the greatest change in limb kinematics. For example, hind limb joint excursions (knee, ankle, and MTP) were significantly lower on this condition compared to all other conditions. In addition, the hind limbs were rotated posteriorly on declines, resulting in digit III of the pes facing a more posterior direction (opposite to the direction of travel). No other condition induced such significant changes in limb orientation. This pes rotation leads to a dramatic shift in foot function that facilitates the use of the adhesive system as a brake/stabiliser during downhill locomotion and, although this rotation is not unique to geckos, it is significant for the deployment of adhesion. Adhesion is not just advantageous for uphill locomotion but can help work against the impacts of gravity during downhill locomotion, highlighting the incredible multi−functionality of this key innovation. Supported by NSF IOS−1147043.

P3.158 HILL, JJ*; DONOGHUE, PCJ; RAYFIELD, EJ; University of Bristol, Bristol UK; *jh12519@bristol.ac.uk*

Evolution of the Lower Jaw of Gnathostomes

The origin of the lower jaw is a key innovation that underpins the adaptive radiation of vertebrates. The jaw has undergone fundamental changes to its composition and has endured major ecological changes including the transitions from water to land, from land to the air, and from land back to water. A shift in lower jaw anatomy or rather a transformation in lower jaw shape may have facilitated the emergence of different feeding behaviors. Here we present an analysis to deduce the timing and tempo of lower jaw shape change through gnathostome evolutionary history. We achieve this via an exploration of lower jaw morphospace and an evaluation of the functional and ecological consequences of lower jaw shape variation. Three hundred lower jaw specimens were examined; a combination of outline and extended eigenshape analysis were used to quantify variation in lower jaw morphology. Fast Fourier transformation (FFT) and principal component analysis (PCA) were performed on the dataset using the Hangle−2D outline and H−match programs in PAST. Results indicate that principal component (PC) 1 accounts for 73% of lower jaw shape variation. PC1 shape variation describes changes to the relative length of the dentary bone and robustness in the posterior lower jaw. PC2 accounts for 14.4% of lower jaw shape variation and describes differences in jaw depth and slenderness of the dentary bone (i.e. changes to the vertical height of the mandible). Acanthodians and amphibians make relatively minor contributions to overall disparity; acanthodians cluster along the PC1 axis, where the dentary bone is elongated and the back of the jaw is short and amphibians cluster where the back of the jaw is bulky. Archosaurs are distributed mainly along the PC1 axis, but also share a region of morphospace with both stem amniotes and chondrichthyans. From these results, it seems most likely that both ecological and functional consequences affect lower jaw shape variation.

3.7 HILL, G/E; Auburn Univ.; *ghill@auburn.edu*

Mitochondrial function, innate immunity, and ornament production

The immunocompetence handicap hypothesis posits that ornamental traits are honest signals of parasite resistance because ornament production is dependent on high levels of steroid hormones that depress immune responsiveness. This hypothesis was proposed with little understanding of hormonal regulation of the immune system or of the mechanisms that could connect ornamentation to immunocompetence. I review a growing biomedical literature that identifies the mitochondrion as the primary site of action for steroid and thyroid hormones and that ties mitochondrial bioenergetics to innate immunity and to the overall immune response. Mitochondria are the source for both ATP and free radical production, and they also serve as core mediators of innate immunity. Thus, under the influence of hormones, mitochondria coordinate tight functional integration of host defense and metabolic processes. Dysfunction of cellular respiration leads to reduced production of ATP and increased oxidative stress via the release of free radicals. Oxidative stress and reduced energy production, in turn, negatively affect ornament production while inhibiting innate immune responsiveness. A fundamental link between cellular respiration and both ornamentation and innate immunity explains the commonly observed associations between ornamentation, oxidative state, and disease and reveals the true information content of ornaments.

S11.8 HILLYER, J.F.; Vanderbilt University, Nashville, TN; *julian.hillyer@vanderbilt.edu*

Integrated immune and cardiovascular function in insects

Insects acquire pathogens via ingestion and through breaches in the cuticle. Upon entry into the hemocoel, pathogens are circulated throughout the body by the insect open circulatory system. Anatomically, this circulatory system consists of a hemocoel, a series of muscular pumps, and a fluid medium called the hemolymph. The primary circulatory organ is the dorsal vessel, which is a muscular tube−like structure that extends along the dorsal midline of the insect and is divided into a thoracic aorta and an abdominal heart. Hemolymph enters the dorsal vessel through ostia that are located at the thoraco−abdominal junction and in each abdominal segment. Once inside the dorsal vessel, hemolymph is propelled across the body and is sequentially released back into the hemocoel at the terminal ends of the insect. Hemolymph then flows back toward the heart and reenters the vessel through the ostia. During an infection, pathogens are swept throughout the body by the swift flow of hemolymph. As they do so, they encounter insect immune factors that range from soluble cytotoxic peptides to immune cells called hemocytes. Recent work has uncovered that the insect circulatory and immune systems have co−adapted to fight infection. This presentation will summarize the structural mechanics of hemolymph circulation in insects (with a special emphasis on mosquitoes), and will detail how infection induces the aggregation of hemocytes on the surface of the insect heart, where they phagocytose and kill pathogens in areas of high hemolymph flow.

83.5 HIMES, A*; BALSCHI, SW; FREDERICH, M; Univ. of New England, Biddeford; *mfrederich@une.edu*

Color morph−specific ion regulation in the European green crab, Carcinus maenas, during oscillating salinity stress

Carcinus maenas occurs in two color morphs: green after molting and red after prolonged intermolt. Ion regulation is well documented in green morphs at constantly low salinity, but few studies have focused on fluctuating salinity levels like that of a natural tidal environment. We investigated how the ability to ion regulate differs between the two morphs, how oscillating salinity affects both morphs, and whether these changes vary with sex. Red and green morphs were exposed to constantly low salinity (12 psu) for 72 h or to oscillating salinity ranging from 12 to 32 psu every 6 h. Whole animal performance was measured by reaction time, treadmill running endurance, and hemolymph osmolarity. Expression of key ion regulators was measured by western blots and qPCR. Our results reveal green morphs as better ion regulators accomplished not by changing the ion transporters, but by enhancing the driving force for the transporters through increased mRNA expression of cytosolic and membrane bound carbonic anhydrase along with Na^+K^+ ATPase. Exposure to constantly low salinity results in greater mRNA expression of these ion regulators demonstrating that constantly low salinity is more stressful than oscillating salinity. Little difference was noted between sexes. An analysis of the full transcriptome by Roche 454 RNA sequencing is currently ongoing. Our data show that the well−documented ion regulatory capabilities of *C. maenas* need to be viewed in a color morph specific context. Oscillating salinity being less strenuous than constantly low salinity is in agreement with the conditions in the crabs' natural habitat as they are rarely exposed to constantly low salinity.

7.5 HLUSKO, LJ*; MAHANEY, MC; Univ. of California, Berkeley, Texas Biomedical Research Institute; *hlusko@berkeley.edu*

Genetic modularity in and evolution of the primate dentition

While evolutionary biologists have long appreciated that selection acts only on variation that is heritable, only recently have we had the tools to assess how genetic effects structure morphological variation. Quantitative genetic analyses provide a useful tool for elucidating how genetic effects influence dental variation, yielding testable hypotheses about the genetic modularity and evolutionary history of the dentition. We used a maximum likelihood−based variance decomposition approach implemented in the computer package SOLAR to estimate the heritability of ~70 linear measurements of tooth size for 632 baboons (*Papio hamadryas*) that are part of a large pedigreed breeding colony housed at the Southwest National Primate Research Center. Because phenotypic correlations can be decomposed into genetic and non−genetic components, as is phenotypic variance for the purposes of heritability estimation, we were able to also estimate genetic correlations between these phenotypes. Our results show that variation in size of the incisors is genetically independent of size variation in the postcanine dentition, and that there is incomplete pleiotropy between premolars and molars. We compared this genetic correlation matrix to phenotypic correlation matrices of dental measurements from other species (*Cercopithecus mitis*, n=95; *Macaca fascicularis*, n=98; *Papio hamadryas*, n=127; *Colobus guereza*, n=125; *Presbytis melalophos*, n=83; *P. rubicunda*, n=80) to test the hypothesis that the genetic modularity estimated for the captive *Papio hamadryas* population characterizes the dental variation represented by the Cercopithecidae more generally. Implications for the evolution of the Hominidae will be discussed. Supported by NSF grants BCS 0616308, 0500179, 0130277, and NIH P51 OD011133 which supports the SNPRC.

49.5 HO, ALFC*; LIN, J; Florida Institute of Technology; *ho.alfc@gmail.com*

Comparative reproductive biology in contrasting wet and dry environments in a group of Neotropical livebearers (Cyprinodontiformes: Poeciliidae), with links to trophic ecology and ecomorphology

The predicted drastic changes in global precipitation levels and distribution will lead to drought like conditions in previously abundantly wet areas. *Poecilia* spp. are livebearers and are ubiquitously distributed across the Americas. In this study we employ them as a model to elucidate which traits are evident in the dry populations, in an attempt to understand the processes governing adaptations in shifts from wet to dry environments. A hierarchical sampling scheme was employed where eight species of *Poecilia* were collected across wet Central and dry northern South America. Specimens were analyzed for various reproductive parameters, muscle tissue analyzed for carbon and nitrogen stable isotopes, and geometric morphometrics performed. A significant effect of precipitation regime was observed between environments (*perMANCOVA*: *Pseudo−F* = 30.08, *d.f.* = 1, 729, $P < 0.001$). *PerANCOVAs* (mean ± SE) showed that *Poecilia* in the wet environment were more massive (0.56±0.36 vs. 0.29±0.01 g dry mass), produced significantly more massive eggs (2.8±0.58 vs. 2.1±0.25 mg dry mass), and neonates (2.1±0.48 vs. 1.6±0.051 mg dry mass). However, fewer eggs (22±1.0 vs. 28±1.4 eggs) and lower reproductive allotment (12±4.0% vs. 17±8.3%) were observed in the wet environment. Species in the dry environment invested less heavily in reproduction, but produced disproportionately fewer but larger neonates, suggesting that a greater abundance of offspring (albeit smaller) are required to persist in drier environments. Additionally, reproductive biology will be discussed in light of trophic ecology (Carbon and Nitrogen stable isotopes) and ecomorphology (linking trophic ecology with geometric morphometrics).

110.5 HOBBS, EC*; MACDOUGALL−SHACKLETON, SA; CLINCHY, M; ZANETTE, L; The University of Western Ontario; *ehobbs3@uwo.ca*

Quantifying the Effects of Perceived Predation Risk on the Avian Brain

Predators are traditionally thought to affect prey solely through direct killing, with the consequences of an attack dissipating shortly after a predator encounter. It is becoming clear that the fear' (the prospect of imminent, violent death i.e. perceived predation risk) of predators shapes prey ecology, in that the mere presence of a predator leaves lasting effects on physiology and reproduction. It is unknown whether or how predation risk alters avian neurobiology and whether there is a fear network' in the brain that processes predator cues. To investigate these changes, black−capped chickadees (*Poecile atricapillus*) were exposed to short−term auditory cues simulating levels of predation risk. We found that the expression of the immediate−early gene (IEG) ZENK was significantly greater in the nucleus taeniae of the amygdala (TnA), a brain region thought to be homologous to the mammalian medial amygdala, in response to playbacks simulating high predation risk (owl calls and chickadee high zee calls) compared to calls representing moderate risk (chickadee mobbing calls) and non−threatening controls (nuthatch calls) In the hippocampus (Hp), on the other hand, expression of ZENK was significantly greater for both conspecific alarm calls. This suggests that cues of predation risk may be processed in both of these areas, but that the TnA is more sensitive to level of risk, while the Hp is sensitive to social cues of threat. The expression of the short−term IEG c−*fos* will be investigated in the same brain regions in order to examine any differences in the expression of these two IEGs. On−going experiments are examining lasting changes in brain activation due to chronic predator stimuli using FosB, an IEG commonly used in small lab mammals, but never before used in birds.

S4.1 HOCHBERG, R.*; WALSH, E.; WALLACE, R.; Univ. Massachusetts, Lowell, Univ. Texas, El Paso, Ripon College, WI; *rick_hochberg@uml.edu*

Soft bodies, hard jaws: structure, function and diversity as exemplified by the rotifers

Jaws have evolved numerous times in the animal kingdom and display a wide variety of structural, compositional, and functional differences that reflect their polyphyletic origins. Among soft−bodied invertebrates, aka worms, jaws are known from annelids, chaetognaths, flatworms, gnathostomulids, micrognathozoans, mollusks, rotifers and several ecdysozoans. Some animals use their jaws only to capture prey (e.g., chaetognaths, flatworms), while others have jaws that function only in prey processing (e.g., gnathostomulids, onychophorans), and yet some animals can both capture and masticate prey using their jaws (e.g., rotifers). Though structural diversity among invertebrate jaws is becoming better characterized with the use of high−resolution light and electron microscopy, many details still remain poorly described such as elemental composition and neuromuscular control, and this absence of data has impeded a greater understanding of their functional diversity and evolutionary origins. With this symposium, we aim to bring together researchers of disparate jawed taxa to draw structural and mechanistic comparisons among species to determine commonalities in invertebrate jaws. Additionally, we show that rotifer jaws, which are perhaps the best−characterized jaws among invertebrates, are still a mystery with regards to their origins and mechanics. Nevertheless, novel technologies such as energy dispersive x−ray spectroscopy (EDS) and 3D CAD software and printing are being used to characterize the inorganic matrices of rotifer jaws and develop physical models of their mechanical properties, respectively. We predict that these methods can also be used to develop biomimetic and bioinspired constructs based on the full range of jaw complexity (structural and compositional), and that such constructs can also be developed from other invertebrate taxa.

P2.162 HOCHBERG, R*; HOCHBERG, A; WALLACE, R; WALSH, E; Univ. of Massachusetts, Lowell, Ripon College, WI, Univ. of Texas, El Paso; *rick_hochberg@uml.edu*
On the ultrastructure of soft and hard protective tubes of sessile rotifers (Rotifera)
Sessile rotifers of the clade Gnesiotrocha secrete a wide variety of gelatinous tubes around their bodies that function as refugia from predators. Based on previous results using energy dispersive x−ray spectroscopy (EDS), we found that these secretions consist mostly C and O, with smaller proportions of other elements such as N, Si, Na and Mg, among others. Here we examine the ultrastructure of the tubes from three species (*Floscularia conifera*, *Limnias* sp., and *Stephanoceros millsii*) to characterize their composition and determine whether they possess features that provide insights into their physical appearance. Results for *F. conifera* confirm earlier observations that the tubes consist of an inner lining of "mucus" and outer construction of pellets. The "mucus" lining is electron dense and up to 0.5 ¼m thick. The pellets are lined by a thin membrane and are heterogeneous in content. By contrast, the hardened tube of *Limnias* is somewhat fibrous and of homogeneous construction, with a smooth inner surface and an outer surface of ridges. The soft gelatinous tube of *S. millsii* differs from the others in that it is mostly electron lucent and with a layered construction − the outermost layer is slightly more electron dense than the underlying layers − all of which contain fibers that loosely interconnect and may provide structure to the gelatinous mass. These tube characteristics are being used as part of a larger ongoing study of the evolution of the sessile lifestyle in gnesiotrochans.

6.3 HOCHBERG, A; Univ. of Massachusetts Lowell; *Adele_Hochberg@student.uml.edu*
Those precocious larvae: Morphology, metamorphosis, and the development of the adult head in larvae of sessile species of Stephanoceros (Rotifera)
The sessile lifestyle is a derived condition within Rotifera. This rare lifestyle is found in approximately 100 species within the Superorder Gnesiotrocha. Sessile rotifers tend to be larviparous, possessing short−term free−swimming larvae that are morphologically and ecologically distinct from the sessile adult. To date, there is limited information about gnesiotrochan larvae or the process of metamorphosis that gives rise to the adult body plan. Here, I use a combination of light microscopy, f−actin staining, confocal laser scanning microscopy, and digital video to capture the metamorphic process in two species of *Stephanoceros* and document both the development of the adult head (aka infundibulum) and associated changes in muscle patterns as the larva undergoes drastic metamorphosis. Results indicate that larvae have a relatively simple orthogonal grid of band−like muscles, and that this grid−like network changes during the precocious development of the infundibulum. This development appears to involve changes in the larval foregut, where the adult head presumably arises from, and leads to the production of five tentacles that each contains their own orthogonal grid of muscles. Contraction of circular muscles in the larval body appears to be responsible for the emergence of the infundibulum through the larval mouth. The adaptive nature of this drastic metamorphic process is explained in the context of the sessile lifestyle.

P2.175 HOFFMANN, S.L.*; SANDERS, R; PORTER, M.E.; Florida Atlantic University; *me.porter@fau.edu*
Swimming kinematics of juvenile Sphyrna lewini
The head of Sphyrnid sharks has an exaggerated cephalofoil, which likely influences their swimming kinematics compared to other closely related shark species. Previous researchers hypothesized that the cephalophoil may act as a stabilizer during turning to maintain the shark's position parallel to the substrate. Sphyrnid sharks have also been shown to be highly maneuverable and more flexible when compared to other shark species. Here we explore the body flexibility and body curvature of Sphyrna lewini (*scalloped hammerhead*) during swimming. We obtained video of juvenile Sphyrna lewini swimming from dorsal and lateral views. We assigned 14 anatomical landmarks on the shark and tracked the movement of each during swimming. Anatomical landmarks included points on the cephalofoil, pectoral fins, caudal fin, and along the body midline. The movements of these points were correlated with swimming performance variables such as velocity, tail beat frequency, and tail beat amplitude. We also examined variables such as head yaw and body curvature along the length of the body.

P3.75 HOFMEISTER, N.R.*; RUBENSTEIN, D.R.; Columbia University, New York, NY; *nrh2114@columbia.edu*
Environmental Uncertainty and the Evolution of the Avian Glucocorticoid Receptor
Much of what we know about the vertebrate stress response to environmental stressors comes from measuring circulating glucocorticoids in free−living animals. However, quantifying glucocorticoid receptor (GR) expression may be equally important as measuring circulating hormones because only when glucocorticoids bind to the receptor does gene transcription begin. GR expression is influenced not only by a variety of environmental stressors, but also by sequence variation in the GR gene (NR3C1) itself, which affects hormone binding affinity and transcriptional activity. Surprisingly, we know little about NR3C1 evolution because few studies have explored GR evolution in free−living, non−model organisms. Here we looked for signatures of selection in the GR in African starlings, a group that inhabits a range of environments from desert to savanna to forest. Previous work in this group has shown that many species may be behaviorally and physiologically adapted to living in environmentally unpredictable environments. To investigate adaptive mechanisms underlying the vertebrate stress response in variable environments, we sequenced all eight exons of NR3C1 in 27 species of African starlings. Sequence variation was analyzed using phylogenetic comparative methods to determine whether substitution rates varied across habitats or were conserved in related species. Preliminary results suggest that the multiple haplotypes of NR3C1 observed in African starlings may reflect adaptation to local environments. This study is the first to examine the molecular mechanisms that underlie the lability of the vertebrate stress response in unpredictable environments. It has important implications for understanding how climate change may impact the evolution of the vertebrate stress response.

P1.200 HOLCOMB, L.M.*; STAHLSCHMIDT, Z.R.; Georgia Southern University; *zstahlschmidt@georgiasouthern.edu*

Effects of ecdysis and digestion on temperature preference and metabolic rate

The integument of animals requires regular turnover to replace damaged cells, reduce ectoparasite burdens, and facilitate growth. However, the physiological processes underlying ecdysis (skin shedding) may be energetically demanding, and shed skin may have high energetic costs of replacement (e.g., over 10% of ingested energy is allocated to skin lost during ecdysis in some snakes). Equivocal evidence suggests that some snakes may mitigate these energetic costs by selecting lower body temperatures during ecdysis. Yet, some critical physiological processes, such as digestion, are accompanied by thermophily. This potential thermoregulatory / energetic conflict may be exacerbated in juveniles given the high energetic demands of growth. Thus, we examined the independent and interactive effects of ecdysis and digestion on temperature preference and metabolic rate (rate of oxygen consumption) in the juvenile corn snake (*Pantherophis guttatus*). Our results provide insight into how young animals balance multiple physiological processes.

12.3 HOLLIDAY, CM*; SELLERS , KC; VICKARYOUS, MK; ROSS, CF; PORRO, LB; WITMER, LM; DAVIS, JL; University of Missouri, University of Guelph, University of Chicago, Bristol University, Ohio University, University of Southern Indiana; *hollidayca@missouri.edu*

The Functional and Evolutionary Significance of the Crocodyliform Pterygomandibular Joint

Crocodyliforms evolved a series of key features responsible for their Mesozoic adaptive radiation. Among these is the pterygoid buttress, the characteristic hypertrophied pterygoid flange in the skull. Although historically approached simply as a palatal element, the buttress forms a prominent articulation with the mandible here referred to as the pterygomandibular joint. We will present lines of evidence from anatomy, development, biomechanics, and the fossil record that show the joint is part of a dual craniomandibular joint system evolved early in suchian evolution and the key factor that stabilized the mandible and released the lineage to evolve high bite forces and robust skulls. The crocodyliform pterygomandibular joint bears resemblance to the eutherian temporomandibular joint as both joints possess sesamoid−like fibrocartilages within evolutionarily−conserved muscle attachments. Thus, crocodyliforms and mammals convergently evolved dual craniomandibular joint systems with similar joint morphologies albeit at different locations. These new findings enable significant new insights into cranial biomechanical modeling, skeletal development and vertebrate evolution.

P1.29 HOLMES, A.E.*; FRANKLIN, D.; CRAIG, C.; SLAUGHTER, A.M.; IGNOFFO, T.R.; KIMMERER, W.J.; COHEN, C.S.; San Francisco State University, Georgia Southern University; *holmesa@mail.sfsu.edu*

Genetic and morphological comparisons of planktonic Acartia spp. (Crustacea: Copepoda) in San Francisco Estuary reveal cryptic genetic diversity

Planktonic marine copepods are abundant and ecologically important. *Acartia* spp. are common globally and in the San Francisco Estuary (SFE). The taxonomy and distribution of *Acartia* spp. in SFE are poorly described due to difficulty in reliable assessment of morphological characters. Genetic comparisons were made to evaluate the utility of common diagnostic characters including morphology of the fifth swimming leg (used in mating, hence often diagnostic of species) and caudal rami, and presence of a rostral filament. Maximum likelihood analysis of an approximately 400−bp segment of the 18s rDNA locus (n=60) revealed three well−supported genetic clades inferred to represent the 3 species recorded in SFE: *Acartia californiensis*, *A. hudsonica* and *A. tonsa*. Caudal rami and rostral filament characters provided the best prediction of genetic clade. Fifth swimming leg morphology can be variable and difficult to quantify. Genetic clades were compared with reference sequences for 9 other *Acartia* spp. Species−level genetic divergence ranged from 9−35%. SFE *A. tonsa* showed 30% genetic divergence from Atlantic coast USA *A. tonsa*. This result supports the designation of Pacific coast *A. tonsa* as a distinct species, as previously reported in the literature. Two SFE clades of morphological *A. hudsonica* were 9% divergent from each other, and 9−10% divergent from *A. omorii*, native to coastal Japan. This result suggests cryptic speciation or a new record of an *Acartia* sp. in SFE. This is the first genetic study of *Acartia* spp. in SFE, part of ongoing work to elucidate cryptic genetic diversity and distribution patterns of this genus.

28.1 HOLT, NC*; DANOS, N; AZIZI, E; UC Irvine; *natalie.c.holt@gmail.com*

Unable to shift gears: the loss of variable gearing in aged muscles

In pennate muscles, shortening of muscle fibers is accompanied by a change in their pennation angle. This fiber rotation can increase whole muscle shortening velocity for a given fiber shortening velocity, a relationship characterized by a muscle's architectural gear ratio (AGR). AGR can change as muscles undergo different shape changes at different levels of force. As a result muscles can shift gears dynamically during different types of contraction. Muscle shape changes are largely determined by the interaction between muscle force and the mechanical constraints imposed by connective tissues. We used an ageing model system to examine how changes in contractile and connective tissue properties alter the variable gearing mechanism. Muscle ergometry and sonomicrometry were used to determine muscle and fiber length changes in young (6mo, n=12) and old (33mo, n=13) rat m. gastrocnemius muscles during isotonic contractions at a range of relative forces. Muscles shortened faster in young rats ($p<0.001$), particularly at lower relative forces. However, there was no effect of age on fiber shortening velocity ($p=0.66$). Muscle power output was significantly lower in old rats ($p<0.05$) due to a decrease in force (35%), and muscle shortening velocity (23%). AGR decreased with increasing relative force in young rats ($p<0.001$) but there was no relationship between AGR and relative force in old rats ($p=0.72$). These findings show the loss of variable gearing in old rats and suggest that an increase in intramuscular connective tissue and a reduction in force capacity constrain muscle shape changes. The loss of a variable gearing mechanism suggests that the muscles of old rats achieve lower velocity during low force contractions and lower forces during forceful contractions. Therefore, changes in the mechanical properties of muscles contribute significantly to the age related decline in muscle performance. NIH AR055295 & NSF 1436476.

S12.4 HOLZMAN, Roi*; CHINA, Victor; ZILKA, Miri; ELMALICH, Tal; YANIV, Sarit; ELAD, David; TAU; *holzman@post.tau.ac.il*

Suction feeding in low Reynolds numbers: Hydrodynamic and biomechanic constraints on larval fishes feeding

Larval fish suffer prodigious mortality rates during the transition from feeding on their yolk sac to actively capturing prey. This mortality has broad implications for population structure and ecology of fishes, and understanding the mechanisms that affect their survival and growth has been an ongoing effort in fish biology. To actively capture prey, larval fishes rapidly open their mouth to generate a flow of water external to the mouth. This "suction flow" is key to feeding success, because it draws the prey item into the predator's mouth, countering any escape response of the prey. However, because larval fish are minute, they start feeding in a low Reynolds numbers (Re) regime, and the hydrodynamics of their suction flows is different than that of their older conspecifics. Coincidently, feeding and capture success rates are low at first feeding, but increases rapidly with ontogeny. In this review, we will describe the biomechanics and hydrodynamics of suction feeding in low Re. We will outline why this hydrodynamic regime impedes suction feeding performance, reducing feeding success and feeding rate, ultimately resulting in "hydrodynamic starvation" in first feeding larvae. Hydrodynamic modelling and high−speed videos show that, for suction feeding in low Re, spatial−temporal gradients are weak, resulting in a diminished ability to exert strong acceleration−bases forces on the prey. In addition, flows inside the mouth cavity facilitate rejection and ejection of prey items after these already crossed the gape into the mouth. Dynamic scaling experiments indicate that these failures result from the hydrodynamic regime imposed on the larvae, directly related to their size. Other age−related changes in morphology, cognition and coordination have relatively small effects on feeding rates and capture success in first feeding larvae.

99.1 HOMBERGER, D.G.*; COZIC, A.M.; Louisiana State Univ., Baton Rouge; *zodhomb@lsu.edu*

New Insights in the Functional Morphology of the Neck and its Organs in Singing Songbirds

Birds have a long neck that can be extended or retracted into an S−shape, but little is known how these movements affect the positions of its organs (vertebral column, trachea, esophagus, cervico−cephalic air sacs, and cervical envelope). The functional morphology of the cervical apparatus was studied by using microdissection, 3D modeling based on CT data, and animation of a 3D model by matching it with x−ray videos of singing birds. In songbirds (e.g., the House Sparrow), the neck is usually extended and the tongue is moved back−and−forth during singing. When the hyoid apparatus and, thus, the larynx and trachea are protracted, the neck expands and the cervical envelope is stretched. When the hyoid, larynx, and trachea are retracted, the neck tightens and the cervical envelope contracts. These configurational changes are enabled by the cervical coelomic cavity in which the trachea and esophagus are tethered to the vertebral column by mesenteries. The paired cervico−cephalic air sacs within the coelomic cavity are inferred to inflate and fill the increased volume when the neck expands. The cervical skin bears narrow dorsal and ventral pterylae that are separated by lateral apteria with circular smooth dermal muscles. Circular and longitudinal striated cutaneous muscles are built into an underlying fascial system. Together, the dermal and cutaneous muscles regulate the tension and resonating properties of the cervical envelope which, therefore, can be tuned to the frequency of sounds generated by the syrinx and traveling through the trachea. The anisotropic cervical skin, tunable cervical envelope, and cervico−cephalic air sacs of songbirds create a sound resonating system that is analogous to the tonal drums of India. Supported by NIH grant NINDS R01 NS029467 and the LSU Foundation

P2.137 HONG, T*; CISNEROS, B; MIZOGUCHI, A; MOFFATT, C; FUSE, M; San Francisco State University, Nagoya University; *tiffanyihong@yahoo.com*

Characterizing prothoracicotropic hormone response to X−ray tissue damage in Manduca sexta larvae

The body's responses to tissue damage can include local inflammatory signaling such as cytokine mobilization, and more long term systemic responses that can result in delayed development. In some insects like *Drosophila melanogaster* and *Manduca sexta*, delayed development has been suggested to facilitate repair and regeneration after tissue damage and to allow the regenerating tissue growth to remain coupled to full body development. The insect hormone cascade mediated in this delay response has been shown to involve the developmental hormone prothoracicotropic hormone (PTTH) from the brain, which signals the prothoracic glands to secrete ecdysteroids and drive molting. In *M. sexta*, we observed developmental delay when damage occurs during a critical window in the early fifth instar, but not late in the instar (as a wanderer), suggesting that hormone titers not yet upregulated in the early fifth instar stage might be manipulated by the damaged tissue to induce the delay. We then used PTTH polyclonal antibody staining, and subsequent confocal imaging of pixel intensity, to estimate PTTH abundance in the brain of wandering larvae during this early period of the delay cascade. Our results suggest that PTTH release is delayed in X−rayed animals during the wandering phase. This is being verified with measurements of hemolymph titers in control and irradiated animals.

11.1 HOOD, W.R.*; MOWRY, A.V.; KAVAZIS, A.N.; Auburn University, Auburn University ; *wrhood@auburn.edu*

Mitochondrial function and life history variation in the house mouse

A central tenet of biology is that the costs of reproduction contribute to earlier senescence. Because reproduction is energetically demanding, it has been assumed that reproduction stimulates the production of reactive oxygen species that damage cells and hasten aging. Yet, several studies have shown that oxidative damage is typically unchanged or reduced in reproductive individuals when compared to non−reproductive controls. To evaluate the relative cost of reproduction, we quantified mitochondrial function in the liver of house mice that bred several times verses those that never bred. Mice were maintained in enclosures that mimic the conditions of free−living wild mice. Reproductive females had the opportunity to breed for 8 months, while non−reproductive females were maintained for a similar duration with infertile male(s). At 10.5 months, the males were removed to curtail breeding. Females were sacrificed at 12 months of age and liver mitochondria were isolated by differential centrifugation and used for analyses. The respiratory control ratio (RCR) of reproductive females was not different compared to non−reproductive females ($p=0.16$). Oxidative damage of liver mitochondria, as measured by 4 hydroxynonenal (4HNE), trended to be higher in reproductive mice ($p=0.09$), despite having higher mitochondrial protein levels of antioxidants (i.e., SOD2 and catalase) ($p<0.05$). Thus, our data indicate that enhanced antioxidant protein production may have been insufficient to prevent oxidative damage to liver mitochondria in animals that reproduced for 8 months. However, additional studies are needed to fully elucidate how mitochondrial function changes with parity and differs among metabolically active tissues.

77.6 HOOVER, A. P.*; MILLER, L. A.; GRIFFITH, B. E.; University of North Caroline at Chapel Hill; *hooverap@email.unc.edu*

Muscular Control of Turning and Maneuvering in Jellyfish Bells

Jellyfish represent one of the earliest and simplest examples of swimming by a macroscopic organism. Contractions of an elastic bell that expels water are driven by coronal swimming muscles. The re−expansion of the bell is passively driven by stored elastic energy. A current question in jellyfish propulsion is how the underlying neuromuscular organization of their bell allows for maneuvering. Using an immersed boundary framework, we will examine the mechanics of swimming by incorporating material models that are informed by the musculature present in jellyfish into a model of the elastic jellyfish bell in three dimensions. The fully−coupled fluid structure interaction problem is solved using an adaptive and parallelized version of the immersed boundary method (IBAMR). We then use this model to understand how variability in the muscular activation patterns allows for complicated swimming behavior, such as steering. We will compare the results of the simulations with the actual turning maneuvers of several species of jellyfish. Numerical flow fields will also be compared to those produced by actual jellyfish using particle image velocimetry (PIV).

P1.104 HOULTON, C.P.*; BALZER, A.H.; KUHN, J.; HOLFORD, K.C.; Purdue University North Central; *choulton@pnc.edu*

Effects of bisphenol−A (BPA) exposure on the development of immature red−swamp crayfish, Procambarus clarkii

Bisphenol−A (BPA, 4,4'−(propane−2,2−diyl)diphenol) is a polycarbonate chemical largely utilized in the production of plastics and epoxy resins. Likely due to large scale use in industry, BPA has been shown to be increasingly ubiquitous in the environment. This is of concern as it has been shown to behave as an endocrine disruptor in many vertebrate species, including humans. BPA has been shown to interact with several types of estrogen and estrogen−like receptors, and can also bind to a multitude of transcriptional co−regulators. Embryonic and immature juvenile forms appear to be the most sensitive to the effects. While considerable attention has been given to the effects on vertebrate animals, the effects of BPA exposure on invertebrates are not widely understood. The primary objective of this study was to determine the effects of BPA exposure on developing red−swamp crayfish, *Procambarus clarkii*. Postembryonic larva were isolated within a week of hatching, split into groups, and repeatedly exposed to BPA at lower (common environmental concentration) and higher (ten−times normal concentration) doses. Untreated animals served as controls for the experiment. A variety of physical (e.g. mass, length, and coloration) and physiological (e.g. molting) parameters were assessed weekly over the course of a fourteen week study. BPA exposure at high concentrations resulted in a difference in mass, but had only a marginal (non−significant) affect at low dose. Neither exposure had an effect on length, nor was there a discernible effect on coloration or pattern. Both low and high levels of exposure appeared to increase the rate of molting of individuals. We are continuing to investigate this effect.

37.7 HOWELL, DB*; WOODS, J; CHAUHAN, N; SANDERS, EJ; DYHR, J; DANIEL, TL; Univ. Washington, Roosevelt High School, Univ. Prep., Northwest Univ.; *darren.b.how14@gmail.com*

Insect abdominal mechanoreceptors show rapid adaptation.

Flying insects rely on multi−modal, tightly coordinated sensorimotor systems to accomplish complex flight trajectories. To execute adaptive, compensatory maneuvers, insects acquire and process feedback from proprioceptive input from a variety of structures including the head, antennae, and wings. Recently, attention has focused on the flight control role played by the abdomen, commonly the structure with the greatest mass in many flying insects. Interestingly, little is known of the proprioceptive feedback provided by any mechanosensory structures associated with the abdomen position. We asked whether information from abdominal mechanosensors can be detected in ventral nerve cord and, if so, what are the temporal characateristics of neuronal responses to mechanical stimulation of the abdomen. Using *Manduca sexta* to examine abdominal mechanosensing we first identified a suite of hairplates located on the dorsal aspect of the abdomen that potentially detect dorsal abdominal extension. We then used multisite extracellular recording methods to measure neural responses in the ventral nerve cord for a preparation consisting of a thorax and abdomen. The abdomen was subject to a step−wise rapid dorsoflexion via a high speed servomotor. We identified neural responses in the form of rapid spiking that occurred within 50 ms of the onset of step stimulus. Additionally, these units show very rapid adaption to the stimulus, ceasing firing within approximately 250 ms. These data suggest that, as expected, there is fast proprioceptive input available to the flying animal. Moreover, that rapid adaption to the stimulus suggests that this input could provide rate detection for abdominal motions.

P3.11 HRISTOV, NI*; ALLEN, LC; RILEY, JA; MERSON, M; UNC Center for Design Innovation / Winston−Salem State University, Winston−Salem State University, TERC; *nickolay.hristov@centerfordesigninnovation.org*

iSWOOP: Interpreters and Scientists Working On Our Parks

The Falk and Dierking 2010 report shockingly indicates that the average American spends only 5% of their time engaged in formal education and acquires most of their STEM knowledge outside of the classroom. Additionally, research shows that US public STEM literacy ranks below that of many other developed nations. With a national decline in visitation to libraries, museums and other sites of public learning, how can we utilize existing centers for informal education and tap into the other 95% of opportunities for public engagement and STEM education? Our nation's zoos, aquaria and national parks, which still attract a large audience of willing participants may provide an answer. iSWOOP is a new, NSF−funded, pilot initiative that seeks to create a model of professional development for national park interpreters to help advance STEM learning for the more than 275 million annual visitors of America's National Parks. iSWOOP is based on a collaboration among scientists, informal science educators and park interpretive rangers. They all work together to design engaging and informative interpretive programs on scientific topics of relevance and interest to the general public with a focus on the process of science. In this first phase of development, the project is discovering best practices that allow visitor engagement through visual storytelling, inquiry and facilitated dialog. Piloted at Carlsbad Caverns National Park, we anticipate the model to grow to other iconic park sites around the US. As the research team looks to scale up the project, we seek to address the challenges and opportunities for scientists, and education researchers to create a support framework that receives buy in from all parties for the advancement of informal STEM learning.

115.2 HU, D.L.*; DAVE, T.; PHONEKEO, S; Georgia Institute of Technology, Atlanta; *hu@me.gatech.edu*
Self healing of fire ant aggregations
Fire ants (*Solenopsis invicta*) link their bodies together to form structures such as rafts, bivouacs and bridges. Such structures are in danger of being damaged by natural disturbances such as passing water currents. In this combined experimental and theoretical study, we investigate self−healing of ant assemblages. We present macro−scale experiments in which we press two ant aggregations together and measure the effect of contact time on the attachment force between the aggregations. We rationalize our results using a mathematical model stating that the rate of creation of new bonds is proportional to the number of ants that have not yet bonded. This rate law is consistent with the construction of rafts and bivouacs, whose growth rate is proportional to the number of ants on the surface of these structures. The present work shows that repair and construction are aspects of the same phenomena and, moreover, that ants can repair the inside of a structure as easily as on their surface. The principles found here may inspire new directions in the engineering of self−healing materials.

P3.195 HU, Y*; DETRICH, HW; ALBERTSON, RC; UMass Amherst, Northeastern University; *yinan@cns.umass.edu*
Morphological diversification in Antarctic notothenioids
Antarctic notothenioids offer a rare example of an adaptive radiation in marine vertebrates. During the dramatic cooling of the Southern Ocean over the past 40 million years, most near−shore fish lineages were locally extirpated. However, the evolution of anti−freeze glycoproteins in notothenioids enabled these ancestrally benthic fishes to survive in their frigid environment, and their evolution of secondary pelagicism fostered their diversification and occupation of newly available pelagic habitats. Antarctic notothenioids now represent the primary teleost lineage in the Southern Ocean and are of fundamental importance to the local ecology. However, little is known about how morphological innovations have contributed to their evolutionary success. In this study, we used a 3D−morphometrics approach to investigate patterns of morphological variation in the craniofacial skeleton, which is directly associated with prey capture and thus plays a key role during exploitation of novel ecological niches. In total we analyzed 30 notothenioid species across all major lineages within this clade. With this resource we address the following questions: 1) What are the primary axes of morphological variation associated with the notothenioid radiation and how do they compare to patterns seen in other teleost radiations; 2) Have different regions of the notothenioid skull evolved at different rates (i.e., do they exhibit patterns of evolutionary modularity?)? These data will provide deeper insights into how fundamental aspects of the notothenioid skull have both facilitated and constrained the adaptive morphological radiation of this important group.

52.3 HUBEL, TY*; MYATT, JP; JORDAN, NR; DEWHIRST, OP; MCNUTT, JW; WILSON, AM; Royal Veterinary College, Birmingham University, Botswana Predator Conservation Trust, Botswana Predator Conservation Trust; *thubel@rvc.ac.uk*
Modern African wild dogs − Opportunists rather than Specialists
The African Wild dog (*Lycaon pictus*) is often identified as the ultimate endurance hunter. Their hunting style has been described as running down prey over long distances with a high level of collaboration between the pack members until the prey is exhausted. This suggests that they represent one end on a spectrum of hunting styles with the opposite end occupied by the cheetah an extremely fast and maneuverable hunter. We collared a pack of six adult African Wild dogs with high resolution GPS/IMU collars and discovered that in their currently most common woodland habitat, while travelling considerable distances at preferred speeds, they did not capture prey after long chases or hunt collaboratively. Wild dogs are rather opportunistic in their hunting strategy, travelling through their habitat as a group with individuals chasing after chance encounters. When approaching a herd of impalas (their main prey) wild dogs chase after different prey mostly individually or as pairs, showing no synchronized approach focusing on only one prey. Chases are rather short and very fast, but acceleration, centre of mass power and turning (centripetal) acceleration are all lower than equivalent values for cheetahs. Lack in maneuverability and speed, compared to cheetahs, are compensated by multiple dogs hunting, larger distances travelled, consequently more prey encounters and more hunting attempts. To what extent hunting strategies in Wild Dogs are flexible and can be adapted to habitat and prey size has yet to be determined.

77.1 HUBICKI, C.M.*; BIRN−JEFFERY, A.V.; JONES, M.; HURST, J.W.; DALEY, M.A.; Oregon State Univ., Univ. of California, Riverside, Royal Veterinary College; *hubickic@onid.orst.edu*
Task−level Priorities in Ground−running Bird Locomotion: Experiments to Math Models to Robots by Way of Optimization
Cursorial ground birds are paragons of bipedal running, even over terrain of highly variable geometry. We hypothesize that these behaviors emerge from underlying task−level control priorities. We formulate this hypothesis as a control optimization problem, seeking to explain and predict features of avian locomotion, across species, by optimizing control applied to reduced−order math models of locomotion. We investigated the relative priority for energy economy and attenuation of gait perturbations (a proxy for gait stability) by running birds over obstacles that put these priorities in direct conflict. We compared the observed maneuvers to optimal control for each priority applied to a reduced−order model (a simple spring−mass damper model with a single linear leg actuator). After validating the model against steady bird locomotion, our obstacle negotiation analysis suggested that birds, from quail to ostrich, prioritize energy economy and avoidance of musculoskeletal injury risk over attenuating deviations from steady gait. Our optimizations suggest that priority for diminishing gait deviations would demand higher mechanical work and leg forces, increasing energy costs and risk of injury. These findings suggest a novel approach to bipedal robot control, and our ongoing work seeks to apply task−level control priorities of economy and injury avoidance on a suitable robot model, ATRIAS, a human−scale biped. Since ATRIAS is designed to mechanically match to our reduced−order model, we hypothesize control optimization for economy and injury avoidance will produce running that is dynamically similar to birds.

86.2 HUDSON, SB*; WILCOXEN, TE; Millikin University; *sbhudson@millikin.edu*

Structural−based plumage coloration as an honest signal of quality in male Indigo Buntings (Passerina cyanea)

Bright plumage coloration is seemingly favored by females of avian species with regards to sexual selection. This particular secondary sexual characteristic has been previously tested and supported to be an honest signal of individual quality among passerines with pigment−based coloration (i.e. yellows and reds). In contrast, structural plumage coloration (i.e. blues) exhibited by birds such as Indigo Buntings (*Passerina cyanea*), have received minimal research on relationships between plumage color intensity and aspects of physiological function. Using free−living Indigo Buntings as a study species, we compared UV and blue color intensity to innate immune responses, antioxidant capacity, and stress physiology. UV or blue coloration of the tail feathers was not correlated with any of the physiological metrics. The overall percentage of blue feathers on individual birds was positively correlated with body condition and negatively correlated with heterophil to lymphocyte ratio, indicating that the overall blueness of male Indigo Buntings is associated with better body condition and lower stress.

P3.69 HUDSON, SB*; ROBERTSON, MW; WILCOXEN, TE; Millikin University; *sbhudson@millikin.edu*

Effects of social habituation on coloration and stress in male green anoles, Anolis carolinensis (Squamata: Polychrotidae)

Male green anole lizards, *Anolis carolinensis*, use visual displays, often involving aggressive behavior, in intrasexual interactions. Communication of agonistic messages can be mediated by changes in body coloration due to a stress response. Aggressive behavior can be reduced through social habituation with conspecifics, but the role of stress hormones and their effects on body coloration are unknown. We examined the effects of social habituation in male *A. carolinensis* with respect to stress hormone levels and body coloration. For two weeks, we allowed randomly paired male *A. carolinensis* to interact for 10 minutes with a 1−day interval between each trial. In week three, we paired individuals with a novel male and repeated the interactions. We collected fecal samples to measure corticosterone levels and recorded body coloration before and after interactions. Prolonged social interaction led to increased corticosterone levels and an overall increase in brown coloration frequency. Although there was no significant correlation between body coloration and corticosterone levels in the initial 2−week period, a close relationship became evident during the third week. Therefore, social habituation may not be mediated by differences in stress levels among subordinate/dominant relationships, and body coloration may instead depend on acute and chronic stress conditions.

S11.11 HUI, JHL; The Chinese University of Hong Kong; *jeromehui@cuhk.edu.hk*

MicroRNAs and comparative genomics in arthropod endocrinology and reproduction

The Arthropoda is the phylum containing the largest number of described living species, and precise regulations of arthropods hormones are crucial to their success in evolution. To date, most of our knowledge on their developmental modes, genomes, and mechanisms of hormonal regulation come mainly from the Insecta. Recent molecular phylogenetics strongly supported the clade Pancrustacea where insects are indeed derived crustaceans. With the advancement of sequencing technologies, I will first show how comparative genomics have changed our views on the Pancrustacea and other non−insect arthropods. Furthermore, I will provide examples showing how gene regulation by microRNAs can shed light on the understanding of arthropod endocrinology and evolution.

92.2 HULETT, R.E.*; GOSLINER, T.M.; California Academy of Sciences/San Francisco State University, California Academy of Sciences; *rhulett@calacademy.org*

The Crushing Truth: Stomach Plates in Tritoniidae (Mollusca: Nudibranchia)

Tritoniidae (Mollusca: Nudibranchia) is a family of sea slugs known to feed on octocorals, including soft corals, gorgonians, and sea pens. The evolutionary relationships of the family have a murky history due to the lack of a fossil record. However, stomach plates are deemed to have high systematic value and have been used as one of the diagnostic characters when differentiating between the two largest genera, *Marionia* and *Tritonia*. Stomach plates are hypothesized to aid in the mechanical destruction of sclerites and may be indicative of certain prey items. A phylogenetic analysis of the family using two nuclear (H3 and 28S) and two mitochondrial (16S and COI) markers in conjunction with expansive taxon sampling allows for a focused approach in determining the origin and evolution of stomach plates and whether Tritoniids with stomach plates form a monophyletic clade. Looking at stomach plates may provide insight that ties into food source and a potential prey shift as well as the overall evolution of prey specificity.

P1.4 HULETT, R.E.*; HALLAS, J.M.; GOSLINER, T.M.; California Academy of Sciences/San Francisco State University, California Academy of Sciences; *rhulett@calacademy.org*
Where Have You Been: Biogeographical Patterns in Tritoniidae (Mollusca: Nudibranchia)
The nudibranch family Tritoniidae (Mollusca: Nudibranchia) is an enigmatic group with members that are cryptic and mimic the shape and color of the soft corals on which they feed. This leads to common misidentification and misplacement of species, impacting the knowledge and understanding of Opisthobranch systematics Previous studies using both molecular and morphological characters have claimed the family is monophyletic; however, this hypothesis is weakly supported. We are expanding on those previous studies by increasing taxon sampling and using four gene fragments− two mitochondrial (16S and COI) and two nuclear (H3 and 28S). We have reconstructed a robust molecular phylogeny using maximum likelihood and Bayesian analyses that depicts the evolutionary relationships of the group. Using this molecular data set we performed an ancestral biogeographic reconstruction to determine the most probable geographic origin of the family as well the major clades within the group. Understanding the placement of several key species as well as the familial placement within the broader Cladobranchia and their origins is important to understanding landmark evolutionary events and dispersal trends.

S2.7 HULTINE, Kevin / R*; BEAN, Dan / W; DUDLEY, Tom / L; GEHRING, Catherine / A; Desert Botanical Garden, Palisade Insectory, Colorado Department of Agriculture, Univ. of California, Santa Barbara, Northern Arizona University; *khultine@dbg.org*
Species introductions and their cascading impacts on native biotic interactions in desert riparian ecosystems
Desert riparian ecosystems of North America are hot spots of biodiversity that support many sensitive species, and are in a region experiencing some of the highest rates of climate change (CC) in North America. Populus fremontii is a foundation species of this critical habitat, but is threatened by CC and by non−native Tamarix, both of which can disrupt the mutualism between P. fremontii and root−associated fungi (RAF). The specialist herbivore (Diorhabda spp.) introduced for biocontrol of Tamarix is altering the relationship between this shrub and its environment. Diorhabda feeds exclusively on Tamarix foliage, resulting in varying rates of dieback and mortality depending on resource availability and genetic variation in resource allocation. Likewise, mortality varies with latitude owing to phenological asynchrony caused by varying developmental cues; Tamarix responds to temperature and Diorhabda responds to photoperiod. We anticipate that 1) defoliation by Diorhabda will reduce the negative impact of Tamarix on P. fremontii / RAF associations, 2) certain P. fremontii genotypes will respond more favorably to Tamarix dieback and mortality than others due to selection pressures to cope with competition, stress and altered RAF communities, and 3) Spatial variability in climate change will modify the capacity for Tamarix to survive episodic defoliation by Diorhabda thereby altering the complex interaction between Tamarix and P. fremontii and its associated RAF communities.

S2.3 HUNT, KE*; ROLLAND, RM; KRAUS, SD; New England Aquarium; *huntk@neaq.org*
Studying the uncatchable animal: the methods, meaning and madness of conservation physiology research on large whales
Advances in noninvasive sampling and remote sampling have recently made it possible to address landscape−scale conservation physiology questions in large whales, a taxon that has historically been very difficult to study. We discuss the North Atlantic right whale (*Eubalaena glacialis*, "NARW"), a critically endangered species that has been under intensive study for nearly four decades, as a case study of applying modern conservation physiology methods to large whales. By combining long−term sighting histories of known NARW individuals with physiological data from newer techniques (e.g., body condition estimated from photographs, endocrine status derived from fecal samples), we have been able to correlate physiological trends in the NARW population with specific anthropogenic impacts. Our approach relies on: sufficiently detailed knowledge of individual history to allow subdivision of physiological data by demographic group (e.g. lactating females, pregnant females, mature males); consistent population monitoring over decades; consistent efforts at endocrine sample collection over many years; continued development and testing of novel physiological tools; and a unique organizational approach that encourages data−sharing across multiple institutions. Logistical limitations include periodic disappearance of large segments of the population to unknown locations; expense of aircraft−based and ship−based population surveys; low sample collection rate; and impossibility of performing certain classic validations (e.g. ACTH challenge) in baleen whales. Ongoing applications to other species, including multi−population comparative approaches, will be discussed.

18.4 HUNT, KE*; STIMMELMAYR, R; GEORGE, C; HANNS, C; SUYDAM, R; BROWER, H; ROLLAND, RM; New England Aquarium, North Slope Borough; *huntk@neaq.org*
Baleen hormones: A potential tool for retrospective assessment of decade−long endocrine history of mysticete whales
Baleen consists of filter−feeding sheets, or "plates", of cornified tissue that grow continuously from the upper jaw of mysticete whales, gradually wearing off at the distal end. We have recently demonstrated that baleen contains steroid hormones that are likely deposited from circulation during the period of tissue growth. Given species−specific baleen growth rates and length of adult baleen, a single plate may represent a continuous endocrine record of the past decade or longer. To test whether baleen hormones reflect known reproductive state, we analyzed multiple subsamples of baleen from sixteen bowhead whales (*Balaena mysticetus*) collected during subsistence harvests in northern Alaska. The sixteen animals included both sexes and a mix of reproductive states and ages (mature and immature males; and mature nonpregnant, pregnant, and immature females). In baleen from the gumline (newest baleen), all pregnant bowheads had higher baleen progesterone than all other bowheads. Pregnant females also exhibited progesterone "profiles" in older baleen (e.g. baleen grown over the past year) that were consistent with estimated gestation length of bowhead whales. Furthermore, several of the nonpregnant mature females had very high progesterone in older baleen (grown more than a year prior), suggesting that baleen might provide an endocrine record of previous pregnancies. Though the technique is still under development, baleen may enable assessment of inter−calving intervals, reproductive trends, and adrenal activity over multi−year timeframes, information that is very difficult to acquire in large whales by other means.

107.4 HUNT, N*; JINN, J; LIBBY, T; JACOBS, L.F.; FULL, R.J.; University of California, Berkeley; *nathaniel.hunt@berkeley.edu*

Learning to launch: targeted leaping from a dynamic obstacle in squirrels

Motor learning is an important complement to pre−determined control because it allows animals to adapt control to changing and/or uncertain bodies and environments. It enables building a movement repertoire specific to local environmental affordances. For many arboreal animals, leaping from a compliant substrate represents a difficult biomechanical challenge in which the animal and the environment are bi−directionally coupled. In principle, these animals may control their leaping dynamics by generating ground reaction forces, creating aerodynamic forces, and by inertial shape change. Previous studies show that many animals modulate their kinematics and kinetics based on substrate compliance, gap distance, and whether they are launching or landing, and may use environmental compliance for energy storage and return. It is unknown whether or how these modifications are learned. Tree squirrels are highly skilled arboreal locomotors, exhibiting long leaps between branches. We presented fox squirrels (*Sciurus niger*) with a novel compliant diving board−like structure to cross a 75cm gap for a food reward in the field. Five wild fox squirrels (body length 29.6±1.0 cm, mean and s.d.) completed 24 gap crossings. We characterized targeting performance as the distance between the center of mass and the landing platform at the end of the aerial trajectory, and by the number of feet that reached the landing platform. Squirrels demonstrated trial and error motor learning within each day. Both targeting error and missed footholds either remained steady or decreased monotonically during a sequence of two to four trials. Targeting error decreased on average 34±40%. Our next step will be to characterize the biomechanical mechanisms and cues for this highly dynamic learning task.

S1.2 HUSAK, J. F.; Univ. of St. Thomas; *jerry.husak@stthomas.edu*

Animal speeds in different ecological contexts: when the laboratory meets nature

Animals move through their environments for a variety of reasons and at a variety of speeds, but what determines those speeds? Although locomotion is often viewed as a trait essential for survival and Darwinian fitness, we still know surprisingly little about how exactly locomotion is used to accomplish that goal. Not only can the stimulus to move in a given instance of locomotion vary, but so can the assessment of risk of that context, and the substrate over which locomotion happens. It is standard practice to assume that traits such as sprint speed measured in a laboratory reflect what animals do in nature, but the limited data available for locomotor capacity use in nature do not consistently show that animals use maximal abilities in every, or in some cases in any, context. Instead, slower adequate' or preferred' speeds are much more common and likely represent optimal speeds that have evolved via multiple selective pressures on the locomotor apparatus, in addition to sensory systems and neural processing. I discuss what we know about animal speeds in different ecological contexts, focusing on lizard locomotion, which has been well studied for decades. I suggest that investigators should be explicit about how their measures of performance are relevant to their study organism, and I discuss why some studies find strong discordance between laboratory and field studies of locomotion. Ultimately, the evolution of locomotion and what speeds animals use in nature depend on predation pressure, habitat complexity, prey performance and availability, tradeoffs with other aspects of performance, and the costs and benefits of using a particular speed in a specific context.

11.4 HUTTENLOCKER, A.*; FARMER, C.; Univ. of Utah, Salt Lake City; *ahuttenlocker@gmail.com*

A PHYLOGENETIC PERSPECTIVE ON THE EVOLUTION OF RED BLOOD CELL SIZES IN TERRESTRIAL VERTEBRATES

Vertebrate red blood cells (RBCs) display a range of sizes among species and higher clades, with some groups differing by orders of magnitude in volume. Although explanations for this disparity range from metabolic costs to constraints imposed by genome size and nucleus volume, patterns of RBC size evolution are rarely considered in their historical context, underscoring a need to understand whether proposed constraints are reflected in the character's phylogenetic history. Here, we present a meta−analysis of RBC diameters from over 290 species in all major extant tetrapod clades to explore the tempo of RBC size evolution. Data were supplemented with measurements from several anurans, non−avian reptiles, birds, and small mammals. Results suggest considerable variation both among and within lineages, even in mammals where RBCs are enucleated. For example, mammals originated with modest RBC sizes but were largest in early−diverging clades and became progressively smaller, especially in some laurasiatheres. PGLS regressions show weak support for correlated evolution with body size. Phylogenetic model−fitting suggests that multi−parameter models better fit observed patterns among clades than the null Brownian model, with saltatory changes in RBC size occurring early and becoming progressively more constrained around an optimum in daughter lineages. The existence of upper (diffusion capacity/metabolic costs) and lower (nucleus size) limits on RBC size may have both contributed to an overall pattern of constrained evolution. More sampling of laurasiatheres would help to test whether the loss of the nucleus relaxed constraints, permitting trends toward smaller RBCs in some mammals. Precise models of RBC evolution will better inform approaches to retrodicting ancestral RBC sizes in extinct lineages.

108.7 HYLARIDES, MJ*; COWLES, DL; Walla Walla Univ., College Pl; *justin.hylarides@gmail.com*

Light Level as a Potential Limiting Factor in the Growth of Eelgrass in the Pacific Northwest

Eelgrasses serve as important nursery habitats in the Pacific Northwest for diverse marine life and are widely recognized as indicators of coastal ecological health. We investigated seasonal differences in respiration and Photosynthesis−Irradiance (P/I) relationships of a population of marine eelgrass *Zostera marina* in Rosario Bay, WA in order to characterize its growth potential in different seasons. We also estimated the local light availability *in situ* for each season by combining direct light measurements under different conditions with hourly weather and tide measurements. Our results showed that *Z. marina* differed both in respiratory and in photosynthetic rates among seasons with its highest rate of photosynthesis occurring in the summer. Yet the P/I relationship was so steep that sufficient light should be present even in the lowest−light winter season so that clean eelgrass may be able to at least support its metabolism by photosynthesis and have net growth. However, epiphytic algae living on the blades of *Z. marina* likely reduce its access to light, especially in summer, and could potentially lead to light limiting conditions.

P1.136 HYND, PI; CZERWINSKI, VH; MCWHORTER, TJ*; Univ. of Adelaide; *todd.mcwhorter@adelaide.edu.au*

Is propensity to obesity associated with the diurnal pattern of core body temperature?

Obesity affects more than half a billion people worldwide, but the underlying causes remain unresolved. It has been proposed that propensity to obesity may be associated with differences between individuals in metabolic efficiency and in the energy used for homeothermy. It has also been suggested that obese−prone individuals differ in their responsiveness to circadian rhythms. We investigated both these hypotheses by measuring the core body temperature at regular and frequent intervals over a diurnal cycle, using indigestible temperature loggers in two breeds of canines known to differ in propensity to obesity, but prior to divergence in fatness. Greyhounds (obesity−resistant) and Labradors (obesity−prone) were fed indigestible temperature loggers. Gastrointestinal temperature was recorded at 10−min intervals for the period of transit of the logger. Diet, body condition score, activity level and environment were similar for both groups. Energy digestibility was also measured. The mean core body temperature (Tb) in obesity−resistant dogs (38.27 ºC) was slightly higher ($P < 0.001$) than in obesity−prone dogs (38.18 ºC) and the former had a greater variation ($P > 0.001$) in 24h circadian core temperature. There were no differences in diet digestibility. Canines differing in propensity to obesity, but prior to its onset, differed little in mean core temperature, supporting similar findings in already−obese and lean humans. Obese−prone dogs were less variable in daily core temperature fluctuations, suggestive of a degree of circadian decoupling. *International Journal of Obesity* (2014) 38, 231−235; doi:10.1038/ijo.2013.110

P3.138 IGOE, L*; GROSS, V; HOCHBERG, R.; Univ. Massachusetts, Lowell, Univ. Lepizig, Germany; *laura_igoe@student.uml.edu*

Three−dimensional architecture and functional morphology of the musculature in Ctenocheilocaris armata (Crustacea: Mystacocarida).

Mystacocarida is a poorly known group of marine microscopic crustaceans characteristic of the interstital (meiobenthic) environment. While only 13 species are described worldwide, the taxon figures prominently in discussions of crustacean relationships because of their presumably plesiomorphic morphology. In this study, we examined the architecture of the musculature in Brazilian specimens of *Ctenocheilocaris armata* to determine if muscle patterns could contribute to our understanding of mystacocarid behavior and phylogeny. Using a filamentous actin marker in combination with confocal laser scanning microscopy and 3D reconstructive software, we mapped the somatic musculature of the appendages, cephalon, thorax and abdominal regions, and the splanchnic musculature of the fore−, mid− and hindgut. Our results show that the somatic musculature is dominated by longitudinal muscles that form three distinct patterns: an anterior−posterior pattern with muscles that span the length of the thorax and abdomen; a dorsoventral pattern wherein dorsal longitudinal muscles make segmental, ventrolateral insertions; and a ventrodorsal pattern wherein ventrolateral longitudinal muscles make dorsolateral insertions. We confirm earlier observations about the complex musculature of the intestine in mystacocarids, which includes strong dilator and circular muscles around the foregut, while mid− and hind−gut regions are dominated by numerous circular muscles. The layering of the circular and longitudinal muscles appears to differ from that described for species of *Derocheilocaris*. Additional details of the musculature are presented and compared to previous results on additional species.

81.6 INGERSOLL, R*; LENTINK, D; Stanford University; *riversi@stanford.edu*

In vivo measurement of aerodynamic weight support in freely flying birds

Sustained hovering is a special behavior that separates the aerodynamic flight techniques of hummingbirds from other birds. This remarkable behavior is aided by the relatively large supracoracoideus muscle allowing the upstroke to produce lift. The ratio of the upstroke versus downstroke lift force defines the symmetry of the wingbeat cycle. Some insects have the ability to invert the chamber of their wings during the upstroke to equally distribute the weight support throughout the wingbeat cycle. While hummingbirds do have stiff wings, they cannot invert the chamber of their wings to maximize their wingbeat symmetry. Previous works have inferred these forces indirectly through kinematics or flow measurements that ignored accelerations and volumetric gradients. To understand the varying weight support, we resolved the instantaneous force generated by a freely hovering hummingbird *in vivo* within a wingbeat directly. Our method is noninvasive and has been validated using independent force measurements on a quadcopter with pulsating thrust. The method is scalable for birds and robots across taxa.

95.2 IRSCHICK, D.J.*; GILMAN, C.A.; IMBURGIA, M.J.; KING, D.R; KUO, C.; SHOWALTER, I.; CROSBY, A. J.; University of Massachusetts at Amherst; *djirschick@gmail.com*

A new framework for understanding the evolution of gecko toepads

Geckos are renowned for their diverse and remarkable toepads. However, while the diversity of gecko toepads has been studied in some detail, a great deal is not understood regarding the diversity of phenotypes, and whether the same phenotypes have arisen multiple times. We applied novel mathematical and statistical techniques for understanding the evolution of gecko toepads. To do this, we quantified the toepad shape for a wide range of gecko species across most of the major groups. We used novel methods for quantifying toepad shape both within the pad, and across the entire foot. We also examined the scaling of toepad size and shape from geckos ranging about 1 g in mass to about 300 g (300x scaling). We conducted this work in a phylogenetic context, and overall there appears to be both remarkable diversity in toepad shape, and also there appear to be strong links with ecology and life history.

23.2 IRVINE, SQ; Univ. of Rhode Island; *steven.irvine@uri.edu*
Proteomic profiles of regenerating tissue in the ascidian Ciona intestinalis
Regeneration may be viewed as the activation of a non−embryonic developmental program in response to injury. This program necessarily involves a change in the expression profile of proteins in order to rebuild the lost organ, including those regulating the process. Shotgun liquid chromatography/mass spectroscopy is a rapidly improving proteomic method for globally assessing protein expression profiles. We have begun using this technology to assay proteins up or downregulated in regenerating tissue in the ascidian *Ciona intestinalis*. This animal is capable of regenerating its oral siphon when removed. By comparing protein expression profiles from intact siphon tissue vs. regenerating siphon blastema we are identifying molecules that may be important for regulating the regeneration process. In preliminary experiments over 300 total proteins were identified, with 133 proteins upregulated and 107 downregulated in regenerating tissue. Of particular interest were a number of signaling molecules, RNA binding proteins, and transcription factors. Ongoing work includes selecting for nuclear proteins, to enrich for transcription factors, and assaying additional stages and replicates.

P1.185 JACKSON, BE*; EVANGELISTA, D; HEDRICK, TH; Longwood University, University of North Carolina at Chapel Hill; *jacksonbe3@longwood.edu*
3D for the people: motion capture in the field with consumer−grade cameras and open−source software
Three−dimensional motion capture based on high−speed videography is a staple technique of comparative biomechanics. Historically, the necessary equipment has been cumbersome and expensive, thus largely precluding use of the technique in natural settings, by specialists in other fields (e.g. animal behavior, ecology), and in financially restricted situations. New consumer grade equipment (e.g. sports/action cameras, DSLR's with HD video) offers far greater portability, and resolution and recording rates comparable to systems costing ten times as much. However, consumer grade equipment lacks the ability to synchronize among multiple cameras and may introduce substantial lens distortion. We have developed a workflow based on open−source Python or MATLAB modules that addresses such problems, and that automates some steps of 3D calibration and animal tracking to reduce both analysis time and reconstruction error. We present several data sets of flying animals (various species of insects and birds) with sample volumes ranging from 0.3 m^3 to over 20,000 m^3. One of our example systems is based on three GoPro Hero cameras, fits in a small backpack, can record continuously for approximately an hour at 120 Hz (battery limited), and is extremely weather− and damage−resistant. Field setup and camera calibration required as little as three minutes, offering the ability to record relatively unpredictable behaviors in remote and harsh conditions. We foresee that such an affordable and intuitive setup will permit the use of 3D motion tracking across a wide range of size scales, environments, and study−areas in biology, and will bring this important technique to researchers with limited funding.

74.2 JACOBS, MW*; HEIN, SR; ODIERNO, JA; McDaniel College, Univ. of Texas, Tyler; *mjacobs@mcdaniel.edu*
Ontogeny of a Behavior: Decorating in Juvenile and Adult Decorator Crabs (Oregonia gracilis)
Adult graceful decorator crabs (*Oregonia gracilis*) decorate by attaching pieces of algae, sponge, or other items from their habitat onto hooked setae, but decoration behavior has not previously been studied in juvenile crabs. Decoration is thought to provide camoflauge in the adult habitat, suggesting that decoration behavior might begin soon after settlement into that habitat. Alternatively, juvenile crabs may rely on crypsis initially and begin decorating once they are too large to hide effectively. SEM revealed that hooked setae were absent in megalopae, but present in first instar juveniles and adults. Megalopae did not exhibit any decorating behaviors, but first instar juveniles actively and profusely decorated with organic debris. Thus, the onset of decorating occurs very soon after settlement into the adult habitat, at the molt from megalopa to first instar juvenile. Crypsis may also be a priority: in a habitat choice experiment, megalopae and first instar juveniles chose the most structurally complex habitat (erect bryozoans) over sponges or red algae. Although decorating behavior begins immediately after settlement, it changes over time: juvenile and adult crabs chose different materials for decorating. This may be the result of size−related differences in which materials make for the most effective camoflauge, or it may be the result of biomechanical differences in the material handling ability of adults and juveniles. We conducted preliminary investigations on material handling behavior in adult crabs, and propose several testable hypotheses regarding size−related changes in material handling ability and preference in decorator crabs.

P3.157 JACOBY, MJ*; GANT, CA; SELLERS, KC; HOLLIDAY, CM; JACOBY, ; JACOBY, ; JACOBY, ; JACOBY, ; JACOBY, ; JACOBY, ; JACOBY, ; JACOBY, ; University of Missouri−Columbia; *mjj9bc@mail.missouri.edu*
Ontogeny and complexity of the mandibular symphysis of crocodylians.
Cranial joints mediate feeding−generated forces while forming linkages between the different bones of the skull. The mandibular symphysis, the joint at the chin, is particularly important for understanding feeding function. Alligators and other crocodilians evolved a derived mandibular symphysis adapted to withstand significant forces during feeding behavior. These adaptations include various shapes and sizes of sutural ligaments, Meckel's cartilage and their corresponding osteological correlates. Few studies have quantified patterns of sutural complexity in vertebrate skulls and the crocodylian symphysis provides exemplary material to test patterns of form and function. Using CT data from an ontogenetic sequence of alligators as well as other extant species of crocodylians, we measured parameters describing the complexity of the suture in order to determine patterns of scaling and disparity. The interdigitation index, number of interdigitations and surface area all scaled with isometry in alligators. Symphyses of crocodiles maintain homogenous patterns of suture shape along the length of the joint. Meckel's cartilage is long and rodlike in longirostrine crocodilids whereas it is short and spatulate in alligatorids. These findings suggest the sutural ligament of crocodylian mandibular symphyses forms a strong linkage between mandibles. These new data enable more accurate interpretations of joint and feeding function in fossil crocodilians as well as histological studies of skeletal tissue growth and adaptive plasticity.

60.2 JAFARI, F.*; TAHMASIAN, S.; ROSS, S.D.; SOCHA, J.J.; Virginia Tech; *jafari@vt.edu*

A theoretical investigation of stability characteristics of flying snakes using n−chain modeling: is gliding possible without undulation?

Flying snakes of genus *Chrysopelea* are able to glide by flattening their entire body and using it as a morphing wing. The most prominent feature of the snake's gliding behavior is undulation, in which the snake assumes an S−shaped configuration and sends high−amplitude traveling waves posteriorly down the body. The role of this highly dynamic postural reconfiguration in the snake's control system is unknown; in particular, how the snake remains stable in the pitch, roll, and yaw directions is not understood. Because undulation periodically redistributes mass and aerodynamic forces, and therefore provides averaged' bilateral symmetry, it has been suggested that undulation is required for stability. Here, we investigated the fundamental dynamics and stability characteristics of an airborne flying snake by developing a series of theoretical n−chain multi−body models. The models were simulated in 3D under the action of gravity and aerodynamic forces using experimentally obtained lift and drag coefficients. Linearization of the equations of motion about their equilibrium solutions showed controllability of those solutions, and stable glide trajectories of the nonlinear equations were found with a closed−loop control. Our results show that it is possible for a chain of snake−like airfoils with sufficient number of links to be controlled to move through the air while maintaining a static configuration. This theoretical modeling suggests that undulation is not strictly necessary for flying snakes to maintain stability while gliding. Partially supported by NSF 1351322.

97.5 JAGNANDAN, K.*; HIGHAM, T. E.; University of California, Riverside; *kevin.jagnandan@email.ucr.edu*

A tale without a twist: The impacts of tail restriction and autotomy on locomotion in geckos

Tail autotomy is an escape strategy commonly observed in lizards that involves the voluntary shedding of the tail in response to a predatory stimulus. In leopard geckos (*Eublepharis macularius*), the tail accounts for one−third of the body length and one−fourth of the animal's mass. Recent data suggests that rapidly losing this large caudal mass results in an anterior shift of the center of mass and consequent kinematic adjustments during steady locomotion. However, in addition to a loss of mass, autotomy may also result in the loss of a hypothesized locomotor function of the tail. Lateral undulations of the tail are suggested to contribute to balance and stability. Therefore, we hypothesize that restricting tail movement while walking will have similar effects to autotomy on body and limb kinematics. In contrast, if tail undulations do not contribute to locomotion, body and limb kinematics should remain unchanged after restricting the tail. Leopard geckos (n=10) were filmed walking on a level surface under three conditions: (1) original tail intact, (2) restricted tail, and (3) autotomized tail. Tails were immobilized by attaching a stiff graphite rod (< 1 g) along the length of the tail. 3D kinematics of the body, fore− and hindlimbs were assessed in 3−5 strides per individual per treatment. Restricting the tail resulted in a greater angle of rotation and rotational velocity of the pelvic girdle as the gecko attempted to compensate for not being able to undulate the tail. Additionally, an immobilized tail resulted in decreased femur depression and knee angles, similar to the response to autotomy. These results suggest that tail undulations play a role in maintaining stability during locomotion, a role that is lost after autotomy. Supported by NSF IOS−1147043 and the UCR Newell Fund.

P1.191 JAMES, WR*; MCCLINTOCK, JB; Univ. of Alabama at Birmingham; *wrjames@uab.edu*

An evaluation of phenotypic plasticity in the early life history of the freshwater amphipod Hyalella azteca in response to a predator−related−cue

Early life exposure to certain environmental factors can have drastic effects on a developing organism's phenotype. Many species have been shown to change morphology and behavior when in the presence of a predator. The amphipod *Hyalella azteca* is a widely used model organism in toxicology studies, but few studies have explored the effects predators may have during development. One of the primary prey of juvenile longear sunfish (*Lepomis megolatis*) is amphipods (e.g., *H. azteca*). The present study investigates various growth metrics of juvenile *H. azteca* when exposed to predator−related cues (kairomones). Amphipods were placed into replicate containers both as isolated individuals and as groups of three individuals and then exposed to either water containing kairomones from the longear sunfish or water alone (control) for a period of 30 days. Morphometric measurements were taken on day 10, 20, and 30 to track the morphometrics of growth. After the exposure period amphipods were tested for behavioral responses. The results will be interpreted based on our hypothesis that individuals exposed to the longear kairomones will develop a phenotype that reduces vulnerability to fish predation.

S12.11 JAMNICZKY, Heather A*; ROGERS, Sean M; University of Calgary, Canada; *hajamnic@ucalgary.ca*

Integrating approaches to biomechanics: developmental phenogenomics of stickleback evolution

The tight fits between form and function in organisms suggests the influence of adaptive evolution in biomechanics; however, the prevalence of adaptive traits, the mechanisms by which they arise and the corresponding responses to selection are subjects of extensive debate. Recent work is demonstrating that an integrative approach, combining the study of genetics and development with a more thorough approach to phenotypic variation, has the potential to render insight into adaptive divergence more tractable. Because organisms are integrated to function as a whole, associations between quantitative traits of evolutionary interest are predicted to arise from correlated selection or for genetic reasons. Adaptive changes in trophic morphology in fishes are particularly relevant from this perspective, as trophic specializations are often a key component of rapid diversification within lineages. The threespine stickleback (*G. aculeatus*) provides an intriguing natural framework in which to examine adaptive diversification in the trophic apparatus using an integrative approach: this organism has undergone rapid, repeated evolution from marine to transitional and freshwater habitats, and during the course of these transitions has adapted to occupy different trophic niches within the water column. We characterized phenotypic covariation structure within the stickleback trophic apparatus and its supporting structures in wild and controlled crosses of fish, revealing a key role for development in facilitating rapid evolutionary change. Further, integrating covariation structure and quantitative trait locus analysis holds tremendous promise for establishing new links between genes, development, biomechanics and the environment.

106.5 JANDZIK, D.; STOCK, D.W.*; University of Colorado, Boulder; Comenius University, Bratislava, University of Colorado, Boulder; *David.Stock@Colorado.edu*

Retention of ancestral developmental potential for dentition in the teleost fish Astyanax mexicanus

Dentition in ray−finned fishes was ancestrally widespread throughout the oropharyngeal cavity, with a predominant evolutionary trend being tooth loss in the central region and retention in anterior and posterior ones. Reversal of this trend is rare but has occurred in a number of groups. We showed previously that competence to respond to transgenic overexpression of a tooth initiation signal (the TNF family ligand Ectodysplasin − Eda) with the production of ectopic teeth is limited to the posterior pharynx of the zebrafish. This result is consistent with the evolutionary conservation of tooth location in the order Cypriniformes, to which the zebrafish belongs. Here we show that similar overexpression of Eda in the Mexican Tetra (*Astyanax mexicanus*), a member of the related order Characiformes, results in the appearance of ectopic teeth in the central oropharynx, both on anterior gill arches and on several bones of the palate. Among these latter bones are ones that variably bear teeth in characiforms, as well as others on which teeth have been regained after long absence in some advanced spiny−rayed fishes (Acanthopterygii). Our results suggest variable retention of the developmental potential for dentition among lineages of fishes. In addition, they implicate alterations in Eda signaling in the loss and reappearance of teeth in vertebrate evolution.

4.5 JASTREBSKY, R/A*; BARTOL, I/K; KRUEGER, P/S; Old Dominion Univ.. Norfolk VA, Old Dominion Univ., Norfolk VA, Southern Methodist Univ., Dallas TX; *rwigt001@odu.edu*

Hydrodynamics of turning in squid

Turning manuevers comprise a large portion of aquatic animal swimming performance, yet little is known about turning hydrodynamics of many swimmers, including squid, which employ a dual mode propulsive system involving flexible, paired fins and a pulsed jet that can be directed within a hemisphere below the body. While 2D velocimetry approaches are useful for examining the individual contribution of either a fin or the jet, 3D velocimetry approaches, such as defocusing digital particle tracking velocimetry (DDPTV), provide more complete information about how the jet and fin components work together to accomplish turning maneuvers. Multi−camera high−speed videography and DDPTV were used to collect kinematic and hydrodynamic data of brief squid *Lolliguncula brevis* during turns. Matlab code was used to analyze body kinematics and calculate impulse and angular impulse for the fins and jet. Several broad turning categories were identified, including wide sweeping turns, tail−first and arms−first sharp turns, and vertically oriented turns. While flow patterns and impulse magnitude varied among the categories, the jet generally created larger impulses than the fins during turns. Fin flows were complex with both isolated vortex rings and regions of elongated tubular vorticity being observed. One common pattern involved one fin acting as a brake while the other fin flapped/undulated to produce propulsive flows. Interactions between jet and fin vorticity were also commonly observed. This study demonstrates that both the fins and jet play important roles in turning and that 3D approaches can provide important insights into turning performance.

P3.103 JAWOR, J*; JACKSON, J; University of Southern Mississippi; *jodie.jawor@usm.edu*

Behavioral and physiological impacts of non−traditional nest box use in Eastern Bluebirds

The eastern bluebird (*Sialia sialis*) is a species of conservation interest. Destruction of habitat and introduction of nesting resource competitors (bluebirds are obligate secondary cavity nesters) led to a reduction in populations across their range. Bluebird recovery has been strongly assisted by their ready adoption of artificial nesting cavities. Traditionally nesting cavities or nest boxes have been wooden in construction; this mimics what bluebirds naturally use, and non−traditional materials were feared to be potentially dangerous or damaging to the individuals using them. Here we report on the development and use of nest boxes constructed from recycled ammunition storage cases. Ammunition cases are approximately the same dimensions as a traditional wooden box and only need an opening drilled in them before use. At the study site (Camp Shelby Joint Forces Training Center, Hattiesburg, Mississippi, USA) bluebird pairs using traditional wooden boxes were compared for a number of behavioral and physiological variables to pairs using metal nest boxes. We have found no differences in the size of offspring produced in wooden versus metal boxes and feeding rates of pairs did not differ based on whether they were using a wooden or metal box, although pairs using metal boxes tended to make more feeding trips. Analyses of nestling growth, adult incubation behavior, and the hormone corticosterone are ongoing. Tentatively we see no issues with the use of metal nest boxes, although some precautions may need to be taken with respects to placement of boxes in the environment. Additionally, future assessment of individuals using or being produced from these boxes is needed to determine if there is any longer term impact.

P1.8 JAY, KR*; COBLENS, MJ; BOYER, SL; Macalester College; *boyer@macalester.edu*

New species of mite harvestmen from Queensland, Australia identified using molecular data and morphology

Mite harvestmen (Arachnida, Opiliones, Cyphophthalmi) are a globally distributed suborder of tiny arachnids inhabiting leaf litter and cave habitats. These animals are extremely dispersal−limited, making them ideal for fine−scale historical biogeographic studies. The mite harvestmen that are endemic to Queensland, Australia are members of the genus *Austropurcellia*, and the highest diversity of species is found in the rainforests of the Wet Tropics in the northernmost part of *Austropurcellia*'s range. In the current study, as part of ongoing efforts to document the diversity of these animals, we collected and identified specimens from 16 localities, including animals that represent two new species. Specimens were hand−collected after sifting leaf litter. We amplified and sequenced DNA for two mitochondrial loci, 12S and COI, which are known to be useful for species delimitation of mite harvestmen, and added them to our lab's growing dataset. Phylogenetic analyses were performed in MrBayes. Males from select localities were dissected and mounted on stubs for viewing in a Scanning Electron Microscope (SEM) to assess morphological differences within and between species. Both molecular and morphological evidence support the discovery of two new species, each of which is known from four localities from the central uplands region of the Wet Tropics. Furthermore, biogeographic patterns have emerged in the phylogeny of *Austropurcellia*, with well−supported clades distributed within distinct geographic areas. Further work in modeling rainforest stability over time will allow for detailed exploration of the link between habitat stability and diversity of mite harvestmen within the Wet Tropics.

40.1 JAYARAM, K*; FULL, R.J.; University of California Berkeley; *kaushikj@berkeley.edu*

Body size limit predictions for mechanically mediated maneuvers

In nature, animals perform a variety of maneuvers to negotiate complex terrain and escape from predators. During rapid behaviors, when neural control systems are less effective due to delays or bandwidth constraints, small animals utilize alternative, yet equally effective, mechanically mediated strategies to ensure successful performance. Small locomotors use their bodies to absorb energy during collisions and objects to redirect and deflect their motion. Larger animals cannot use these mechanical strategies without severe injuries, because viscoelastic body elements are size−dependent. Here, we present a model for scaling of body mechanics assuming Kelvin−Voigt behavior. Assuming dynamic similarity for the scaling of body velocity as a function of mass (M), we expect velocity to scale as $M^{0.16}$, closely agreeing with data on the maximum running speed of animals at $M^{0.17 \pm 0.04}$. Thus, possible kinetic energies relative to body mass (KE_{max}) increase according to the power law $M^{1/3}$. We find the ability to dissipate energy per unit mass (EA_{max}), calculated as a product of the material toughness and cross−section area of the animal, is also size−dependent, ($M^{-1/3}$), placing small animals at a definite advantage. KE_{max} and EA_{max} functions intersect showing that beyond a critical body mass (<1 kg), the animal's entire kinetic energy cannot be fully dissipated without undergoing irreversible plastic deformation. Therefore, we predict that animals smaller than 1 kg can employ mechanically mediated maneuvers. Although collisions with objects appears to be an inelegant control strategy, relying on the robustness of a body's mechanical systems represents a paradigm shift for understanding control in both small animals and robots.

CXL.CXL JAYAWARDENE, S.A.*; JIMENEZ, A.G.; DOWD, W.W.; Loyola Marymount University; *sjayawar@lion.lmu.edu*

Metabolic rates and antioxidant capacities of intertidal mussels vary between sites and with recent experience

The ribbed sea mussel *Mytilus californianus* exhibits inter−individual variation in physiology due to inherent and environmental factors. This study aims to quantify several aspects of variation between sites and among individuals by measuring whole animal metabolic rate, oxyradical absorbance capacity, and catalase activity before and after common gardening. Mussels were collected at Hopkins Marine Station from two different field sites, one exposed and one protected, which varied significantly in thermal regime. One group of mussels from each site was immediately exposed to controlled thermal stress to examine patterns of variation when individuals retained physiological "memory" of their recent thermal experience in the field. The remaining mussels were common gardened for 28 days in order to eradicate residual effects of environmental factors and to observe inherent variation. Metabolic rates of individuals decreased following common gardening, and individuals' rank among the entire sample remained consistent among mussels from the exposed but not the protected site. In addition, mussels from the exposed site had faster metabolic rates than those from the protected site; this trend persisted after common gardening. Mean catalase activity and the amount of inter−individual variation in activity also decreased through common gardening in mussels from both sites. Individuals from the exposed site had lower catalase activity compared with mussels from the protected site after common gardening. Mussels freshly collected from the exposed site responded differently to thermal challenge than did mussels from the protected site. Overall, our data suggest that both site of collection and recent environmental experience contribute to the metabolic status of individual mussels.

52.1 JENSEN, M.M.*; STIMPERT, A.K.; FRIEDLAENDER, A.S.; ABERNATHY, K.; POTVIN, J.; GOLDBOGEN, J.A. ; Stanford Univ., Moss Landing Marine Labs., Oregon State Univ., National Geographic, St. Louis Univ., Stanford Univ. ; *mmjensen@stanford.edu*

Mechanics of breaching humpback whales

Breaching is one of the most iconic behaviors among aquatic vertebrates, yet fundamental questions remain unanswered regarding how and why these maneuvers are performed. In addition to being a spectacular biomechanical event, breaching may have important implications for many physiological and behavioral processes. Breaching in baleen whales is hypothesized to occur for several reasons: parasite removal (e.g. barnacles and remoras), as a communicative social behavior, or it may simply be enjoyable for the animals. Because breaching often involves a full departure of a large body from the sea surface, the kinematics leading up to and during the breach may be an important test of maximum locomotor performance. In order to quantify the kinematics of this behavior, we analyzed multi−sensor and video data from suction−cup tags attached to humpback whales (*Megaptera novaeangliae*) that breached. First, we assessed the stereotypy of breaching behavior among tagged individuals (adults and one calf) by analyzing changes in depth, body orientation (pitch, roll, yaw), velocity, and fluke stroke rate. We integrated these kinematic data with estimated morphological data into a mathematical model of ballistic trajectory to predict maximum breaching height as a function of animal velocity and mass. Using this predictive model, we estimated the energetic demands for a given breaching event and compared those values to other high performance maneuvers, such as lunge feeding. Lastly, we extended our model to the upper limits of body mass observed in baleen whales to explore the physical limits of breaching.

20.5 JEWELL, C.P.*; RESSLER, J.; HANGARTER, R.P.; MOYLE, L.C.; Indiana University Bloomington; *cpjewell@indiana.edu*

Variation in floral behavior is associated with circadian clock genes and ecological differences in the wild tomato clade

Many long−lived flowers have a diurnal pattern of opening and closing which determines how long they stay reproductively available during periods of pollinator activity. In the wild tomato clade (*Solanum* sect. *Lycopersicum*) there is variation in this floral behavior: flowers of Awake' species open before sunrise and close after sunset, while flowers of Sleepy' species open significantly later and close significantly earlier in the day. In this study, we 1) characterized the reproductive behavior of 10 species in the wild tomato clade as Awake' or Sleepy,' 2) assessed ecological variation among species to identify selective conditions associated with behavioral variation, and 3) examined the genetic basis of this trait using a recombinant F2 population segregating for this behavior. First, we found that floral opening and closing was a repeatable and diurnal behavior in a common garden across all four Awake' and six Sleepy' species. Second, using georeferenced climate data, we found that Awake' species tend to be at lower elevation and in environments that are more arid and experience more temperature variation, compared to Sleepy' species. Third, an F2 population was created from a cross between Awake' and Sleepy' parent species, and we screened both parents and F2s for allelic variation in known circadian clock genes. F2 segregation patterns indicate that behavioral variation is due to at least three loci. Patterns of association between circadian clock genotypes and floral phenotypes implicate PhytochromeA (a cytoplasmic photoreceptor) as one of these loci. This work broadens our understanding of how selective conditions could shape floral circadian rhythms, and the genetic underpinnings of such reproductive behaviors.

32.6 JIMENEZ, A.G.; COOPER−MULLIN, C. *; ANTHONY, N.B. ; WILLIAMS, J.B.; The Ohio State University, University of Arkansas; *ccooper−mullin@my.uri.edu*

Cellular metabolic rates in cultured primary dermal fibroblasts and myoblast cells from fast−growing and control Coturnix quail

Although fibroblast cells have been used in pivotal experiments in medicine, physiology, physiological−ecology and conservation biology, the link between the physiology of fibroblasts and the physiology of other cell types of the same animal is unknown. Dermal fibroblasts play an important role in cutaneous wound repair, and in generating new connective tissues, but were thought to be metabolically inactive until needed to mend tissue damage. Therefore, the question remains, are fibroblasts a good representative model system for the metabolic profile of the whole organism, as compared with cells isolated from other tissues? To determine whether fibroblasts have the same cellular metabolic profile as myoblasts cells isolated from muscle, we cultured myoblasts and fibroblasts from two lines of Japanese quail (Coturnix coturnix japonica), one that had been artificially selected for fast growth for over 60 generations and a control line. The lines were paired in each individual quail. Isolated primary fibroblasts and myoblasts from the fast−growth line had higher rates of oxygen consumption, glycolysis and higher mitochondrial volume than cells isolated from the control line. These findings indicate that fibroblasts are a representative system on the cellular level for a whole organism metabolic signature. Additionally, fibroblasts had higher rates of metabolism for every parameter measured, including rates of oxygen consumption, glycolysis and mitochondrial volume, than myoblast cells isolated from the same individual.

59.4 JIMENEZ, A.G.*; JAYAWARDENE, S.A.; DOWD, W.W.; Loyola Marymount University; *ajimen25@lmu.edu*

Micro−scale spatial variation in body temperature and physiological abilities to cope with oxidative stress in the ribbed sea mussel, Mytilus californianus.

Rocky intertidal populations are routinely subjected to receding tides coupled with increases in body temperatures, leading to fluctuating physiological demands and stress. This dynamic thermal variation is compounded by within−site variation in individuals' body temperature. For example, data from our first field season have confirmed that in *Mytilus californianus*, the ribbed sea mussel, variation in body temperature among adjacent individuals can exceed 6ºC, a range comparable with between−bed and regional−scale mean differences. This micro−scale variation represents a potentially critical caveat to the conclusion that a number of species currently live close to their thermal tolerance limits; rather, only a subset of individuals within a species are likely to do so. We assessed mechanistic consequences of micro−scale variation in body temperature within this species by abolishing such variation and quantifying several aspects of their physiology. Individuals were assayed 1) directly from the field, 2) after common gardening in the laboratory for 1 month, and 3) after outplanting individuals back into the field after common gardening. We measured whole−organism metabolic rate; tissue catalase activity, glutathione reductase activity, and total antioxidant capacity; and reactive oxygen species (ROS) production in hemocytes. Some individuals were used for baseline correlations at the control temperature (13°C), and others were assayed following exposure to controlled thermal challenges. Here we correlate individuals' body temperature and ROS production in hemocytes to physiological abilities to cope with oxidative stress associated with thermal extremes.

P2.174 JIMENEZ, Y.E.*; MACDONALD, I.; GIBB, A.C.; Northern Arizona University; *yej2@nau.edu*

When is a C−start not a C−start? Escape behavior in the English Sole (Parophrys vetulus)

Like other teleosts, young flatfishes produce escape responses by imparting momentum to the water using the lateral aspect of the body. After metamorphosis, however, older flatfishes dwell on the seafloor and must produce the escape movement while their lateral aspect is in contact with the substrate. How do benthic−based escape movements compare to those performed by fish in the water column? We used high−speed video to capture images of *Parophrys vetulus* performing escape responses from the benthos and compared these behaviors to midwater escape behaviors in larval flatfishes and other teleosts. Benthic−based escapes begin with an upward head movement, while the tail remains against the substrate. Flatfish then peel the anterior body off of the substrate, accelerating the body vertically (~90° to the substrate). Finally, the tail follows the path of the head, at which point the fish leaves the substrate and moves into the water column. The fish then forms a whole−body bend toward the substrate and glides to the bottom. The differences between midwater and benthic escapes are as follows. (1) Phase 1 of a midwater escape is characterized by a C−shaped bend on the side of the body contralateral to the negative stimulus; phase 1 of a benthic escape is characterized by a J−shaped bend ipsilateral to the negative stimulus. (2) Phase 2 of a midwater escape is characterized by a wave of bending along the ipsilateral posterior body, which creates a tail−beat; phase 2 of a benthic escape is characterized by the contralateral side of the fish bending toward the substrate. The unusual kinematic features of the benthic escape response suggest that benthic−based escapes may be driven by a modified motor pattern produced by the Mauthner neurons, or perhaps even by an entirely new motor pattern.

P1.62 JING, DJ*; WANG, VR; VILLARREAL, CM; DARAKANANDA, K; SUZUKI, Y; Wellesley College; *vwang2@wellesley.edu*

The recruitment of Hedgehog signaling during the evolution of larval morphology

The origin of metamorphosis is one of the biggest mysteries in insect evolution. In particular, the evolution of the larval morphology remains poorly understood. To identify the mechanism underlying the development of the specialized larval appendage morphology, the role of Hedgehog (Hh) signaling was examined in two insects: a hemimetabolous insect, the large milkweed bug, *Oncopeltus fasciatus*, and a holometabolous insect, the red flour beetle, *Tribolium castaneum*. RNA interference−mediated knockdown of the components of the Hh signaling pathway showed that Hh is required for both larval limb maturation and outgrowths in *Tribolium castaneum*, but only for limb maturation in *Oncopeltus fasciatus*. Our findings suggest that Hh signaling plays both shared and derived roles in limb development of hemimetabolous and holometabolous insects. In addition, the relationship between endocrine regulators of metamorphosis and Hh signaling will be discussed. We will present a model for the evolution of metamorphosis in which Hh signaling was co−opted for larval appendage outgrowth, conferring sensitivity to endocrine regulators responsible for metamorphosis.

21.6 JINN, J.*; NIRODY, J.; JUSUFI, A.; LIBBY, T.; JACOBS, L.F.; FULL, R.J.; University of California, Berkeley, University of Cambridge; *judyjinn@berkeley.edu*

Quadrupedal locomotion on the water's surface by geckos

Lizards are known to swim by tucking their limbs next to their body then undulating their body and tail. However, Basilisk lizards can run bipedally on water surfaces. Field observations in Southeast Asia revealed that house geckos rapidly locomote on the water's surface quadrupedally. Here, we describe surface water locomotion in the non−aquatic house gecko (*Hemidactylus frenatus*, svl: 57.9±1.8mm, weight: 5.7±0.5g). While these lizards used typical undulatory motions at low velocities, we observed kinematics with similarities to Basilisk lizards when house geckos reached velocities higher than approximately 40 cm/s. At these velocities (62.8±9.7cm/s), all four limbs exit the water and stroke downwards creating air cavities, allowing geckos to lift their head and front−torso high out of the water. Similar to rapid terrestrial trotting, house geckos showed a stance (20.0±4.0ms) and swing (45.8±9.8ms) corresponding to a duty factor less than 0.5. We show that the height of the forelimb above the water is strongly correlated with forward velocity. This is likely due to the positive relationship between forelimb height and the magnitude of slap impulse. By analyzing the relationships of Bond, Reynolds and Weber Numbers, estimates using hydrodynamic models of maximum slap and stroke impulses predict that house geckos are incapable of producing forces large enough to lift their entire body weight out of the water to produce "true" water running. However, the upward forces produced still appear to benefit the animals by allowing them to move faster than regular swimming. Quadrupedal surface locomotion may have important behavioral consequences in nature.

78.1 JO, H.S.; PARK, W.G.*; JEONG, G.S.; IM, Y.J.; Kunsan National University, Gunsan, Korea , Pukyong National University, Busan, Korea, West Sea Fisheries Research Institute, NFRDI, Incheon, Korea, West Sea Fisheries Research Institute, NFRDI, Incheon, Korea; *wpark@pknu.ac.kr*

Population study of commercial shrimps near Kanghwa Island in the mid−western coast of Korea

Populations of commercial shrimps were investigated near Kanghwa Island, where influenced by freshwater input of Han−River, in the mid−western coast of Korea. Shrimps were monthly collected by a stow−net at three stations from April to December in 2012. Zooplankton was also sampled to investigate the larval recruitment of the shrimps in the research area. Water temperatures and salinities were simultaneously measured, using an YSI. Water temperatures ranged from 3.7−27.2°C, which was the highest in August and the lowest in April. Salinities were fluctuated during the summer months from 16.4−28.7 PSU, being resulted from river freshwater inputs. Shrimp harvests were relatively higher in September and October while they were relatively lower July and August than other months. Among shrimp species, Exopalaemon carinicauda and Leptochela gracilis were dominant in March to July, while Acetes chinensis was dominant from September to November. In December, Palaemon gravieri and E. carinicauda predominated. Mean carapace length of A. chinensis and E. carinicauda increased from March to July. Small sizes of A. chinensis occurred from September. Mean carapace length of L. gracilis increased from March to June and a new generation was recruited in July. Any larvae of above commercial species was not found from plankton samples. A. chinensis, L. gracilis and E. carinicauda had two generations while P. gravieri had one generation in a year. In conclusion, the population structures of commercial shrimps varied with species and seasons in the research area. Also, larvae of above commercial shrimps might not be recruited from locally produced populations.

P1.199 JODREY, A.D.*; LUOMA, R.L.; STAHLSCHMIDT, Z.R.; Georgia Southern University; *zstahlschmidt@georgiasouthern.edu*

Consequences of complex environments: Temperature and energy intake interact to influence growth and metabolic rate

The field of comparative physiology has a rich history of elegantly examining the effects of individual environmental factors on performance traits linked to fitness (e.g., thermal performance curves for growth or locomotion). However, animals live in complex environments wherein multiple environmental factors vary simultaneously. Thus, we investigated the independent and interactive effects of temperature and energy intake on the growth and metabolic rate of juvenile corn snakes (*Pantherophis guttatus*) in the context of shifts in complex environments. Unlike previous studies that imposed constant or fluctuating temperature regimes on animals, we manipulated the availability of preferred thermal microclimates (control *vs.* warmer−than−preferred regimes) for eight weeks and allowed snakes to behaviorally thermoregulate among microclimates. By also controlling for energy intake, we demonstrate an interactive effect of temperature and energy on growth relevant temperature shifts had no effect on snakes' growth when energy intake was low and a positive effect on growth when energy intake was high. Thus, acclimation to warmer−than−preferred thermal options can result in increased rates of growth in a taxon in which body size confers a fitness advantage. Temperature and energy also interactively influenced metabolic rate snakes in the warmer temperature regime exhibited reduced metabolic rate (O_2 consumption rate at 25°C and 30°C) if they had relatively high energy intake. Although we advocate for continued investigation into the effects of complex environments on other traits, our results indicate that warming may actually benefit important life history traits in some taxa and that metabolic shifts may underlie thermal acclimation.

P2.22 JOHANSON, Z.*; CLOSE, R. A. ; TYLER, J. C. ; FRIEDMAN, M.; Natural History Museum, London, Univ. of Oxford, Oxford, Smithsonian Institution, Washington; *z.johanson@nhm.ac.uk*

A remarkable new beaked tetraodontiform fish from the early Eocene London Clay Formation, UK

Pufferfishes and relatives (Acanthomorpha: Tetraodontiformes) are a taxonomically diverse, morphologically disparate, and widely−distributed group, including model genomic species (e.g., *Fugu rubripes*, *Tetraodon nigroviridis*), but whose phylogenetic relationships remain problematic, particularly with respect to the beak−toothed gymnodonts. The tetraodontiform fossil record is rich and well−studied, but mostly limited to flattened fossils. These fossils present unusual combinations of tetraodontiform characters relative to extant groups (e.g., *Eospinus*, *Eoplectus*), indicating their importance to reconstructing tetraodontiform relationships as a whole. However, a new 3D−preserved beaked tetraodontiform from the early Eocene (London Clay Formation, Ypresian; 53 Ma) provides an opportunity to study the skull and postcranial skeleton in detail, via micro−CT tomography. This new tetraodontiform is coeval with the oldest crown−tetraodontiforms, and again presents unprecedented character combinations, including a fused beak comprising individual teeth with prominent dorsal fin spines inserting anteriorly along the skull, supported by dorso−ventrally flattened and expanded proximal radials. This combination supports homoplasy in the evolution of beaked dentition (gymnodont tetraodontiforms) or dorsal−fin anatomy (absent in gymnodonts, but present in various tetraodontiforms, including monocanthids and balistids, possessing a more typical teleost dentition). The unusual morphologies apparent in this new tetraodontfiorm, along with other fossil taxa, are particularly relevant in the context of recent molecular analyses that strongly refute the monophyly of beaked gymnodont puffers, a group recovered by studies of comparative morphology.

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Interrogation of cricket germ line development by Vasa transgenic analyses and Wnt pathway knockdowns

Germ line cells are essential for propagation of a species. Despite their importance, the origin of germ line cells in mammals (also called primordial germ cells) has remained elusive. The cricket *Gryllus bimaculatus* is an emerging model organism that holds promise for elucidating a number of biological questions, including the development and evolution of the germ line. Currently, germ line development in this invertebrate is largely uncharacterized. As a basally branching species, analysis of *G. bimaculatus* germ cell development holds both independent scientific merit and the ability to contribute significantly to comparative analyses of germ line development across species, especially in a contrast to the highly derived mode of development in the fly *Drosophila melanogaster* which has been thoroughly investigated. To this end, we have investigated the expression of the known vertebrate germ line marker *vasa* and confirmed that *vasa* expression becomes upregulated in cells as they acquire germ cell fate in *G. bimaculatus*. One overall aim is to create visual documentation of the lineage of *vasa* expressing cells through the use of transgenic techniques and time lapse photography; in doing so we seek characterize a precise spatiotemporal expression pattern of *vasa* and a cell lineage map of cricket germ line development. In vertebrates, expression of Wnts plays an important role in embryo patterning and primordial germ cell development. Independent but complementary to the investigation of *vasa* lineages, we are performing RNA interference (RNAi) knockdowns for members of the Wnt pathway, and determining whether germ cell formation or development requires Wnt signaling by assaying the number of germ cells present at midembryonic stages.

P1.181 JOHNSON, A.K.A*; MORAN, C.; DICKSON, K.; GIBB, A.C.; Northern Arizona University, California State University, Fullerton; *aj529@nau.edu*

Locomotor behaviors exhibited by California Grunion Leuresthes tenuis during spawning runs on southern California beaches vary with environmental conditions

California grunion (*Leuresthes tenuis*) face an unusual set of physical challenges when they emerge onto sandy beaches to spawn. Are locomotor behaviors produced by grunion associated with particular environmental conditions? Grunion were filmed spawning on Cabrillo Beach (CA) in May 2014 with a camcorder (120 fps). Data were analyzed in a series of five−second clips during which at least five individuals were moving throughout the sampling period. We observed tail flip jumping (a fish rotates its head over the posterior body, then pushes the tail against the substrate and leaps into the air), swimming−like movements (cyclical undulation in the posterior body), and two previously undescribed behaviors: "inching" and "frontfliping." During inching, the fish presses the tail and head onto the substrate, then elevates the center of mass and displaces it laterally. During frontfliping, a fish plants its head on the substrate and pushes the tail against the substrate to rotate the tail about the head; at the end of the movement, the tail is positioned ~180° from the starting point. Tail flip jumping was usually observed in high density conditions and where the substrate was variable. Swimming−like movements were produced only when water was present. Inching and frontflip movements were observed at low fish densities, when there was no wave action, and where the substrate was composed of small particles. Inching and swimming−like movements were used to move rapidly in a direct path, while jumping and frontfliping were used to navigate obstructions. Grunion employ diverse locomotor behaviors when faced with physical obstacles and heterogeneous substrates in the sandy intertidal zone.

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Effects of the xenoestrogen 4−nonylphenol on endocrine physiology of the estuarine arrow goby Clevelandia ios

Recent evidence indicates that some of California's coastal estuaries are contaminated with 4−nonylphenol (4−NP), but it is not yet known whether the organisms inhabiting these environments are experiencing health impacts from this contamination. The chemical 4−NP is established as an endocrine disrupting compound that has estrogenic properties, and 4−NP exposure has been shown to alter testicular structure, decrease sperm counts, and cause intersex gonads in fish. In California's estuaries, some of the highest tissue burdens of 4−NP recorded worldwide were found in the benthic intertidal arrow goby (*Clevelandia ios*). Here, we examined the impacts of 4−NP exposure for endocrine and reproductive function in the arrow goby, with the dual aims of validating biomarkers induced by xenoestrogen exposure in this species and determining the time course of detectable biomarker responses to 4−NP. Adult male arrow gobies were exposed in seawater (33 ppt) to either ethanol vehicle control (negative control), 17²−estradiol [E2] at 50 ng/L (positive control), 4−NP at 5 ¼g/L (low 4−NP dose), or 4−NP at 50 ¼g/L (high 4−NP dose). Fish were sampled at time points of 0 hrs (baseline), 24 hrs, 72 hrs, 12 days, and 20 days after commencing exposures, and relative expression levels of several estrogen−responsive genes (e.g., vitellogenin A [vtgA], vitellogenin C [vtgC], choriogenin L [cgL], choriogenin H [cgH]) were quantified using quantitative real−time RT−PCR. Exposure to E2 significantly elevated liver cgL and cgH mRNA levels within 24 hrs, liver vtgA within 72 hrs, and vtgC within 12 days. Our data thus far suggests that exposure of gobies to the high dose of 4−NP induced moderate elevations in liver choriogenin and vitellogenin transcript abundance, indicating the utility of quantifying mRNA levels of these genes as biomarkers for xenoestrogen exposure in this species.

32.1 JOHNSON , JG*; PAUL, M; KNIFFIN, CD; ANDERSON, PE; BURNETT, LE; BURNETT, KG; College of Charleston;
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Deep sequencing of the hepatopancreas transcriptome reveals new isoforms of hemocyanin and their regulation in response to low O2/high CO2 in the Pacific whiteleg shrimp, Litopenaeus vannamei

Acclimation to low O_2 in many organisms involves changes at the level of the transcriptome. Here we used high throughput RNA sequencing to explore the global transcriptomic response and specific involvement of new isoforms of hemocyanin (Hc) in the multistressor low O_2/high CO_2 response. Hepatopancreas mRNA of juvenile *L.vannamei* exposed to air−saturated water, low O_2, or low O_2/high CO_2 for 4 or 24 h, was pooled, sequenced (HiSeq 2500) and assembled (Trinity: 52,190 contigs) to create a deep strand−specific reference transcriptome. Annotation of the assembly revealed sequences encoding the single large and small Hc subunits, two previously undescribed full−length isoforms of the large subunit, and 12 partial sequences. mRNA of individual shrimp was sequenced (6/treatment); resulting reads were quantified (eXpress) and regulated genes identified from pairwise comparisons at each time (DESeq2). GO term enrichment (Roff− Bentzen; $p < 0.0001$) and PCA analysis demonstrated a distinct pattern of regulation between prolonged low O_2 and low O_2/high CO_2 treatments, showcasing the stabilization of energetically costly translational machinery, mobilization of energy stores, and downregulation of the ubiquitin/proteasomal degradation machinery. The antagonistic effect of CO_2 on the transcriptomic response of Hc subunits to low O_2 was confirmed in this study, and we are exploring the importance of these novel full length and partial isoforms to the structural and functional response of Hc in low O_2 alone and with high CO_2 (NSF IOS−1147008).

59.2 JONASSON, K. A. *; GUGLIELMO, C. G.; University of Western Ontario, Canada; *kjonasso@uwo.ca*
Sex differences in torpor use of spring migrating silver−haired bats (Lasionycteris noctivagans)
Several North American bat species undertake long−distance latitudinal migrations, which are thought to consist of alternating periods of flight and refueling at stopover sites. Recent work in our lab found that silver−haired bats (*Lasionycteris noctivagans*) use a torpor−assisted migration strategy, which dramatically reduces daytime thermoregulatory costs, and increases net refueling rate. Daytime torpor facilitates very brief (1−2 day) stopovers in the fall. However, spring and fall migration pose different challenges. The concurrence of migration and pregnancy in the spring creates a conflict for female bats. Daily torpor use will spare energy stores for migratory flight, but delay fetal development. Thus, sex may substantially affect the energy budgets of spring migrating bats in ways that would not occur during the fall. This hypothesis supported by our earlier finding that female bats have significantly longer stopovers, and had larger fat stores than males in the spring, as would be expected if females incurred higher maintenance costs. Here we investigate sex differences in thermoregulation at stopover in the spring. We predicted that female bats would use shorter torpor bouts, enter torpor at lower ambient temperatures than males. *Lasionycteris noctivagans* were captured in April and May 2014 at Long Point, Ontario, Canada. We measured fat and lean body mass using quantitative magnetic resonance, and fitted each bat with a temperature−sensitive radio transmitter. We tracked bats to their day roost, and measured skin temperature and roost temperature continuously throughout the day. Our data will be used to test our hypotheses about the effects of sex and body composition on torpor use and migratory stopover.

P3.26 JONES, KM*; KRAJNIAK, KG; Southern Ill Univ Edwardsville; *kevijon@siue.edu*
A Comparative Study of Neuropeptides on the Body Wall of Lumbricus terrestris
Our lab has shown thatFMRFamide alters the contractions of the smooth muscle tissues in *Lumbricus terrestris* including the body wall. Recently new annelid FMRFamide−related peptides (FaRPs) have been identified, including tetrapeptides and N−terminally extended peptides, and therefore we decided to examine their effects on the body wall. A body wall strip without the ventral nerve cord was placed in a tissue bath and exposed to increasing concentrations of peptides. Mechanical contractions were recorded on a computer with a Grass force transducer attached to an Iworx A/D converter. FMRFamide increased amplitude with a threshold of 10^{-7} M and decreased rate with a threshold of 10^{-7} M. APKQYVRFamide increased amplitude with a threshold of 10^{-7} M and had a biphasic effect on rate, decreasing it at 10^{-9} M, and increasing it at 10^{-8} M. YMRFamide increased amplitude with a threshold between 10^{-8} and 10^{-7} M and decreased rate with a threshold of 10^{-8} M. AGAYYVRFamide caused a biphasic change in amplitude, decreasing it at 10^{-9} M and increasing it between 10^{-8} and 10^{-7} M and a biphasic rate change, decreasing it at 10^{-9} M and increasing it at 10^{-8} M. YVRFamide increased amplitude with a threshold of 10^{-9} M and decreased rate with a threshold between 10^{-9} and 10^{-8} M. FVRFamide increased amplitude with a threshold of 10^{-9} M, but had no effect on rate. These data suggest that tetrapeptides and N−terminally extended YVRFamides may be acting on different receptors

P1.5 JONES, C.L.*; HAMIDI, H.M.; CUI, H.; RODENHAUSEN, T.; WU, H.H.; THACKER, R.W.; Univ. of Alabama at Birmingham, Univ. of Arizona, Univ. of Arizona; *dr.bob.thacker@gmail.com*
Exploring Taxon Concepts of Sponges (Porifera) through Natural Language Processing of Systematic Monographs
Phylum Porifera contains over 8,000 described sponge species that are represented in systematic monographs ranging from Linnaeus (1759) to Systema Porifera (2002) to now. The concepts underlying the traditional morphological classification of sponges have changed dramatically over the past 100 years, and these concepts often conflict with modern molecular−based phylogenies. To explore and quantify how taxon concepts have changed with advances in both morphological and molecular systematics, we are testing novel natural language processing software, the Explorer of Taxon Concepts (ETC − Beta version), with regional and global systematic monographs of Porifera. ETC enables users to create xml files from the text of semi−structured taxon descriptions, and then parses these files using terms from morphological ontologies and those it discovers from the descriptions. Users then review the terms discovered by ETC, placing the terms into categories (such as anatomical structures, life−history stages, or colorations) and/or combining terms as synonyms. Based on this user feedback, ETC builds a morphological character matrix that incorporates these terms. Users can extensively edit the character matrix, for example, by color−coding data cells and controlling the states that characters can take. Our tests indicate that ETC quickly parses characters associated with numerical measurements, but to assess characters based on the presence or absence of a particular trait, the user needs to carefully categorize the discovered terms.

P1.155 JONES, IT*; MAAS, AM; TARRANT, AM; Woods Hole Oceanographic Inst (WHOI) & Univ Maine, WHOI; *Ian_Jones@umit.maine.edu*
A circadian metabolic rhythm in the cnidarian Nematostella vectensis
Cnidarians exhibit diel rhythms including cycles in locomotor activity, tentacle extension, and spawning. Behavioral and molecular studies conducted in corals and the anemone *Nematostella vectensis* suggest the presence of an endogenous circadian clock. In bilaterian animals, the circadian clock is intimately involved in regulating energetic metabolism; however, circadian regulation of metabolism has not been described in cnidarians. Because *Nematostella* exhibits greater locomotor activity at night, we hypothesized that oxygen consumption would also increase at night. To test this, we entrained *Nematostella* to a 12 h light : 12 h dark cycle (LD), a reversed light cycle (DL) or constant darkness (DD). Oxygen consumption rates were measured during intervals within 24−hour periods using an optical oxygen meter. Contrary to our prediction, respiration rates were highest during the light period under either the LD or DL cycles and during daytime under DD conditions. During a second experiment with higher temporal resolution, respiration rates peaked during subjective afternoon (ZT 6−12, where ZT 0 is 7 am, the time of subjective dawn). Our results suggest that respiration rates in *Nematostella* are under circadian control and that the cycle in respiration rate is not driven by the daily cycle in locomotor activity.

39.5 JONES, BC*; SMITH, AD; BEBUS, SE; SCHOECH, SJ; Univ. of Memphis, Univ. of Rhode Island; *bcjones8@memphis.edu*

Spectating is stressful: witnessing two seconds of a predator attack increases levels of circulating glucocorticoids.

HPA axis activation and glucocorticoid (GC) secretion in response to a predator is well studied, but common methods expose subjects to live or model predators for 15 − 60 min, whereas most predatory attacks are considerable shorter (e.g., < 5 sec). Given the moderate success rates of most predators (< 50%) and many species learn antipredator behavior by observing attacks upon other individuals, escaping or witnessing a predatory encounter occur commonly. Yet, the nature of the assumed stress response from these exposures is largely unknown, including whether these short−lived exposures actually induce a pronounced (or even measurable) GC response. To better understand the nature of the HPA axis response to predation, we measured levels of GCs in wild−caught European starlings (*Sturnus vulgaris*) in response to witnessing a live raptor attack (ca. 2 sec duration) upon a conspecific, witnessing a human attack' (i.e., a researcher handling a conspecific), capture and restraint, and an undisturbed control. GC levels were highest after witnessing a raptor attack (mean ± SD; 34.1 ± 12.4 ng/ml), which paralleled levels in response to capture and handling (34.7 ± 11.0 ng/ml). GC levels were substantially different after witnessing a human attack' (21.3 ± 7.7 ng/ml), and after undisturbed controls (7.2 ± 3.9 ng/ml), which mirrored baseline values (7.1 ± 3.6 ng/ml), Our results indicate that 1) a stimulus lasting only seconds can activate the HPA axis to a similar extent as the widely used capture and restraint protocol, and 2) witnessing a predator attack can be a physiological stressful event in free−living birds, which may affect how birds learn to recognize and appropriately react to predators.

79.5 JONES, A I*; GIBB, A C; Northern Arizona University ; *aj324@nau.edu*

How does the intramandibular joint facilitate feeding in Poecilia mexicana?

The intramandibular joint (IMJ) is located in the lower jaw of several substrate−feeding teleosts and is typically found between the dentary and angular−articular. This secondary jaw joint allows an increased gape angle, which enables the fish to place its jaws in greater contact with attached prey. The IMJ is well documented in marine fishes like parrotfishes and angelfishes, but data for freshwater fish with IMJs are limited. We compared the biomechanics of the IMJ of the freshwater shortfin molly (*Poecilia mexicana*), with two non−IMJ bearing species: the mangrove rivulus (*Kryptolebias marmoratus*), a distant relative of the shortfin molly, and the Western mosquito fish (*Gambusia affinis*), a close relative of the shortfin molly. Dissection, 3D micro−CT scans, and clearing and staining were used to describe and quantify the morphology of the lower jaw. The number of independent bony elements in the lower jaw apparatus appears to be reduced in IMJ−bearing species, while the separation between the angular−articular and dentary is enlarged. Video sequences of feeding events for each species were used to determine the range of motion of the lower jaw and other cranial elements. Bones isolated from micro−CT scans, kinematic data, and the program Blender were used to generate a 3D model of the movements of the IMJ and anterior and posterior elements of the lower jaw during feeding. We predict that bite force and the reliance on suction−based−capture are decreased in the shortfin and other IMJ−bearing freshwater taxa, although we expect IMJ−bearing species will have greater control over lower jaw movements. This study will yield an improved understanding of IMJs in freshwater fish and provide new insight by outlining the biomechanical limitations and advantages of possessing and employing an IMJ during substrate−based feeding.

P1.112 JOSEFSON, CC*; BENTZ, AB; HOOD, WR; WADA, H; Auburn University, University of Georgia; *ccj0011@auburn.edu*

Epigenetic modifications associated with early−life exposure to exogenous corticosterone in Eastern Bluebird (Sialia sialis) nestlings

The perinatal environment an individual experiences can permanently affect adult physiology. In songbirds, the brain is vulnerable to hormonal fluctuations during the first few months post−hatch due to rapid neurodevelopment, particularly in the telencephalic song nuclei. Elevated corticosterone (CORT) during this sensitive post−hatch period is correlated with decreased song quality and glucocorticoid receptor (GR) expression in song nuclei. Post−natal exogenous CORT exposure also permanently elevates baseline CORT in adults. To date, few studies have examined the mechanisms behind this physiological priming associated with changes in the developmental environment. We hypothesized that CORT alters the epigenetic status of the neural GR via DNA methylation, causing changes in the sensitivity of the hypothalamic−pituitary−adrenal (HPA) axis function during adulthood, ultimately lowering song quality and reducing negative feedback to the HPA axis. Here, we administered CORT orally to wild Eastern Bluebird nestlings and examined the methylation status of the GR promoter using bisulfite sequencing. Our results have the potential to impact the understanding of how epigenetics can modify secondary sexually selected processes, such as song as a reflection of the early life environment.

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Morphospaces, Adaptive and Epigenetic Landscapes, Phylogenetic Networks, and n−Dimensional Niches: Re−Visioning Quantitative Biology Education

Morphospaces, Adaptive and Epigenetic Landscapes, Phylogenetic Networks, and n−Dimensional Niches are imaginary worlds constructed upon the basis of theoretical models or the mathematical analysis of multivariate data. Their power often lies not only in aesthetics and the improvement of our conceptual understanding, but also in the planning of experiments, the decisions of what field data to collect, or the re−interpretation of already collected data. How do we help biologists interpret and appreciate the mathematical models and analyses that underlie these imaginary worlds? I will illustrate four models that instantiate the paleontologist Dolph Seilacher's dictum: "I wouldn't have seen it, if I hadn't believed it." Analyses of multivariate, multi−scale nonlinear phenomena require new tools and conceptual approaches. Four of the biological software applications that we have developed are based upon computational geometry, spatial statistics, graph theory, cellular automata, and fractals. Some of the questions that will be addressed are: How do designs emerge without designers? How can complex patterns be generated by simple rules? When do slogans like "survival of the fittest" break down? How do we test trees as hypotheses or ask how tree−like is a network? In this context, mathematics is a lens that helps us see from a perspective. In particular, I believe that if the mathematics is easily accessible to biologists, then they are not only apt to use mathematics, but also they are more likely to understand how mathematics helps them with their work. Furthermore, this approach helps biologists better appreciate Richard Hamming's dictum that: "The purpose of computing is *"insight"*, not numbers.

74.4 JURCAK, AM*; MOORE, PA; Bowling Green State University , Bowling Green State University; *ajurcak@bgsu.edu*

The indirect effect of predation on crayfish decision making, nutrient dynamics, and primary production in streams

Animals make important ecological decisions regarding resource use based on a cost−benefit analysis of predation risk. Such decisions will result in tradeoffs between costs and benefits and ideally will maximize resource use while minimizing predation risks. To investigate ecological decision making under this cost−to−benefit context, we presented a crayfish with a choices of resource rich and poor habitats under different sensory conditions that would mimic a predation event. The simulated predatory event, resource distribution, and resource quality was randomized in the choice area of a y−maze. Because of recent interest in non−consumptive effects of predators on prey behavior, we also tested the impact of simulated predation events on multi−trophic level interactions mediated through crayfish shredding. We quantified potential alterations nutrient levels and primary producer biomass. Trials were seven days with a simulated predatory event placed in streams every 12 hours. The results show that crayfish will make decisions on habitat choice based on the presence of predators as well as the presence and type of resources. As a keystone species, the consequences of these choices and resource use as a result of predation events will alter carbon movement within aquatic habitats. The complexity of habitat and resource distribution as well as the types of predators are critical in the ecological decisions of crayfish and how these decisions impact the environment.

P2.106 KAATZ, I. M.*; STEWART, D. J. ; LOBEL, P. S.; Independent Presentation; *imkaatz@yahoo.com*

Do miniature catfishes vocally communicate with pectoral spine stridulation: testing hypotheses of sound function in the genus Corydoras

Corydoras catfishes produce sounds with microscopic ridges on the base of the pectoral spine. Sounds are a series of broadband frequency pulses greater in duration in courtship than agonism or disturbance for aquarium populations. Sound production is rare for nonbreeding fish, linking the significance of sounds to social and mate interactions for breeding−conditioned individuals. Startle sounds are rare and similar to courtship sounds. Three hypotheses were tested to determine the behavioral significance of courtship and startle sounds: 1) incidental sound hypothesis: incidental by−product of male fin displays during female courtship movements; 2) physiological priming hypothesis: female stimulation or mating synchronization during spawning; or 3) communication hypothesis: species recognition, females assessing male quality or social signals. Courtship sound pulse number correlated with duration: A) *C. paleatus* $n = 56$, $r = 0.91$, $F(1,54)= 277.1$, $p<0.001$; B) *C. leopardus* $n = 56$, $r = 0.90$, $F(1,54) = 225.7$, $p<0.001$; and C) *C. aeneus* $n = 103$, $r= 0.82$, $F(1,101) = 205.3$, $p < 0.001$. Startle sound pulse number correlated with duration ($n = 31$, $r =0.82$, $F(1, 29)=22.5$, $p<0.00005$) for a pooled group of species (*C. aeneus*, $n = 14$; *C. leopardus*, $n = 9$; *C. sychri*, $n = 3$; *C. reticulatus*, $n = 4$; *C. paleatus*, $n = 1$). Courtship associated sounds differ among species suggesting male display. Startle sounds were spectrographically similar across species suggesting an alarm signal to conspecifics or congeners. The presence of temporally patterned sounds in specific behavioral contexts supports the communication hypothesis.

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Demosponges in disguise: Formation of new syncytial tissue in a glass sponge, Aphrocallistes vastus

Within the Phylum Porifera, glass sponges (Class Hexactinellida) are an anomaly. As a group, they are almost completely restricted to the deep sea, they can fuse their skeletons into rigid scaffoldings of glass, and most remarkably, they are the only animal group whose whole body organization is syncytial rather than cellular. Hexactinellid larvae are cellular until the 32−cell stage, when cells begin to divide unevenly and fuse together. The sponges are then syncytial for the rest of their lives. While the formation of the larvae is well described, how adult hexactinellids grow and produce new syncytial tissue is unknown. We collected the glass sponge *Aphrocallistes vastus* from 40 meters depth in Saanich Inlet, BC and exposed portions of the body tissues to EdU, a thymidine analog, for up to 5 days. Very few new nuclei labeled in the main body of *A. vastus*. However, growing tissues at the lip of *A. vastus* revealed a surprising finding: EdU−labeled cells' formed a band in the lip of the osculum. We have since observed new skeletal growth also occurring in that region using the ratiometric dye PDMPO. Using fluorescence, scanning, and transmission electron microscopy, we find that the labeled cells more closely resemble demosponge choanocytes than the anucleate collar bodies that populate chambers of the adult glass sponge. These findings prompt a completely new view of glass sponge syncytia: that chambers are first formed with similar structure to that of cellular sponges, but then grow in size, recessing the nuclei below collar bodies as they form part of the main body of the sponge. Adult glass sponges thus produce syncytial tissue from a cellular foundation.

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Correlated evolution of proxies for pre− and postcopulatory sexual selection across squamate reptiles

The net opportunity for sexual selection depends on the joint contributions of precopulatory selection, which arises from variance in mating success, and postcopulatory selection, which arises from variance in fertilization success. These two components of sexual selection can act in concert or in opposition to one another, but it is generally unknown whether the opportunities for pre− and postcopulatory selection tend to covary in predictable fashion. To test for a general relationship between pre− and postcopulatory sexual selection, we collected data from 148 species of squamate reptiles (116 lizards, 32 snakes). In squamates, competition for territories and mates often favors large body size in males, such that the degree of male−biased sexual size dimorphism (SSD) can be treated as a proxy for the intensity of precopulatory selection. In species experiencing strong postcopulatory selection, males typically invest heavily in testicular tissue to increase sperm production, such that testis size (relative to body size) can be treated as a proxy for the intensity of postcopulatory selection. Using both conventional and phylogenetically based analyses, we found a significant negative relationship between relative testis size and male−biased SSD across squamates. Lizards and snakes thus appear to be arrayed along an axis ranging from those that experience relatively strong pre− and weak postcopulatory selection, to those that experience relatively strong post− and weak precopulatory selection. This suggests that precopulatory selection may constrain the opportunity for postcopulatory selection, but that when precopulatory selection is relaxed, the opportunity for postcopulatory selection may increase. This inverse relationship between these two components of sexual selection suggests that their impacts on trait evolution may be non−independent.

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Quantifying Reaction Norms of Variation

Correlations between environment and phenotype are often attributed to the ability of individual organisms to alter labile traits in response to environmental conditions. Most previous discussions of labile traits and phenotypic plasticity have focused on the average phenotypic response of populations across environments; however, focus has recently shifted to how variation among individuals in both average responses (reaction norm intercepts) and direction and magnitude of plasticity in individual phenotypic responses (reaction norm slopes) can influence population level patterns. Yet, despite the torrent of recent studies illustrating significant variation among individuals in plasticity across multiple discrete environments, no study to date has analyzed the effects of treatment variance on either among− or within−individual variation. We quantify individual variation in prey anti−predator behavior in response to varying magnitudes of predator temporal variation using a crayfish (*Procambarus sp.*), bluegill (*Lepomis macrochirus*) and freshwater snail (*Physa acuta*) system. *Physa* were exposed to indirect chemical cues of predation risk from either crayfish or bluegill for 12 consecutive days and their behavior recorded for 5 hours post exposure. Treatments altered the pattern in which these cues were administered so that snails experienced different levels of environmental variation. We model the time dependence and magnitude of *Physa* anti−predator behavioral responses and quantify among− and within−individual variation in behavior in response to environmental variation. Higher environmental variation decreased individual variation in behavior by homogenizing anti−predator responses. Increased environmental variation also reduced time to mortality in the presence of lethal predators and altered oviposition site choice by prey.

76.4 KAJIURA, SM*; TELLMAN, SL; Florida Atlantic University; *kajiura@fau.edu*

Quantification of Massive Seasonal Shark Aggregations

South Florida witnesses an enormous migration of marine apex predators each year as massive aggregations of blacktip sharks (*Carcharhinus limbatus*) overwinter in nearshore waters. The narrow shelf and close proximity of the Gulf Stream Current to the Palm Beach County (PBC) shoreline constrain tens of thousands of sharks to the shallow, coastal environment. This natural bottleneck provides a unique opportunity to estimate abundance. Over a 39 month period, a biweekly aerial survey was flown along the length of PBC and the number of sharks was directly counted. Shark abundance peaked in the winter (January−March) and declined precipitously to nearly zero in the summer months. Shark abundance was correlated with water temperature with sharks found in large numbers only when sea surface temperature ranged from 21−24° C. A subset of sharks was instrumented with acoustic transmitters and 70% of instrumented individuals were detected at various locations along the eastern seaboard. Sharks appear to follow their preferred temperature, traveling as far north as Delaware Bay in the summer before returning to overwinter in south Florida. The straight line movements from point to point represent a minimum travel velocity of up to 31 km^{-day}. These baseline abundance data can be compared to future studies to determine if shark population size is changing and if sharks are restricting their southward migration as global water temperatures increase.

66.6 KAMRAN, M*; MOORE, P.A; Bowling Green State University, Bowling Green; *mkamran@bgsu.edu*

Comparative homing behaviors in two species of crayfish, Orconectes rusticus and Fallicambarus fodiens

The ability of animals to navigate to and from resources such as breeding grounds, richer pastures for foraging as well as locations of shelters is essential for survival. Homing behaviors are seen across the animal kingdom, with the underlying mechanisms varying to a great degree. Invertebrates, such as crayfish prove to be excellent models for comparative research, with relatively simple nervous systems that have been extensively studied, combined with a rich behavioral repertoire that has been well documented. Although, research has highlighted the abilities of crayfish to learn locations based on both place and response cues, relatively little is known about their homing abilities particularly upon return from foraging excursions. This particular study aims to explore the mechanisms that maybe utilized by crayfish when homing to their burrows. Two species are examined *Orconectes rusticus* and *Fallicambarus fodiens*, both of which utilize burrows, but only *F. fodiens* constructs the burrows. Hence, there is a critical evolutionary question on the how the importance of ownership and building a burrow influences the homing behavior. The crayfish species were selected based on the varying complexity of the environments within which they reside as well as the amount of energy invested in constructing burrows.

52.5 KANE, S.A.*; ROSENTHAL, L.; FULTON, A. H.; Haverford College; *samador@haverford.edu*

When hawks attack: video studies of goshawk pursuit strategies

We report here on video studies of Northern Goshawks pursuing live, wild prey in natural settings, capturing artificial moving lures and landing on perches. We analyzed both videos of pursuits recorded from videocameras on the ground and recorded by a miniature videocamera mounted on the goshawk's head while it foraged and pursued prey. Animal−borne videos of chases were analyzed to determine apparent prey positions on the goshawk's visual fields during pursuits as well as the motion of the prey relative to the optical flow of fixed background objects. Video recorded from the ground was analyzed to determine the predator and prey trajectories in space. These data then were interpreted using computer simulations of pursuit steering laws previously used to interpret pursuits by falcons, insects and mammals. We found goshawks use different strategies for approaching perches and stationary targets vs. chasing moving live prey or lures. Goshawks appear to use hybrid combinations of simple pursuit models to pursue prey in the scenarios studied here.

S12.8 KANE, E. A.*; HIGHAM, T. E.; Colorado State University, University of California, Riverside; *emily.kane@colostate.edu*
Complexity and integration in biomechanics: Using prey capture in fishes to explore a novel approach for understanding organismal performance

Organisms comprise multiple interacting parts, and an increased number or specialization of those parts leads to greater complexity and the necessity for integration (the ability of those parts to perform together to maintain organism function). Although this idea is widely recognized among biologists, organisms are more tangibly studied when those parts are considered independently. This approach has successfully advanced our understanding of organism performance, but how performance of one system might (or might not) be dependent on performance of another system to achieve a relevant outcome is poorly understood. In other words, we are now poised to begin questioning the interaction among systems and the role of this integration in our understanding of sub−and supra−organismal processes. We synthesize the concepts of complexity and integration and discuss their application in a biomechanical context. Additionally, prey capture in predatory fishes is used as an example to highlight the application of these ideas. Using kinematics of sculpin (Scorpaeniformes: Cottidae) prey capture, we show that different species exhibit multivariate integration of performance in distinct ways, adding insight into potential ecological differences. Finally, we discuss new insights into organismal performance gained through study of integration as an emergent property of performance across systems. Integration is rarely the trait of interest, but we show that future work should adopt a holistic approach to understand why and how animals perform complex behaviors.

P1.146 KANG, H.E; JEON, J.M; LEE, W.S*; YOON, T.H; KIM, H.W; Pukyong National University; *blueinsky24@pknu.ac.kr*
The molecular characterization and effect by siRNA injection of Adiponectin receptor like gene isolated from the tissues of Portunus trituberculatus

Adiponectin is a hormone secreted primarily by adipocyte, and its functions associated with obesity and reproduction are mediated by adiponectin receptors. Since these adiponectin receptors genes have already been identified by genetic study of crustaceans, we isolated and characterized adiponectin receptor (Pot−AdR) cDNA from swimming crab, *Portunus trituberculatus* with degenerated PCR and RACE analysis The cloned Pot−AdR cDNA was consisted of a 1549 nucleotide sequence, and ORF sequence (1,236bp) which encoded a protein of 411 amino acids. Pot−AdR exhibited the highest amino acid sequence identity (95.6%) to amino acid sequence corresponding to transcriptome (GenBank accession number: KA662395) known from the Chinese mitten crab, *Eriocheir sinensis*. In addition, transcriptional variant of Pot−AdR was identified by 3'RACE experiment, and the rest sequence of 3' region is on confirmation by analysis. End−point RT−PCR results showed that Pot−AdR gene was ubiquitously expressed in almost all sexes tissues except the epidermis and eyestalk of male, and expressed highly in the muscle tissues and hepatopancreas. To determine Pot−AdR function, As the synthetic Pot−AdR dsRNA (30uM − 50uM) were treated by injection through the arthrodial membrane of the last walking leg of crab, Pot−AdR functions of muscles and hepatopancreas is under through RT−PCR analysis of all tissues. It suggest that adiponectin function maybe is related to physiological conditions and various function.

P3.15 KAPPER, M.A.*; STIRBA, P.J.; Central Connecticut State University; *kapper@ccsu.edu*
Induction of HSP(70) as a Response to Increased Salinity in the Ribbed Mussel

Osmoconforming estuarine bivalves modulate concentrations of intracellular free amino acids to eliminate the osmotic gradient imposed by tidal variations in environmental salinity. Before adaptation takes place, there is a transient osmotic water flux. Since locomotion is absent or restricted, as environmental salinity changes, these organisms adapt so that the intracellular osmotic concentration matches that of the environment. We are testing the hypothesis that an induced heat shock protein (Hsp(72)) is produced in gills of the ribbed mussel *Geukensia demissa* as part of an adaptive response to increased salinity. Heat shock proteins (HSPs) act as molecular chaperones, binding to target proteins to restrict their folding. Constitutive HSPs are used during protein translation and import. Another group of HSPs are encoded by genes whose expression is typically modulated by thermal stress, but have also been shown to respond to other forms of stress including inflammation, heavy metal or bacterial contamination. Western blots show that *G. demissa* is able to produce both the stress−induced Hsp(72) and the constitutively expressed Hsc(73) forms of the protein. The data also suggest that the amount of the induced form (Hsp(72)) seems to increase in the first half hour of a high−salinity exposure. A semi−quantitative reverse transcription−PCR method is being developed to determine if there are changes in expression of Hsp(72) during high−salinity adaption, and whether or not these data support the Western Blot data. Preliminary PCR findings suggest that the appropriately designed primers are able to easily discriminate between induced and constitutive forms based on predicted amplicon size (Hsp(72) = 469bp, Hsc(73) = 688bp). Data will be presented to show whether changes in salinity induce production of induced Hsp(72). Supported by a CSU−AAUP grant to MAK.

87.5 KARADGE, UB; GOSTO, M; NICOTRA, ML*; University of Pittsburgh; *nicotraml@upmc.edu*
Molecular basis of allorecognition specificity in a colonial cnidarian

Allorecognition is the ability to distinguish between self tissues from those of conspecifics via cell−cell contact. This ability is shared by most reef−dwelling colonial invertebrates, including sponges, corals, hydroids, bryozoans, and colonial ascidians. Upon contact, compatible colonies typically fuse or peacefully coexist, while incompatible colonies compete for space, often aggressively. Despite the importance of allorecognition in determining the life history of colonial organisms, how colonies are able to distinguish self from nonself remains largely unknown. Here we report a mechanism for allorecognition specificity in a cnidarian model of allorecognition, *Hydractinia symbiolongicarpus*. Allorecognition in *Hydractinia* is controlled by at least two histocompatibility genes, *alr1* and *alr2*, which encode transmembrane proteins. The extracellular regions of these proteins are highly polymorphic and their sequence determines allorecognition outcomes. Colonies with matching extracellular domains fuse, while colonies with different extracellular domains reject. Using in vitro assays, we demonstrate that alr1 and alr2 are capable of acting as ligands for each other across opposing cell membranes. This homophilic binding is allele−specific, meaning that protein alleles only bind to themselves but not to other variants. We hypothesize that this allele−specific homophilic recognition is what determines compatibility between colonies in vivo. This is the first plausible biophysical mechanism of allorecognition specificity in any invertebrate and provides a step toward understanding the evolution of allorecognition systems in cnidarians.

P1.98 KARLE, K.A.*; GIBSON, Q.A.; Univ. of North Florida;
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Seasonal changes in group composition and behavior of female bottlenose dolphins (Tursiops truncatus)

Female bottlenose dolphins exhibit seasonal reproduction with peak mating and calving in spring and summer. However, analyses of tooth rake marks indicate female dolphins in the St. Johns River (SJR; Jacksonville, FL) receive more aggression during the non−breeding season. Here, we examine seasonal group composition and behavior of SJR females to explain this pattern. Photo−identification surveys were conducted from Mar. 2011−May 2012 (508 sightings; 290 individuals) and separated by season (winter: Dec−Feb; spring: Mar−May; summer: Jun−Aug; autumn: Sep−Nov). Females were identified by the consistent presence of a calf in infant position; all others were unknown sex. Groups were sorted into three categories: females only (F), females with unknown sex (F+U), and unknown sex only (U). Analyses used G tests of independence. Of group types, F+U were consistently most prevalent (mean=0.59). Yet, relative proportions of each group type varied seasonally (p=0.02). U were least prevalent (0.15) during summer, when F+U were most prevalent (0.67). Within group types, behavior did not differ across seasons (F, p=0.39; F+U, p=0.09; U, p=0.45). Travel was consistently the predominant behavior of F (mean=0.67) and F+U (mean=0.65). Yet, F and F+U behavior differed (p<0.001). Foraging was more common for F (mean=0.31) than F+U (mean=0.18). F were never observed socializing compared to 0.14 of F+U; there was also a trend towards more socializing in winter. These data suggest that females associate with unknown sex (presumed males) year−round, socialize only in mixed sex groups and primarily in winter, supporting the hypothesis of herding outside of summer.

26.5 KARSTEN, K.B.; California Lutheran Univ.;
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Sexual dimorphism in morphology, signaling, and performance in two species of Sceloporus lizards

Signals can vary substantially, even within a somewhat closely−related taxon. In *Sceloporus* lizards, many species are dimorphic and signal via blue ventral and throat patches. In the most common scenario, males are larger and have more extensive blue patches, whereas females are smaller with lesser/no blue patches. In southeast Arizona, two sympatric species deviate from this typical pattern and have contrasting modes of visual signals. In *S. jarrovii*, both males and females are characterized by large body size and extensive blue ventral and throat patches, whereas both sexes of *S. virgatus* have smaller body size, no ventral blue patches, and minimal throat patches. Our aims were to explore dimorphism in body size, ventral patch size, and throat patch size in both species and determine if these signals correlated with a measure of whole−animal performance: bite force. We found that *S. jarrovii* were not sexually dimorphic in body size or ventral patch size, but were significantly dimorphic in throat patch size and bite force (males being greater in both). However, after correcting for body size, we found no relationship between ventral or throat patch size and bite force in males. Surprisingly, in females, we found a negative relationship between both ventral and throat patch sizes and bite force. In contrast, *S. virgatus* were dimorphic in body size (females being larger) but with no statistical dimorphism in throat patch size. Although females had stronger absolute bite forces, there was no dimorphism in bite force after correcting for body size. There was no relationship between throat patch size and bite force in females, but there was a significant negative correlation between throat patch size and bite force in males. Our findings indicate that in these atypical' *Sceloporus* species, the relationship between signals and performance is complex.

S7.5 KATIJA, Kakani; Hopkins Marine Station, Stanford Univ., Pacific Grove and Monterey Bay Aquarium Research Inst., Moss Landing; *kakani@stanford.edu*

Biogenic inputs to ocean mixing: Changes in morphology alter mixing efficiency in medusae

Recent studies have provided spirited debate about whether biologically generated (or biogenic) mixing can have an impact on mixing in the ocean. Estimates of biological energetic inputs to the ocean show that the biogenic contribution to mixing is of the same order as winds and tides. Biogenic ocean mixing is a complex problem that requires detailed understanding of a variety of factors that include marine organism behavior, morphology, swimming mechanics, and the physical environment. An additional constraint in understanding mixing by swimming organisms is defining a metric that allows for accurate comparison between biological and physical processes in the ocean independent of the length scale used. Here we employ a dynamical systems technique to quantify mixing efficiency, and analyze small−scale mixing induced by a rhizostome medusa *Phyllorhiza punctuate*. Animals were placed in a glass filming vessel, and fluid motion was quantified using high−speed Digital Particle Image Velocimetry. To evaluate how mixing induced by swimming changes with morphology, the oral arms were excised from an individual *P. punctuate* and flow measurements were obtained. The measured velocity fields are then used to quantify mixing efficiency. Changes in morphology (i.e., removal of oral arms) dramatically altered the measured flow fields by reducing fluid drift, thereby reducing mixing efficiency. These observations have implications for the types of organisms that have the potential for large scale mixing in the ocean.

P1.193 KATZ, H.R.*; HALE, M.E.; University of Chicago;
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Decrease in axial elongation through post−embryonic development is conserved across teleost fishes

Teleost fishes display a remarkable diversity of both body shapes and locomotor strategies. One fundamental aspect of fish shape is body elongation. Elongation is often expressed as the ratio of axial length to width or depth of the body. The elongation ratio has been shown to be associated with axial bending produced during swimming, with more elongate species often generating deeper and/or more numerous bends along the body axis. Elongation varies not only among species but also within individuals through their development. This study aimed to identify trends in body shape change by quantifying body elongation at larval and adult stages across a wide range of fish clades. Based on developmental work in several species, we hypothesized that most teleost fish would exhibit a decrease in elongation ratio through development. Using images from the literature and online image databases (e.g. fishbase), we have measured elongation ratio (axial length relative to depth) at larval and adult stages of a morphologically diverse range of teleost fishes. Axial length was measured from the center of the eye to the end of the caudal fin. Depth was measured at the anus for larval stages and just anterior to the anal fin for adult stages. Our data, including measurements of 53 species from 17 orders, indicate a widespread decrease in elongation ratio across teleost fishes. Only a few anguilliform species demonstrate a prominent increase in elongation ratio. These results have implications for understanding the development of locomotor behaviors. They suggest that the axial locomotor systems of a broad diversity of fishes may undergo elongation−related changes through early life history. In addition, they demonstrate striking conservation of this body shape change across a wide array of teleosts.

21.4 KAWANO, S.M.*; BLOB, R.W.; NIMBioS, Clemson Univ.; *skawano@nimbios.org*

Mixed chains of safety factors in the limb bones of salamanders: implications for differential limb function in the evolution of terrestrial locomotion

The capacity of vertebrate bones to resist loads has important implications for their functional capabilities. Bones can often resist loads that are higher than they normally experience through an extra load bearing capacity, called a safety factor (SF). Alexander's "mixed−chain" hypothesis proposed that different SFs might be found among "links" within a biological system ("chain") as an adaptation to help accommodate unpredictable loads or variation in the energetic costs of elements, or if SFs were generally high across body structures. Data on the presence of "mixed chains" in vertebrate limbs are sparse; however, understanding the generality of "mixed chains" of limb bone SFs could shed light on a long−standing question of how different functional roles of forelimbs and hind limbs could have contributed to the invasion of land. We compared the mechanical properties and locomotor loading of the humerus and femur of tiger salamanders (*Ambystoma tigrinum*) in relation to the "mixed−chain" hypothesis, in order to assess the conditions under which functional diversity in SFs might emerge. Although the forelimbs and hind limbs appear similar in *A. tigrinum*, bone stresses in the humerus were roughly half (and SFs twice as great as) those observed in the femur, in part due to differences in muscle arrangements between the limbs. Also, regional heterogeneity in bone mechanical properties contributed to larger hardness values in the dorsal and posterior regions of both bones. Such intraspecific variation between and within bones may relate to the different biomechanical functions of these locomotor modules, and could have facilitated the acquisition of novel locomotor capabilities during the evolutionary invasion of land by tetrapods.

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Protein markers and mechanisms of infection by Flavobacterium psychrophilum in Rainbow Trout (Oncorynchus mykiss) revealed using mass spectrometry proteomic analysis

Aquaculture is a rapidly expanding agricultural field, especially at the international level. One of the largest issues which arise from raising high densities of fish in a confined area is infection and rapid transmission of disease within the population. There are currently few federally approved pharmaceutical treatments for fish, making rapid and accurate diagnosis essential for maintaining healthy populations. The current study focuses on the infection of rainbow trout *Oncorynchus mykiss* by the gram−negative bacteria *Flavobacterium psychrophilum* which manifests as Bacterial Cold Water Disease (BCWD). The approach involves examining the physiological effects of infection in these fish at the protein level. Using LC−MS techniques, the majority of proteins in the kidney, spleen, plasma, and muscles at site of infection are analyzed for differential abundance between infected and control populations. Artificially infected cohorts are compared against fish taken from an active hatchery to determine whether lab results are reflected in a real−world context. Sets of proteins which change in abundance as a response to BCWD infection make ideal candidates as bio−markers which can be used in the development of diagnostic tools. This method also reveals the underlying mechanisms of the infection and response through gene ontology and pathway analysis. Initial analysis indicates infection affects physiological processes associated with muscle contraction, complement cascade immune response, and cell differentiation. Identifying these pathways and specific proteins of interest can ultimately be used to promote the search for effective treatments. Supported by NSF Grant IOS−1355098

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The Role of Air− and Waterborne Odors in Orientation and Food Detection in Three Species of Marine Turtles

The cues used by sea turtles to locate foraging areas in the open ocean are largely unknown but satellite tracks suggest that they often accomplish that feat. One possibility is that they locate those sites using chemical cues carried downwind in the air. Previous studies have shown that loggerheads (*Caretta caretta*) are capable of detecting airborne odors from synthetic food, as well as natural odors from mud and dimethyl sulfide (DMS), a substance that is found in high concentrations in highly productive oceanic areas. In this study, our goal was to determine if juvenile loggerhead and leatherback (*Dermochelys coriacea*) sea turtles, swimming in a water−filled tank, would orient into a laminar flow of air above the water that contained the odor of DMS or odors associated with particular prey items they are known to consume (shrimp, jellyfish, *Sargassum*, and squid). None of the turtles oriented into the air current. In other experiments, we examined how the turtles responded to air− and waterborne odors when a neutral visual stimulus (a small plastic ball) was suspended inside the water−filled tank. There was once again no response evoked by airborne DMS, but a food odor (squid) presented either in the water or in air induced both juvenile loggerheads and green turtles (*Chelonia mydas*) to orient toward the visual stimulus and attack it. We conclude that (i) air currents carrying either DMS or food do not induce turtles to orient upwind, (ii) turtles can detect and respond to food odors in air and underwater, and (iii) behavioral responses to food odors differ from those shown to DMS. None of our results provide support for the hypothesis that turtles locate productive areas in the ocean from long distances using odor cues.

S3.6 KEENAN, S.W.*; ELSEY, R.M.; ENGEL, A.S.; Saint Louis University, Louisiana Dept. of Wildlife and Fisheries, University of Tennessee; *keenansw@slu.edu*

The good, the bad, and the unknown: microbial symbioses of the American alligator

Vertebrates coexist with microorganisms in diverse symbiotic associations that range from beneficial to detrimental to the host. Most research has aimed at deciphering the nature of the composite microbial community genome, or microbiome, from the gastrointestinal (GI) tract and skin of mammals (i.e. humans). In mammals, the GI tract microbiome aids digestion, enhances nutrient uptake, and prevents the establishment of pathogenic microorganisms. However, the GI tract microbiome of the American alligator (*Alligator mississippiensis*) is distinct from all other vertebrates studied to date, being comprised of Fusobacteria in the lower GI tract with lesser abundances of Firmicutes, Proteobacteria, and Bacteroidetes. The function of these communities is largely unknown. But, microbiome taxonomy can help to diagnose host health or disease. Pathogenic and harmful microorganisms associated with crocodilians are known to include *Salmonella* spp. and others. Changes in the overall microbial community composition may also help to determine microbiome (and host) response to environmental perturbations, including physicochemisty, diet, and stress. Moreover, GI tract microbial communities have likely co−evolved with their vertebrate host over geologic time, which means that evolutionary hypotheses can be tested from microbiome information. A review of the current understanding of microbial symbiosis associated with alligator health (the good) and disease (the bad) reveals new avenues for reptile and amphibian microbiome research (the unknown). Exploring the present−day associations between alligators and their symbiotic microorganisms provides a window into the geologic past, and will likely be invaluable for identifying host health or disease in the future.

P3.184 KEIL, DP*; BELY, AE; University of Maryland, College Park; *dkeil@umd.edu*
Identifying Correlates of Regeneration Loss in Annelids
Although regeneration has been studied for hundreds of years some of the most basic questions in the field remain unanswered. What is the distribution of regenerative ability throughout animals? What traits correlate with a loss of regeneration? Our goal is to identify morphological and behavioral characters that may be correlated with the loss of anterior regeneration in annelids. We are focusing efforts on several annelid families in which a spectrum of regenerative ability exists and testing several possible correlates of regeneration. First, sedentary annelids often extend a portion of their anterior end above the substrate or their protective tube, exposing this body region to predation. Does a sedentary lifestyle lead to increased selective pressure for anterior regenerative ability in sedentary annelids as compared to an errant lifestyle? Second, annelids vary considerably in their body proportions (e.g., short and stout vs. long and thin), and body proportions could influence susceptibility to breakage from biotic and abiotic factors. Does a larger length/width body ratio correlate with higher regenerative ability? We are using comparative analyses and tests of correlated character evolution to address both of these questions. Identifying correlates of regeneration will further our understanding of why and how regeneration ability evolves.

P1.50 KELLER, EL*; NEEDHAM, CN; BERKE, SK; Siena College; *skberke@gmail.com*
Invertebrate community responses to an invasive alga (Gracilaria vermiculophylla) in Virginia's coastal bays
Invasive species commonly alter community structure within invaded habitats. We investigated the effects of an invasive red alga, *Gracilaria vermiculophylla*, on epifaunal and infaunal communities in the coastal bays of Virginia. Native to the Western Pacific, *G. vermiculophylla* has represented 90% or more of all macroalgal biomass in these habitats since at least 2003. Epifaunal communities on *G. vermiculophylla* show lower taxon richness and total abundance compared to the most abundant native alga, Ulva. Yet, at the same time, infaunal communities under mats of *G. vermiculophylla* show greater species diversity compared to unvegetated areas, possibly because *G. vermiculophylla* offers refuge from predation. This may suggest that epifaunal and infaunal communities respond differently to the invasion of *G. vermiculophylla*. Worryingly, *G. vermiculophylla* has displayed the ability to seasonally form thick, continuous mats in these habitats, which have historically lacked algal mats. Within these seasonal mats, the native polychaete *Diopatra cuprea* has exhibited elevated mortality rates, possibly associated with a reduced oxic layer. This suggests that *G. vermiculophylla* may initially facilitate infaunal communities, but extensive mat formation may negatively impact infauna. Understanding (i) how widespread *G. vermiculophylla* mats are becoming, (ii) what underlying factors cause the differences in epifaunal and infaunal community responses to *G. vermiculophylla*, and (iii) the causal link (if any) between *G. vermiculophylla* and *D. cuprea* mortality are important questions for future work.

16.4 KELLER, J. S.*; JANSA, S. A.; FOX, D. L.; University of Minnesota; *kell1077@umn.edu*
Dental divergence of nesomyine rodents from the murine developmental model
The endemic rodents of Madagascar (Nesomyidae: Nesomyinae) compose a small radiation of remarkable morphological and ecological diversity, but the tempo and mode of their evolution is not well understood. We inferred a species−level phylogeny for the 28 recognized species of nesomyines and examined dental evolution within this phylogenetic context. We examined whether nesomyine rodents adhere to a developmental model of molar−size evolution derived from murine rodents (Kavanagh et al. 2007). This model plots the ratio of m2/m1 planar occlusal area by m3/m1 area, creating a simple system to evaluate dental morphospace. All extant muroid rodents examined to date follow the classic activation/inhibition pattern of molar development in which the anteriormost molar inhibits growth of successive molars resulting in m1 as the largest tooth and m3 as the smallest. Many other mammals follow the same pattern, but few have large m2s or m3s. Nesomyines diverge significantly from this pattern. Uniquely, we found that nesomyines encompass nearly as much variation in molar−size ratios as observed across all mammals. To examine tooth morphology in greater detail, we uCT−scanned nesomyine mandibles at 5−12 um resolution and calculated shape metrics of lower tooth rows that describe aspects of functional morphology. These metrics comprise a suite of 14 variables including orientation patch count (OPC), volumetric enamel:dentin ratios, occlusal surface descriptors, and vertical complexity measures. Based on a similar study of North American rodents, these tooth metrics predict trophic categories with high accuracy. We use this model to predict trophic categories for nesomyines. Using multivariate comparative methods, we estimate rates of evolution for these dental characters among lineages and over time to better characterize the nature of this radiation.

42.2 KENALEY, C/P*; MARECKI, M; LAUDER, G/V; Harvard University; *cpkenaley@gmail.com*
Dynamic Mechanical Advantage? The Role of an Overlooked Muscle in Lower−jaw Adduction in Fishes
The functional design of actinopterygian cranial musculoskeletal systems and its contribution to aquatic prey capture has been the subject of study for nearly two centuries. Even today, the complex kinematic basis and physiological determinants of fish feeding behavior remains an active and productive area of comparative research. Most fishes rely on inertial suction to overtake a prey item, a behavior reliant upon the rapid expansion of the oral cavity. While buccal expansion has been described as organizationally complex, models of buccal compression remain relatively simple. In particular, the musculoskeletal elements associated with jaw adduction in most fishes adheres to a third−order lever model. Accordingly, adductor muscles actuate jaw closing by applying force to an in−lever some distance from the jaw joint. In this study, we considered to what degree the organizational complexity of the adductor muscle system has in jaw closing performance. Through biomechanical modeling of jaw−adduction systems in three species of teleosts, we reveal that the architectural design of adductor muscle−tendon units imparts an ability to dynamically alter the mechanical advantage of major inputs to the lower−jaw lever system. Specifically, we show that a division of adductor muscle system the AÉ may play a role in applying adduction torques to more distal positions along the lower jaw, thus increasing mechanical advantage. The role of dynamic mechanical advantage brought on by this design is discussed in terms of behavioral responses to feeding requirements and the performance tradeoffs dictated by different prey types.

P3.60 KENDALL−BAR, J.M.*; IYENGAR, V.K.; Univ. of California, Berkeley, Villanova University; *jmkb999@gmail.com*

Sexual selection by the seashore: mate choice and competition in the maritime earwig

Sexual selection often leads to exaggerated traits that provide reproductive advantages either through mate choice (intersexual selection for ornaments) or competition (intrasexual selection for armaments). Teasing apart the relative contributions of these selective forces is a critical step in understanding mating systems. In cases where both sexes possess weaponry, many potential combinations and complexities arise. We examined the mating system of the maritime earwig *Anisolabis maritima*, an insect well−suited for studies of sexual selection because males differ markedly from females in body size (males are more variable in size, and often substantially larger, than females) and weaponry (males possess asymmetrical, curved forceps whereas females have straight forceps). We examined the roles of these two factors, body size and forceps asymmetry, as it relates to four types of sexual selection: female choice, male choice, male competition, and female competition. Using trios of earwigs in artificial arenas where we could restrict the movement of certain individuals, we monitored the distribution of free−moving individuals to determine the relative roles that these factors may play in spatial patterns and gain insight into the mating system. Our results revealed strong sexual selection for larger sizes through both competition and choice, but there was no preference based on forceps asymmetry. We found significant results in all four trial types, including not only the more traditional male competition and female choice, but also female competition and male choice. This pattern suggests that the weaponry possessed by both sexes could operate in intrasexual competitive battles as well as serve as a basis for assessing quality of a potential mate.

93.1 KENNY, M*; SOCHA, J.J.; Virginia Tech; *mck66@vt.edu*

Does Murray's law apply to the tracheal system in insects? A 3D study of the beetle Platynus decentis

The architecture of fluid transport systems has been well studied in many organisms. Diverse groups across taxa have evolved network geometries that tend toward the minimization of energy loss in fluid transport. Three basic principles apply to these networks: (1) transfer processes must occur over short spatial distances; (2) large and small vessels must be used for bulk flow and exchange sites, respectively; and (3) flow velocities must be limited across transfer sites. Optimal branching design is sometimes reflected in Murray's law, which states that for laminar flow at any branch point, the radius of the parent vessel cubed equals the sum of the cubes of the radii (x=3) of the daughter vessels. This relationship balances forcing flow against the fluid's viscosity with the costs of building and maintaining the system. Murray's law has been found in networks such as mammalian circulatory vessels and the canal system in some species of sponges; however, Murray's law has not yet been studied in the tracheal network of insects. Here, we utilized synchrotron microtomography of the beetle, *Platynus decentis*, a species that uses convective airflow to augment gas exchange. Tomographic data were obtained at the Advanced Photon Source at Argonne National Laboratory at beamline 2−BM. 3D segmentation and measurement of tracheal tubes with 16−20 µm diameters were performed using Avizo software. We identified tube branch points and measured the effective radii of both the parent and daughter vessels. Preliminary analysis suggests that Murray's law does not apply in the tracheal system of this beetle species. Further analysis indicated that a diffusion−based design provided a better a fit, with an average exponent of approximately x=1.8. Supported by NSF 0938047.

94.1 KERBL, A; BEKKOUCHE, N; STERRER, W; LAUMER, C; GIRIBET, G; WORSAAE, K*; University of Copenhagen, Denmark, Bermuda Aquarium,Museum and Zoo, Bermuda, Harvard University, USA; *kworsaae@bio.ku.dk*

The spiralian missing link − Lobatocerebromorpha

Still unplaced, *Lobatocerebrum* (Lobatocerebridae, Spiralia incertae sedis) is one of the most enigmatic bilaterian left. It was described in 1980 by Reinhard Rieger as an unsegmented, completely ciliated, thin and 2 mm long interstitial worm lacking any form of appendages or bristles, but possessing a glandular cuticle, a ventral mouth and through gut. Detailed LM and TEM studies revealed a range of apomorphies such as a large multilobed brain as well as similarities to Platyhelminthes and Annelida. However, after 30 years we still haven't been able to resolve its exact position in Spiralia. With ongoing studies of new material employing phylogenomic analyses and detailed morphological reconstructions we hope to get closer to an answer. The last decades of research have accumulated a much broader knowledge on the spiralian nervous system, mainly facilitated by the progresses in immunohistochemistry and confocal laser scanning microscopy. With these techniques we have now collected comparative data on the *Lobatocerebrum* muscle− and nervous system, showing several previously undiscovered features such as a mid−ventral nerve, a third trunk commissure, and specific neurotransmitter patterns. Furthermore, we were able to confirm many of the discoveries of R. Rieger as well as unravel the detailed architecture of, e.g. the brain commissures, nerve cords emerging from the brain lobes and the muscular layout. Possible plesiomorphies and synapomorphies with Nemertea, Platyhelminthes, Gastrotricha and Annelida are discussed relative to the new phylogenomic spiralian tree topology, and various evolutionary scenarios of the neuro−muscular systems are presented.

94.2 KERBL, A.*; FOFANOVA, E.G.; MAYOROVA, T.; VORONEZHSKAYA, E.; WORSAAE, K.; University of Copenhagen, Denmark, Russian Academy of Sciences, Russia; *alexandra.kerbl@bio.ku.dk*

Paedomophic traits in muscular, nervous and ciliary development in Dinophilus (Annelida: Dinophilidae)

Paedomorphosis is often suggested to be the evolutionary pathway leading to the origin of interstitial meiofauna. The environmental demands of the interstices supposedly warrant a one−step miniaturization from macroscopic to microscopic animals. Serial paedomorphic events may lead to more reduced descendants within interstitial groups. Here, we examine this phenomenon within the genus *Dinophilus* (Dinophilidae) − having two morphotypes as well as dwarf males. While monomorphic *D. taeniatus* has a very long life cycle including encystment, the dimorphic *D. gyrociliatus* has a life cycle of less than one month. The onset of muscular, nervous and ciliary development is very similar between these two species. The main differentiation occurs short before hatching, when *D. taeniatus* adds longitudinal and transverse muscles to the early layout, while *D. gyrociliatus* females do not. More peculiar is the nervous system, forming first one thick neurite bundle per segment linking the two prominent longitudinal strands, and afterwards splitting into three thinner ones. While *D. gyrociliatus* seems to retain this layout in the adult stage, *D. taeniatus* later in development again fuses the three commissures to one per segment. The additional ciliary band per segment in *D. taeniatus* forms short before or even after hatching. Although there is no molecular data on how these two species are related, we have some evidence, that their common ancestor probably resembled *D. taeniatus*. This would mean that the neuro−muscular architecture of *D. gyrociliatus* is paedomorphic. However, a molecular phylogeny of the genus *Dinophilus* is needed to clarify and support this hypothesis.

P3.71 KERNAHAN, N*; ANDERSON, C; EARLEY, RL; Univ. of Alabama; *nikernahan@crimson.ua.edu*

Does Female Color Elicit Aggression in Convict Cichlids?

Males of many species possess bright colors and armaments, which are thought to function primarily in displaying male quality to prospective mates. Convict cichlid fish (*Amatitlania siquia*), however, exhibit reversed sexual dichromatism; only females exhibit a carotenoid−based orange patch located on the ventral surface of the body. The adaptive value of vibrant color in female convict cichlids remains unclear but has been hypothesized to function as a quality indicator to males and other females. High−quality females might threaten the stability of pairbonds thus we hypothesized that cichlids of both sexes would be more aggressive towards females possessing larger orange patches. To determine whether orange patch size affects cichlid behavior, we exposed males and females of a range of body sizes and color phenotypes (females only) to one of three treatments: a cichlid model with no patch, a small patch, or a large patch. We recorded interactions digitally and quantified all aggressive behavior towards the models. Our analyses revealed no significant sex or treatment differences in the levels of aggression directed towards models. However, both sexes show a moderate increase in aggression towards models with small patches, but not large patches, relative to models without patches. Patch asymmetry (females), absolute body size, and relative body size did not explain variation in aggression towards models for either sex. Data collected in the field using a similar paradigm showed that pairbonded convict cichlids increase aggression towards models with orange patches when defending young. These data suggest that female color elicits aggression in a context−dependent manner, primarily in mated animals that might benefit from deterring intruders that threaten to disrupt the pairbond during joint offspring care.

P1.154 KHALILIEH, AI*; MCCUE, MD; PINSHOW, B; Ben−Gurion University of the Negev, Israel, St. Mary's University, San Antonio, Texas; *anton_khalilieh@yahoo.com*

House sparrows have two phases of fuel use during fasting, rather than the classic three

Previously, we found that house sparrows (*Passer domesticus*)(~28g) can fast for only 24 h, if their fast begins after feeding in the morning and that their fast did not follow the three−phase model found in many species. Recently, however, we found that house sparrows can sustain a 43 h fast if it begins when they go to roost. We tested the prediction that, under such circumstances, fasting house sparrows sequentially oxidize substrates in the classic order: carbohydrates − lipids − protein. We analyzed the birds' breath for $^{13}CO_2$ at regular intervals for 43 h after feeding them millet enriched with ^{13}C−(glucose, palmitic acid, or leucine) for 12 days. We also analyzed blood plasma. Contrary to our predictions, the main fuels oxidized during the first 21 h were carbohydrates and lipids, while during the subsequent 22 h, protein and lipids were metabolized. In the final 4 h, protein was the main fuel oxidized. Also, glucose levels followed a circadian rhythm; ketone levels increased until hour−31, then decreased significantly until hour 43; and glycerol levels decreased during the first 13 h and then stabilized at low levels. Thus, house sparrows that begin fasting at sundown have only two phases of metabolic fuel use; first carbohydrates and lipids, then lipids and protein. This enables the birds to fast for longer than when they began to fast after feeding in the morning. Interestingly, these results mesh closely with those of our earlier study.

P2.97 KILMER, J.T.; University of Wisconsin − Milwaukee; *jtkilmer@uwm.edu*

Constraints of brain size on memory content in the spider Pholcus phalangioides (Araneae: Pholcidae)

The evolutionary reduction of brain and body size presents a major challenge for animals. At extremely small sizes, neurons become so small and so few in number that they risk losing proper functionality. As a result, tiny animals are expected to be constrained in their cognitive abilities, including memory. Because the central nervous system controls behavior, behavioral assays are useful tools for evaluating the quantity and quality of information an animal retains as well as how an animal uses information to make decisions. For example, when a web−building spider loses captured prey, it searches for the prey by tugging on silk threads while moving about its web until it either finds the prey or gives up. Spiders search longer for larger, more valuable prey, suggesting that prey evaluation and memory are involved in decisions made about searching behavior. In this study, I measured prey−searching behavior of long−bodied cellar spiders (*Pholcus phalangioides*) to test the hypothesis that miniaturization limits the duration and quality of memory. I gave prey of different sizes to large and tiny spiders, which I then induced to search by stealing the prey. I compared time and effort invested in searching across trials to determine the effects that brain size has on a spider's ability to evaluate prey and to use memory to make foraging decisions. Search behavior of small spiders differed from that of large spiders in several ways, including the amount of time it took for them to begin searching and the rate at which they tugged while searching. Results from this experiment suggest that brain size imposes limitations on an animal's ability to acquire, store and use information. I discuss these results within the context of brain size constraints on cognition, and I describe the future directions of this ongoing project.

48.1 KILVITIS, H.J.*; BORUTA, M; RICHARDS, C.L.; MARTIN, L.B.; University of South Florida; *hkilviti@mail.usf.edu*

Effects of early−life stressors on sickness behaviors in adulthood in zebra finches

Exposure to stressors within critical periods of development can have enduring effects on adult phenotype. In the context of disease dynamics, behavior is an important link between within−host resistance and among−host transmission because it can reduce demand on immunological processes and directly influence contact rates between healthy and infected individuals. For instance, many animals express sickness behaviors in response to infection, which are often considered adaptive strategies intended to promote host survival by reducing energy expenditure and conserving resources. Despite the significance of such behaviors, little is known about how early−life experiences contribute to variation in a host's behavioral response to infection later in life. Here, we used zebra finches *Poephila guttata* to examine how early−life exposure to bacterial components that induce inflammatory responses (i.e. lipopolysaccharide, LPS) and/or stress hormones (i.e. corticosterone, CORT) affected sickness behaviors specifically lethargy and anorexia in adulthood. Because the early−life environment may act as a cue, potentially preparing an individual for the environment in which they will experience in adulthood, we predicted that individuals exposed to LPS early in life would have reduced expression of sickness behaviors, due to immunological priming, in comparison to individuals that did not receive LPS. Analyses are ongoing. This study is among the first to assess how variation in early−life experience contributes to variation in hosts' behavioral response to infection later in life and highlights the potential implications of such individual−level heterogeneity on population−level processes (e.g. disease emergence and/or spread).

P1.139 KIM, A.R.*; LEE, J.H.; LEE, S.R.; KIM, K.R.; YOON, T.H.; KIM, H.W.; Pukyong National University; *tass5910@naver.com*
Molecular characterization of adiponectin receptor and effects of its knockdown in white shrimp, Litopenaeus vannamei
In mammals, adiponectin (also known as AdipoQ or Acrp30) is a protein that plays an important role in stimulating glucose utilization, fatty acid oxidation and improving insulin sensitivity. Adiponectin conveys its signals through the adiponectin receptors (adipoRs), which belong to G protein−coupled receptors (GPCRs). AdipoR is classified as PAQR (progestin and adipoQ receptors), which shows a unique inversed topology different from the typical GPCRs and has been paid attention for its medical implications. Since it plays key roles in glucose and fatty acid metabolism, AdipoR can be important targets for the various industrial purposes. In present study, we identified the full length cDNA encoding mammalian AdipoR homolog (Liv−AdipoR) from the shrimp, *Litopenaeus vannamei*, by the next generation sequencing and bioinformatics analysis. The full length Liv−AdipoR (1245 bp) encoded a protein with 415 amino acid residues. Liv−adipoR has high similarity to AdipoR from insect including *Zootermopsis nevadensis* (67%) and *Apis dorsata* (62%). Liv−AdipR exhibited the conserved 7 transmembrane domains (7 TMs) and its expression was ubiquitous. Change in expression level was also measured during molting and feeding cycles by qPCR. In order to estimate its function, sequence−specific Liv−AdipoR dsRNA (360 bp) was injected and its effects were studied. 10 pmol of dsRNA efficiently knocked down its expression by 74 % 3days after injection and Level of glucose and fatty acids in hemolymph was also measured. Long−term knockdown experiment was also performed injecting of 10pmol dsRNA weakly for 2 months and molting cycle and growth rate were measured.

P1.140 KIM, K.R*; LEE, J.H; KIM, A.R; LEE, W.S; KIM, H.W; Pukyung National University; *arctickkl@gmail.com*
cDNAs encoding chitin synthase from shrimp (Pandalopsis japonica) : molecular characterization and expression analysis
Crustacean growth occurs via molting, the periodic shedding of the exoskeleton. Understanding the genes involved in chitin metabolism associated with the periodic molt cycle is important for various applications to decapod crustacean aquaculture. Chitin synthase is an important enzyme in the chitin biosynthetic pathway that plays a major role in synthesis of new cuticle after molting. In this study, we isolated a full−length cDNA encoding chitin synthase (PajCHS) from Pandalopsis japonica through a combination of PCR (Polymerase chain reaction)− based cloning and bioinformatics analysis. The identified PajCHS encodes a transmembrane protein with 1525 amino acid residues (175 kDa). Comparison with other CHSs from insects revealed that PajCHS contains three domains: N−terminal domain A, catalytic domain B, and C−terminal domain C. Three conserved motifs (EDR, QRRRW, and SWGTR) were also well conserved within and near the catalytic domain B, suggesting that Paj−CHS is functionally active. Variation in the transmembrane helix within the N−terminal and C−terminal domains suggested that the orientation of each CHS may be different. Phylogenetic analysis suggested that PajCHS is an ortholog of CHS1 group members from insect species. However, tissue expression profiles indicated that epidermis, hepatopancreas, intestine, and gill were the major production sites for PajCHS transcript, which is considerably different from insect CHS1. qPCR results showed that eye stalk ablation and 20 hydroxyecdysone (20E) injection increased the expression level of PajCHS mRNA, suggesting that the expression of PajCHS1 may be controlled by endogenous 20E.

P3.62 KIMMITT, A.A.*; DIETZ, S.L.; KETTERSON, E.D.; Indiana Univ, Bloomington, North Carolina State University; *aakimmitt@gmail.com*
Does male preference play a role in subspecies divergence?
Sexual selection is believed to play a significant role in many cases of population divergence. While sexual selection is typically associated with female choice, males also make decisions when seeking mates. Natural selection is another significant source of population divergence. In migratory species, natural selection on phenology may lead to population divergence if one population migrates away from a resident population to breed, and therefore, the populations do not co−occur during breeding. We asked whether males differ in their courtship of females from diverged but closely related populations that differ in their migratory behavior, appearance, morphology, and phenology. We predicted that if male preference played a role in population divergence, males would significantly prefer females from their own subspecies. Alternatively in the absence of reinforcement, as subspecies do not co−occur during breeding season, resident males might court females regardless of subspecies or even prefer females from another subspecies. The dark−eyed junco, *Junco hyemalis*, is a small socially monogamous songbird that is comprised of both resident and migratory populations. The Carolina and Northern subspecies winter in the Appalachian Mountains, but breed separately after Northern juncos migrate to Canada in the spring. We conducted simulated courtship interactions, in which females were presented on Carolina males' territories, and we recorded male visual and acoustic courtship displays. Each male was presented with a female of each subspecies on different days in random order and we compared courtship effort to determine whether males exhibited a preference for one subspecies or the other. Results are pending.

P2.44 KINCHELOE, MN*; WILCOXEN, TE; SEITZ, J; NUZZO, J; Millikin University, Illinois Raptor Center, Illinois Raptor Center; *mkincheloe@millikin.edu*
Hematological metrics associated with injury, disease, and recovery in birds of prey admitted to the Illinois Raptor Center.
Wild birds, like most wild animals, are subject to naturally−occurring and human−caused incidents that greatly impact their health. One group of wild birds that are often the focus of wildlife rehabilitation efforts are birds of prey, or raptors. We are interested in both the circumstances that led to admittance of a raptor at the Illinois Raptor Center, in Decatur, Illinois, and their overall health state upon admission to the center and prior to their release. In this study, we examined hematological metrics associated with the health of birds, including hematocrit, protein levels, and calcium levels. Through this study, we also assessed baseline values for these physiological measures in different raptor species, many of which were previously unknown, and related them to variation in life history and natural history. Exploring these vital metrics in raptors will facilitate our understanding of ecophysiology in free−living raptors that are not in a rehabilitation setting as well as improvement of rehabilitation, and the ability to monitor the progress from the time of arrival to the time of successful release from rehabilitation.

P2.104 KING, C*; CICERO, C; BENEDICT, L; KARIN, B; Univ. North Florida , Univ. of California, Berkeley, Univ. Northern Colorado, Villanova Univ. ; *n00960341@ospreys.unf.edu*
Cultural evolution in Bell's and Sagebrush sparrows (Artemisiospiza belli and A. nevadensis): Does song reflect phylogeny and ecology?
The Bell's Sparrow (*Artemisiospiza belli*) and Sagebrush Sparrow (*A. nevadensis*) were split recently based on genetic, morphological, and ecological differences. These species meet in a narrow contact zone in eastern California where the Mojave Desert meets the Great Basin. The Bell's Sparrow is smaller than the Sagebrush Sparrow, occupies a different ecological niche, and migrates shorter distances. We add to prior work by examining song differences at two scales: (1) among populations of *A. nevadensis* and three of four subspecies of *A. belli*; and (2) in detail across the contact zone. We studied over 8900 songs from 427 individuals and 27 sites, and measured a number of variables on sound spectrographs to quantify the frequency and temporal characteristics of songs. On a broad scale, songs reflect ecological similarity versus phylogenetic relatedness. Songs of *A. b. belli* are distinctive from a cluster that includes *A. nevadensis*, *A. b. canescens*, and *A. b. clementeae*. Within that cluster, *A. nevadensis* songs are distinctive from the other taxa. The endemic, threatened island subspecies (*A. b. clementeae*) has songs more typical of the ecologically similar *A. b. canescens* than the geographically proximate *A. b. belli*. At both scales, *A. nevadensis* and *A. belli* show marked differences in song frequency and temporal characteristics. Songs across the contact zone generally matched patterns of mtDNA and morphology, with more typical *A. nevadensis* songs at the northern end of the zone, more typical *A. b. canescens* songs at the southern end of the zone, and genetically mixed populations showing song characteristics of both taxa.

35.1 KINGSOLVER, J.G.*; HIGGINS, J.K.; MOORE, K.J.; HILL, D.S.; Univ. of North Carolina, Chapel Hill; *jgking@bio.unc.edu*
Quantifying nonlinear and time−dependent effects of fluctuating temperatures on insect growth and heat tolerance
Temperature has nonlinear effects on most biological rates, so that fluctuating temperatures can alter the mean rates of performance in ectotherms. However, the temporal order and duration of exposure to temperatures (time−dependence) can also have important consequences for thermal sensitivity and performance of ectotherms. For example in *Manduca sexta*, temperatures that maximize larval growth rates over hourly to daily time scales can be suboptimal or lethal over longer time scales. We quantified how different mean temperatures and diurnal fluctuations in temperature during development can determine mean growth rates and heat tolerance in *Manduca* larvae. The effects of diurnal temperature fluctuations on mean growth rate depended strongly on mean temperatures. Diurnal fluctuations generally decreased mean growth rates. Our analyses suggest that both nonlinear and time−dependent effects of rearing temperature influenced mean growth rate, especially at higher temperatures. We also tested whether rearing conditions affect larval survival in response to a brief (2h) heat shock at 46−48°C (heat−hardening). Initial studies indicate that diurnal fluctuations increased heat−hardening (greater survival after heat shock) even at moderate rearing temperatures. This suggests that fluctuations in temperature, rather than temperature itself, may be more important for eliciting heat−hardening responses.

50.8 KINGSTON, ACN*; CRONIN, TW; University of Maryland Baltimore County; *anahm1@umbc.edu*
Identical opsins in the retina and central nervous system of crayfish, Procambarus clarkii
There are several photosensing systems in epigeal crayfish that operate simultaneously. The eyes, brain, and caudal photoreceptor (CPR) are known to generate responses to light. While the opsin in the long−wavelength sensitive photoreceptor cells in the main rhabdom has been identified as a typical crustacean long−wavelength sensitive opsin, we have now discovered the opsin responsible for light detection in the short−wavelength receptor, the eighth retinular cell which lies distal to the main rhabdom. Here, we characterize the short−wavelength sensitive opsin in the crayfish retina, and provide evidence that both opsins are expressed throughout the central nervous system of the crayfish, *Procambarus clarkii*. We used RT−PCR to identify the short−wavelength sensitive opsin in the retina, and to detect both opsin transcripts in the brain and each ganglion of the ventral nerve cord. We used immunohistochemistry to label the short− and long−wavelength opsins in the retina and throughout the CNS, including the sixth abdominal ganglion where the CPR exists. We hypothesize that visual opsins are involved in photoreception throughout the central nervous system. Furthermore, our results suggest the presence of a more extensive system of photoreceptors than previously recognized.

P2.99 KIRCHER, BK*; CASTRO, DJ; ROBINSON, CD; JOHNSON, MA; University of Florida, Trinity University; *kircherb@ufl.edu*
Androgen receptor expression in Anolis lizard muscles: the evolution of endocrine mechanisms of social behavior
Androgens play important roles in the development, expression, and maintenance of the male reproductive system across a wide variety of species. Generally, androgens bind to androgen receptors (AR) to induce physiological changes to male sex organs and/or secondary sex characteristics. *Anolis* lizards provide a robust system for the study of androgen−regulated characteristics. In anoles, androgens are important regulators of social display behaviors (specifically throat fan, or dewlap, extensions and pushup displays) during the breeding season. However, interspecific variation in circulating testosterone levels in this genus is not associated with the frequency of dewlap display, suggesting another mechanism for the regulation of this behavior. In this study, we aimed to determine whether anole species with increased display behaviors exhibited an increased concentration of AR in the muscles controlling those behaviors. In six species of anoles that demonstrate significant variation in the frequency of dewlap and pushup displays, we measured the percentage of AR+ nuclei present in the ceratohyoid muscle (controlling dewlap extension) and the bicep muscle (controlling pushup display). Using phylogenetically−informed analyses, we found that species with a greater proportion of AR+ nuclei in the bicep exhibited higher rates of pushup displays; however, we did not find the same pattern in the dewlap−controlling muscle. These results suggest that AR expression may play a critical role in the evolution of social behaviors in this group, but because this pattern was not consistent across the muscles we examined, other mechanisms are likely to influence these behaviors as well.

75.5 KIRK, NL*; SLAPETA, J; LINARES, M; THORNHILL, DJ; KEMP, DW; FITT, WK; SANTOS, SR; Oregon State University, University of Sydney, New South Wales Australia, Defenders of Wildlife, Washington DC, University of Georgia, Auburn University, Alabama; *kirknat@gmail.com*

The tale of two apicomplexans: Are associations between scleractinian corals and apicomplexans (Alveolata) specific?

Apicomplexa are ubiquitous parasites of vertebrates and invertebrates and at least one lineage commonly associates with corals at high prevalence. Apicomplexans contain the causative agents of malaria as well as opportunistic human pathogens *Toxoplasma gondii* and *Cryptospordium* spp. To infer evolutionary origin of the coral−associated Apicomplexa, 18S−rDNA were amplified from a broad sampling of scleractinian and gorgonian corals from the Caribbean Sea and Great Barrier Reef. Phylogenetic trees confirmed monophyly of all coral−associated Apicomplexa, which is basal to the coccidian lineage. Using 18S−rDNA there was little evidence of coevolution within the coral−associated apicomplexan clade as constraint trees mirroring host phylogeny were significantly worse. To further examine the extent of host specificity of coral−associated Apicomplexa, highly variable ITS1 rDNA (~45% similarity) were amplified from the scleractinian corals *Porites astreoides*, *Orbicella* (=*Montastraea*) *faveolata* and *O. annularis* across 5 reefs in the Caribbean Sea. Although other types were detected, two distinct host−adapted ITS genotypes of coral−associated apicomplexans were recovered at all examined reefs. These data suggest specificity between coral host and Apicomplexa indicating a complex interaction between partners.

113.1 KITCHEN, S*; SHINZATO, C; HARII, S; SATOH, N; WEIS, V; Oregon State University, Okinawa Institute of Science and Technology, University of Ryukyus, Tropical Biosphere Research Center; *kitchens@science.oregonstate.edu*

Consequences of Hyperthermal Stress on Coral Larvae Undergoing Symbiont Colonization

Climate change threatens the health of reef−building corals. Under prolonged hyperthermic stress, coral−dinoflagellate partnerships collapse, resulting in coral bleaching or the loss of dinoflagellates from the host. The physiological and molecular consequence of symbiosis and elevated temperature on host−symbiont associations in adult corals has been widely investigated. However, very few studies have examined the ramifications of these combined stressors on coral larvae. Understanding the mechanisms that underlie the formation of coral−algal partnership during early developmental stages is critical to predict how coral recruitment and resilience will change in periods of warmer seas forecasted with climate change. This project extends the investigation of the combined stress from temperature and symbiosis by examining larval health and survival, symbiont colonization, and gene transcriptional profiling. In this study, we monitored early stages of symbiosis in the larvae of *Acropora digitifera*, a coral model that is thermally sensitive. From the survivorship analysis, both temperature and symbiotic state were found to have an effect on larval survival rates, with increased mortality in larvae exposed to the combined stress. The combined stress also decreased symbiont colonization and symbiont density of the larvae over two weeks of observation. Lastly, we identified novel transcriptional patterns in the coral molecular stress−response through RNASeq, an unbiased, high−throughput approach to expression profiling. Our data suggest that the combination of physical and biotic pressures can dramatically decrease larval health in *A. digitifera*.

105.5 KLAASSEN VAN OORSCHOT, B*; TANG, HK; TOBALSKE, BW; Univ. of Montana, Mount Holyoke College; *brett.kvo@umontana.edu*

Evolution, form, and function of slotted primary feathers in flying birds

Slotted or *emarginated* primary feathers are a common feature of the distal wing among many disparate avian taxa. However, the selective forces shaping primary feather morphology remain unclear. Here, we describe the phylogenetic pattern associated with these slotted feathers and test the functional aerodynamic significance of feather bending to better understand what influences primary feather shape. Slotted feathers have a characteristic notched taper that keep them separated when the wing is fully extended. This gap allows them to vertically separate and bend when aerodynamically loaded. We hypothesize that these notched feathers enhance longitudinal stability by bending and redirecting lift forces proximally over the bird's center of mass. We tested this by measuring the aerodynamic forces produced by individual feathers over a range of attack angles and bending angles. Our results are consistent with this hypothesis: 1) bending is most prominent in notched feathers; 2) feathers resist bending more at positive attack angles; and 3) regardless of attack angle (+/−) and bending direction, lift forces tend to be oriented proximally. Furthermore, controlling for phylogeny, body size is not correlated with feather emargination. Rather, phylogenetic relatedness and aeroecological factors appear to be the main factors shaping primary feather morphology. Funded by the following grants: NSF GRFP DGE 809127 and DGE‘313190.

15.3 KLANN, M*; STOLLEWERK, A; Whitney Laboratory, St. Augustine, Queen Mary, London; *meritmarleen@aol.com*

Evolutionary changes in proneural gene expression − atonal and ASH in Daphnia magna

In insects the large number of sense organs can be subdivided into groups based on their morphology and corresponding function. The molecular and morphological development of sense organs has mainly been analysed in *Drosophila melanogaster*. Sense organ development requires proneural genes for the selection of sensory organ progenitors (SOPs), but also for their subtype identity. The proneural genes of the Achaete−Scute family, for example, are required for external mechanosensory organ development, while members of the Atonal family specify chordotonal organs and a subset of olfactory sense organs among others. We investigate the morphological and molecular development of sensory organs in *Daphnia magna* to address the question if evolutionary changes in the expression and function of proneural genes correlate with modifications in structure and function. Surprisingly, we found that in *D. magna ASH* and *atonal* are expressed in an overlapping pattern in several areas of the peripheral nervous system. Examples are the distal parts of the antennae, the mandible and the thoracic appendages, as well as the posterior margin to the proctodeum. Since it is not known which sense organs are generated in these areas, we are analyzing the structure and function of the larval sense organs and trace their origin back to embryonic stages. The partial co−expression of *ASH* and *atonal* in *D. magna* indicate that either the molecular mechanisms in sense organ determination have changed during crustacean evolution or that sense organs are formed that show characteristics distinct from insect sense organs. Therefore, we used stable germ line transformation to create *D. melanogaster* transformants, which carry the *Daphnia atonal* gene in order to perform over−expression and rescue experiments.

P3.67 KLEIN, E J*; RUVINA, K; BENI, M; ANDRINGA, R; KOTHARI, P; CARLSON, A ; BERGMAN, D A; Grand Valley State University; *kleined@mail.gvsu.edu*

An Investigation of the Intrinsic and Extrinsic Influences on the Aggressive Behavior of Crayfish

Aggressive (i.e. agonistic) interactions play a significant role in the establishment of a social hierarchy in many species. Hierarchies and rank within them can greatly influence the quality of life of an animal and are often necessary to obtain valuable resources such as food, shelter, and mates. Several influences have been identified as important in determining aggressive hierarchy formation in crayfish, however the relative significance of these factors has yet to be determined. This study compares several aggressive influences, including previous winning or losing experiences, prior shelter possession, starvation, olfaction obstruction, and control treatments to determine which of these factors affect aggressive interactions to the greatest extent. The analysis will reveal which of these effects is strongest when directly confronted against one another. Each crayfish received one of the above treatments and then interacts with another size−matched crayfish that received a different treatment. All trials were recorded and then analyzed using a blind analysis scheme that utilized a behavioral ethogram to quantify the intensity of aggressive interactions and the eventual agonistic bout outcome.

42.7 KLEINTEICH, T.*; GORB, S.N.; Kiel University, Germany; *tkleinteich@zoologie.uni−kiel.de*

Fast, wet, and sticky: the functional morphology of frog tongues

Frogs are well known to catch prey by using a sticky tongue that can either be protruded over the tip of the jaw or in many species may be ballistically fired towards remote targets. Often frogs are generalist feeders and frog tongues stick to a vast diversity of different prey surfaces. Due to the rapidness of feeding in frogs, their tongues have to adhere instantaneously. Frog tongues are covered in mucus and the interaction of this mucus with the tongue and the prey surface will be critical for a successful feeding event. Thus, frog tongues provide an interesting example of a wet adhesive system that acts at high speeds on a variety of substrates. Here we measured the forces with that frogs of the South American genus *Ceratophrys* attach to glass. We recorded the forces during the impact and pulling phases of the feeding strike. We found that the maximum pulling forces were on average beyond the body weight of the animals. Further, pulling forces decreased over time while the frogs detached their tongues, which suggests a similar detachment mechanism like in so−called pressure sensitive adhesives (PSAs) that are of common technical use as adhesive tapes or labels. By using high speed videography, we were able to show fibrillation of the mucus during detachment. Further, we studied the comparative anatomy of frog tongues from the macroscopic to the microscopic level in nine different taxa, comprising species with protrusible and projectable tongues. For this we used a combined approach of micro−CT imaging and scanning electron microscopy. Among different frog taxa, we found a high degree of variation in tongue anatomy on all levels comprising the general shape, the internal anatomy, and the size, shape, and distribution of surface microstructures. The observed variation appears to be a mosaic of functional and phylogenetic patterns.

P2.204 KLOK, CJ*; CAMPBELL, J; HARRISON, JF; Arizona State University; *cjklok@asu.edu*

Using respiratory water vapour release rates to investigate tracheal ventilation during oxygen challenges in small and giant insects

Prior studies, of insect taxa with a range of body sizes − four orders of magnitude − have now consistently demonstrated that insects have very uniform O_2 safety margins. For quiescent insects these margins are quite low − 1 to 2.5 kPa PO_2, independent of size. It's argued this is due to the extensive array of tracheae penetrating insect tissues, evolved to optimise O_2 delivery during maximal O_2 demand. Additional studies indicated distinct scaling compensation in tracheal dimensions relative to body size. However, this tracheal hypermetry is insufficient by itself to effect optimal O_2 delivery. Insects rely, quite significantly, on active ventilation for optimal tissue oxygenation when challenged with O_2 demand vs O_2 availability. The standard method of determining critical PO_2 ($CritPO_2$) is to reduce O_2 during flow through respirometry to measure metabolic rates − assessed from CO_2 release rates (VCO_2). As PO_2 is reduced VCO_2 declines steadily, until a clear break in VCO_2 occurs ($CritPO_2$). However, ventilation increases notably from 7.5 to 3 kPa PO_2, but due to reduced O_2 availability to maintain metabolism this ventilatory increase is not reflected in the VCO_2 patterns. Thus to investigate ventilation we also measured respiratory water vapour release rates (VH_2O) as a proxy. As insects approach 7.5 kPa PO_2 the drastic increase in ventilatory activity is clear from VH_2O increases, and, conversely, closer to the $CritPO_2$ ventilatory muscle activity decreases due to O_2 starvation indicated by VH_2O decreases. In this study, using scarabaeid beetle species ranging in size from 35 to <1 gram, we investigate whether insect body size has an effect on the onset and magnitude of ventilatory activity when challenged with O_2 demand vs O_2 availability. Supported by NSF IOS 1122157.

S10.5 KNADEN, Markus; Max Planck Institute for Chemical Ecology; *mknaden@ice.mpg.de*

Homing in desert ants using multiple sensory modalities.

Cataglyphis fortis ants forage individually for dead arthropods in the inhospitable salt−pans of Tunisia. Locating the inconspicuous nest after a foraging run of more than 1000 meters demands a remarkable orientation capability. As a result of high temperatures and the unpredictable distribution of food, *Cataglyphis* ants do not lay pheromone trails. Instead, path integration is the fundamental system of long−distance navigation. This system constantly informs a foraging ant about its position relative to the nest. In addition, the ants rely on visual landmarks as geocentric navigational cues to finally pinpoint the nest entrance. Here I show that − apart from its visual navigation − *Cataglyphis* a) uses environmentally derived olfactory cues in order to locate its nest entrance. b) exhibits far−reaching crosswind runs to localize food plumes efficiently. c) benefits from the combinatorial use of visual and olfactory information. Because of its visual and olfactory navigation capabilities, *Cataglyphis* represents a valuable model for the investigation of crossmodal processing.

14.7 KNOLL, K.M.*; LEONARD, J.B.K.; Northern Michigan University; *kknoll@nmu.edu*

The Effects of Anthropogenic and Natural Barriers on Fish Morphology: a Geometric Morphometric Analysis

Dams are one of the most widespread and disruptive anthropogenic modifications of ecosystems worldwide. While it has been shown that large dams with upstream reservoirs can cause divergent selection in fish morphology, the effect of small dams without an upstream reservoir is largely unknown. We investigated the contribution of isolation to morphological variation in fishes while controlling for divergent flow selection created by an upstream reservoir. This project also investigated the effects of isolation time on fish morphology by comparing morphological divergences of fish associated with older barriers (waterfalls) to very new barriers (dams). A total of 950 fish across 18 species were sampled from May to August in 2014 from nine waterfalls and five dams in the southern Lake Superior Watershed. Geometric morphometrics will be used to analyze body shape differences between fish above and below barriers. Initial results show significant differences in mean total body length between above and below populations at three study sites: *Rhinichthys cataractae* separated by Middle river dam (WI), *Cottus cognatus* separated by Miners falls (MI), and *Cottus cognatus* separated by Au train falls. These findings suggest that genetic drift due to isolation from small dams and waterfalls can lead to morphological variation in native fish populations.

36.6 KNUTIE, S.A.*; MCNEW, S.M.; BARTLOW, A.W.; VARGAS, D.A.; CLAYTON, D.H.; University of Utah; *saknutie@gmail.com*

Darwin's finches combat introduced nest parasites with fumigated cotton

Introduced parasites are a threat to biodiversity when naïve hosts lack effective defenses against such parasites. Several parasites have recently colonized the Galápagos Islands, threatening native bird populations. For example, the introduced parasitic nest fly *Philornis downsi* has been implicated in the decline of endangered species of Darwin's finches, such as the mangrove finch (*Camarhynchus celibates*). In our study, we show that Darwin's finches can be encouraged to "self−fumigate" nests with cotton fibers that have been treated with a mild insecticide (1% permethrin solution). Nests with treated cotton had significantly fewer *P. downsi* than control nests, and nests containing at least one gram of treated cotton were virtually parasite−free. Nests directly fumigated with permethrin had fewer parasites and fledged more offspring than nests treated with water. The results from this study demonstrate that self−fumigation can be used to mitigate the effect of nest flies on Darwin's finches and potentially in other systems.

26.4 KOCH, R.E.*; WILSON, A.E.; HILL, G.E.; Auburn University; *rek0005@auburn.edu*

The impact of carotenoid intake on the physiological effects of supplementation in ornamented bird species

Carotenoid coloration is the one of the most frequently studied ornamental traits in animals. Many studies of carotenoid coloration are focused on the associations between dietary intake of carotenoids, measures of performance such as immunocompetence and oxidative state, and production of ornamental coloration. Such studies commonly involve supplementing the diets of captive birds with carotenoids. In many cases, however, the amount of carotenoids administered is extrapolated from studies of other species of different body mass. We used meta−analysis to synthesize published studies where bird diets were supplemented with varying concentrations of carotenoids to elucidate the relationship between carotenoid supplementation, color, and immune function. Allometric scaling equations estimated the per−gram carotenoid consumption of subjects, and meta−regression contrasted the impact of differences in adjusted carotenoid intake on differences in coloration, plasma carotenoid level, and immunocompetence between supplemented and control groups of birds. Additional subgroup analyses discriminated effects of carotenoid supplementation between species with ornamental color in their bills or legs and those with colored plumage ornaments. Supplementation effects varied among ornament types, but there was significant heterogeneity in responses across studies and species. Our results emphasize the importance of using dosage trials or measuring actual carotenoid intake to validate that supplementation levels are appropriate for a particular study species and experimental design.

S7.4 KOEHL, M.A.R.; Univ. of California, Berkeley; *cnidaria@berkeley.edu*

Swimming in an Unsteady World

When animals swim in aquatic habitats, the water through which they move is usually flowing. Therefore, an important part of understanding the physics of how animals swim in nature is determining how they interact with the fluctuating turbulent water currents in their environment. The research systems we have been using to address this question are microscopic marine animals swimming in turbulent, wavy water flow over spatially−complex communities of organisms growing on surfaces. Field measurements of water motion were used to design realistic turbulent flow in a laboratory wave−flume over different substrata, particle−image velocimetry was used to measure fine−scale, rapidly−varying water velocity vector fields, and planar laser−induced fluorescence was used to measure concentrations of chemical cues from the substratum. We used individual−based models of small animals swimming in this unsteady flow to determine how their trajectories were affected by their locomotion through the water, rotation by local shear, response to odors, and transport by ambient flow. We found that the shears, accelerations, and odor concentrations encountered by small swimmers fluctuate rapidly, with peaks much higher than mean values lasting fractions of a second. Although microscopic organisms swim slowly relative to ambient water flow, their locomotory behavior in response to the rapidly−fluctuating shears and odors they encounter can affect where they are transported by ambient water movement.

P2.11 KOENIG, KM*; MEYER, E; SUN, P; GROSS, JM; University of Texas at Austin, Oregon State University; *kmkoenig@utexas.edu*

The Cephalopod Single−Chambered Eye as a Model for Complex Eye Evolution and Development

Understanding the evolution of complex organ systems is an important aspect of understanding the evolution of diversity. The visual system is a particularly compelling example because of the high level of morphological diversity and complexity in photoreceptive organs across the Metazoa. Our research interest is to better understand visual system evolution across the Bilateria from a developmental perspective. While complex image−forming eyes have been well studied in select deuterostome and Ecdysozoan species at a developmental, molecular and genomic level, there are no Lophotrochozoan models for which comparative analyses can be made. We aim to better understand the evolution and development of complex image−forming eyes across the Metazoa by establishing the single−chambered eye of the squid, *Doryteuthis (Loligo) pealeii*, as a model. We have generated a substantial amount of transcriptomic, molecular and morphological data to support these studies and are poised to address questions of conservation versus novelty, and to better understand the influence of developmental constraint on the evolution of visual systems

S9.4 KOHLER, B. R. *; BRUDER, A.; Utah State University, Colorado College; *Brynja.Kohler@usu.edu*

Limnology and Inversions in Multivariable Calculus

Students who have lived a winter in Utah are familiar through first hand experience with the fact that temperature inversions trap pollution. And temperature gradients in lakes are also familiar to outdoor enthusiasts who enjoy a summer swim or fishing trip, but are they aware of how climate change may influence lake ecology? Even less familiar is how to model or study such systems mathematically. As part of our undergraduate curriculum development project: Laboratory Experiences in Mathematical Biology, we have developed a lab that introduces students quantitatively to atmospheric temperature inversions, and basic limnology while addressing mathematical topics from multivariable calculus. In this laboratory, students work in groups to gather temperature data from a glass in which a fixed volume of cool milk is inserted beneath an approximately equal volume of hot coffee. The purpose of the lab is to give students a hands on experience with a function of two independent variables (time and space), expose them to the challenges of making mathematical models of real life phenomena including the process of discretizing continuous variables and making measurements, as well as to introduce/strengthen student experience with the following mathematical technical notions: functions of two variables, graphs of surfaces, contour maps of surfaces, level curves, limits of multivariable functions, and partial derivatives. In the presentation, I will share the results of our trials of this lab with students, as well as the current state of our resources for implementing the lab.

S5.3 KOHN, A.B.*; MOROZ, L.L.; Univ. of Florida, Whitney lab; *abkohn@msn.com*

Genomic portrait of synapses and their evolution

Hypotheses of origins and evolution of neurons and synapses are controversial, mostly due to the lack of comparative data. Here using advanced sequencing technologies and an unbiased approach we investigated the distribution of canonical synaptic and neuronal machinery' among basal metazoans and lophotrochozoans. Results of this analysis lead us to propose an alternative hypothesis that not only have neurons evolved in parallel, but also synapses. Novel techniques combining quantitative immunoblotting and mass spectrometry, electron microscopy and super−resolution fluorescence microscopy, recently employed to identify proteins and generate a 3D space of an average synapse, were used as a starting point in our comparative analysis. The presence and distribution of over 200 presumed presynaptic and postsynaptic proteins were characterized across phyla. Interestingly, *Trichoplax*, an organism with no neurons had more orthologs of bilaterian synapse/neuron related genes than ctenophores (e.g. *Pleurobrachia*) with well−defined neuronal and synaptic organization. Surprisingly, we found that most of these synaptic' genes are being expressed before neurons ever appear in development suggesting that this secretory machinery is commonly recruited for a diversity of non−neuronal functions and cannot be used as neuronal markers per se. We further expanded our list to include all known components controlling excitability and reception. As a result, we developed a model to reconstruct parallel evolution of synapses in distinct cellular lineages.

33.1 KOHN, AJ; Univ. of Washington; *kohn@uw.edu*

Antipredator defenses of polychaete prey vs. offenses of conoidean gastropods

An important ecological role of polychaetes in marine benthic environments is that they provide the exclusive prey of most members of by far the largest marine gastropod Superfamily, the Conoidea, including all of its families. This talk poses the questions: 1) Is the specialized venom−assisted prey−capture mechanism of conoideans adapted to the particular polychaetes they capture, and if so in what ways? 2) Do the prey polychaetes have structural or behavioral defensive adaptations that enable them to deter or avoid conoidean predators, and if so, how effective are they? 3) Can we detect evidence of coevolutionary arms races? Sally Woodin and I planned to collaborate on a study of these questions after she completed her Ph.D. work, but we were never able to do so. This presentation will thus be relatively data−free, but it seeks to articulate hypotheses, marshal evidence from other relevant studies over the past 40 years, and encourage others to explore these poorly known but widespread and ecologically important predator−prey relationships.

P2.191 KOLMANN, MA*; LOMAX, JJ; CROFTS, SB; SUMMERS, AP; Univ. of Toronto, Univ. of South Florida, Univ. of Washington, Univ. of Washington; *matthew.kolmann@mail.utoronto.ca*

The effect of jaw curvature on crushing performance in durophagous stingrays

Durophagy has evolved several times within the elasmobranchs. The stingray family Myliobatidae is composed almost entirely of durophagous taxa, except for the planktivorous manta and devil rays. These durophagous rays use rigid jaws, pavement−like dentition, and hypertrophied jaw muscles to crush and consume mollusks and crustaceans. The curvature of the upper and lower tooth plates vary considerably from one another, as well as between related taxa. We hypothesize that this difference in curvature will affects feeding performance and, therefore, patterns of ecological niche partitioning. For this study, we focused on the genera that represent the two morphological extremes: *Aetomylaeus* where a moderately curved top tooth plate occludes with a relatively flat lower tooth plate, and *Rhinoptera* which have highly curved both upper and lower tooth plates. We hypothesize that: (1) greater disparity between the curvature of the upper and lower jaws will decrease the load necessary to initiate prey fracture (yield load) and (2) occluding a curved tooth surface against a more planar surface is optimal for crushing large prey. Using aluminum stingray jaw replicas fixed to a mechanical loading frame, we measured the forces necessary to fracture uniformly manufactured ceramic tubes as well as two size series, live gastropods (*Nucella* sp.) and, 3D−printed shell replicas. There was no difference between the two ray species for most of the prey items, but (A) *Aetomylaeus* performed better when forcing smaller, printed shells to fracture; (B) intermediate shell sizes (printed) required the least amount of force to fracture, followed by smaller shells and then larger ones; (C) Finally, both printed and live shells failed consistently in the same region, at the base of the spire, while ceramic tubes showed greater variation in location of fracture.

99.6 KONOW, N*; HEDBERG, M; SWARTZ, SM; Brown University; *nkonow@brown.edu*

Joint kinematics and motor patterns of swimming and flight in the big brown bat (Eptesicus fuscus)

The typical locomotor mode of bats is flight, but many species swim capably. Earlier studies have characterized the kinematics of swimming in the big brown bat (*Eptesicus fuscus*) as a low−amplitude version of their flight kinematics. The kinematic differences could arise from fundamentally different motor patterns during the two locomotor modes, or from similar motor patterns realized differently in air versus water, fluid media with different physical properties. To explore these alternatives, we asked whether activation and recruitment patterns of several limb muscles in bats differ between flight and swimming We measured fore and hindlimb joint kinematics and electromyography (EMG) from biceps brachii (short head), triceps brachii (lateral head) and gracilis in *E. fuscus*. Our experiment allowed each subject to fly and swim with the same EMG implants. We then examined relationships between onset and peak timing of EMG and joint kinematics (shoulder, elbow, hip and knee flexion−extension) using cross−correlation analyses to determine phase−lag. After accounting for difference in medium by duty−cycle normalization, lags between peak muscle intensity and peak joint kinematics were significantly larger during swimming than flight. During flight, all three muscles were active during joint movements supported by their anatomical lines of action. By contrast, during swimming, their activation timing shifted by up to 75−80% of the limb motion cycle, to coincide with the opposite joint movement. This finding suggests that energy might be stored elastically in the slender tendons of triceps, biceps and gracilis during swimming. Studies of muscle and tendon length change during swimming and flight will help test this hypothesis directly. Funded by AFOSR.

50.5 KOPPERUD, KL*; TAYLOR, SM; GRACE, MS; Florida Institute of Technology; *kkopperud2010@my.fit.edu*

Circadian rhythms in the retina of Atlantic tarpon, Megalops atlanticus

Biological clocks and the rhythms they produce are fundamental to eukaryotic life, allowing organisms to *anticipate* change in the environment. While many physiological and behavioral life processes may change in direct response to external influence, most also change over time because of internal timekeeping mechanisms − biological clocks. Extensive research has defined the anatomical locations and molecular make−up of clocks in people and some lab animals, but we understand very little about the functional utility of clocks and rhythms in the natural world. This research aims to shed insight on these issues by examining clock operation in the Atlantic tarpon (*Megalops atlanticus*), one of the most sought−after game fish. Tarpon undergo ecological shifts as they mature from larvae to adults. These shifts are accompanied by significant alterations in photoreceptor cell type and distribution, making tarpon exceptional models for studying how retinal structure and function adjust to a changing light environment. Using immunofluorescence, we have determined that tarpon begin life with rod−dominated retinas, and then add cone photoreceptors at key life transitions. Furthermore, after the compliment of rod and cone cells have developed, photoreceptors begin to undergo daily changes in position within the retina according to time of day. The development of these retinomotor movements is part of a suite of changes we have identified in the tarpon retina that occur over the course of the day and over the course of the lifetime. These dramatic changes in retinal form and function support survival of these fish as they transition among habitats, and may support their survival in the face of anthropogenic disturbance that alters light quality, such as exposure to light at inappropriate times due to coastal development.

84.4 KOSMAN, E.T.*; LEVITAN, D.R.; Florida State University, Tallahassee; *etkosman@bio.fsu.edu*

Interactions between molecular and physiological gamete traits on fertilization success under sperm−limiting and polyspermy conditions

Sperm availability may influence the evolution of gamete traits in broadcast spawners. Gamete characteristics that are advantageous under sperm limiting conditions might be deleterious, as the probability of male−male competition and egg death via polyspermy increases with increasing sperm density. Gamete traits that can modify the sperm−egg collision rate, such as sperm swimming speed and egg size, and those that can modify the sperm−egg fusion rate, such as compatibility between sperm and egg proteins, are known to influence fertilization success. What remains unclear is how these factors interact to influence fertilization success. We utilized no−choice diallel crosses to examine the interactions between sperm swimming ability, egg target size and sperm−egg compatibility on reproductive success under polyspermic and sperm−limiting conditions in the tunicate *Ciona intestinalis*. Crosses were conducted utilizing two different sperm−egg contact times. To examine the role of sperm−egg compatibility on fertilization success, crossed individuals were sequenced for candidate male and female gamete recognition proteins. A common non−synonymous SNP was identified for both the egg protein in dams and sperm protein in sires. These protein variants were examined for how they interacted to influence fertilization success in statistical models that also incorporated sperm behavior and egg size. Preliminary results indicate that interactions between gamete trait, male genotype, and female genotype can influence fertilization success, and the significance of those interactions is dependent on sperm availability and contact time.

S6.5 KOTRSCHAL, Alexander*; KOLM, Niclas; Stockholm University; *alexander.kotrschal@zoologi.su.se*

Artificial selection reveals the costs and benefits of large brain size in a vertebrate

Vertebrate brain size is remarkably variable at all taxonomic levels. This variation is believed to have evolved through the balance between positive selection from cognitive advantages of larger brains and prohibiting energetic costs associated with the development and maintenance of a larger brain. Whether this is the case remains untested. Although comparative studies highlight several important selection pressures, experiments testing the consequences of a larger brain are absent. Our recent success in creating large− and small−brained lines of guppies (*Poecilia reticulata*) via artificial selection now enables us to experimentally test the costs and benefits of having smaller or larger brains. Our results demonstrate that an 11 % difference in relative brain size between up− and down−selected replicate lines can evolve surprisingly fast − but at some cost. Large−brained animals show a decreased fecundity, develop smaller guts, and exhibit an impaired immune response. These costs are likely offset by a selective advantage of large−brained offspring in cognitively challenging environments, since relatively larger brains should confer a cognitive benefit. To test this hypothesis, we compared learning performance between large− and small−brained animals and indeed found that large−brained individuals outperform small−brained individuals in several aspects of cognitive ability. We confirmed the ecological relevance of increased cognition by discovering a survival advantage of large− compared to small−brained females under semi−natural conditions. These results provide the first experimental evidence of costs and benefits of brain size evolution and have important implications for our understanding of the evolutionary reasons for the remarkable variation in brain size evident among vertebrates.

P3.84 KOUTEIB, S.*; DAVIES, S.; DEVICHE, P.; Arizona State University; *soukaina.kouteib@asu.edu*

Adjusting to urban life: endocrine and immune responses of a songbird to acute stress

Urbanization profoundly impacts the environment, creating novel habitats that differ vastly from surrounding non−urban habitats. This transformation may result in urban birds adjusting phenotypically such that they are better suited for the opportunities and challenges of their new habitats. To address this question, we compared free−ranging adult male Abert's Towhees, *Melozone aberti*, sampled during their breeding season in urban (n = 16) and surrounding non−urban (n = 20) areas in metropolitan Phoenix, Arizona. Birds were caught and bled within two minutes (Initial), restrained for 60 minutes, bled again (Stress), measured, and released on site. Urban towhees were heavier and had longer wings than non−urban birds, but were in similar body condition and had similar visible fat reserves and sizes of the cloacal protuberance, an androgen−dependent secondary sexual characteristic. Urban birds had lower Initial plasma corticosterone (CORT) than non−urban birds, but the two groups of towhees increased plasma CORT to similar levels during stress, suggesting higher stress sensitivity in urban settings. The lysis and agglutination capacities of blood did not differ between non−urban and urban towhees, but in both groups decreased during stress, suggesting rapid modulation of immune function during a stressful event. In summary, the adjustment of Abert's Towhees to urban areas involves changes in body size and in the endocrine, but not immune, response to acute stress. Supported by BCS−1026865, Central Arizona−Phoenix Long−Term Ecological Research (CAP LTER).

P3.116 KOVALIK, C.M.*; TOTH, L.T.; KAN, H.; ARONSON, R.B.; Florida Institute of Technology, Melbourne, Kyushu University, Fukuoka, Japan; *ckovalik2008@my.fit.edu*

Was the Eastern−Pacific Hiatus in Coral Growth a Trans−Pacific Phenomenon?

Coral reefs are among the most diverse and economically important ecosystems on the planet. Understanding the effects of previous climatic events on coral reefs can provide insight into the potential for future change. Reefs of the tropical eastern Pacific experienced a 2,500−year hiatus in coral growth and reef−framework construction during the mid− to late Holocene. The hiatus was correlated with increased variability of El Niño Southern Oscillation and its coupling with the Intertropical Convergence Zone. In this study, push−cores were extracted from uncemented reef frameworks at Kumejima, Ryukyu Islands, Japan and Kiritimati, Republic of Kiribati. Kiritimati is located in the equatorial Pacific, whereas Kumejima is located outside of the tropics in the western Pacific. The coral contents of the cores were identified, classified by taphonomic condition, and radiocarbon−dated to test the hypothesis that the hiatus was a trans−Pacific phenomenon.

62.4 KOZMA, M.T.*; SCHMIDT, M.; DERBY, C.D.; Georgia State University, Atlanta; *mtottempudi1@student.gsu.edu*

Chemoreceptor and perireceptor proteins in crustacean chemoreception: identification and phylogeny.

Crustaceans are a large and diverse group of arthropods with varied habitat, morphology, and behavior. Although crustaceans have been effectively used as models for understanding neural mechanisms underlying chemical sensing and control of behavior, a molecular/genetic level of understanding of their chemical senses is significantly lacking, especially compared to recent discoveries for insects. The purpose of this study is to summarize our current knowledge of chemosensory genes in crustaceans. We surveyed open−access databases to identify and compare crustacean genes for chemoreceptor proteins, including ionotropic receptors (IRs), odorant/olfactory receptors (ORs), gustatory receptors (GRs), and trace amino acid receptors (TAARs), and for perireceptor proteins, including odorant binding proteins (OBPs) and chemosensory proteins. Data are available for representative species from phylogenetically and ecologically diverse crustacean groups, including cladocerans (*Daphnia* spp.), copepods (*Calanus finmarchicus, Caligus rogercresseyi, Acartia pacifica*), brachiopods (*Artemia franciscana, Triops cancriformis*), and decapods (*Homarus americanus, Panulirus argus, Coenobita clypeatus, Pagurus bernhardus*). We provide a phylogenetic comparison of these chemosensory genes with each other and against those of other major clades, especially insects and other arthropods, nematodes, and vertebrates. Supported by a GSU Brains & Behavior seed grant.

P1.81 KOZOL, RA*; WILEY, DJ; D'URSO, G; DALLMAN, JE; Dept. of Biology, University of Miami, Dept. of Cellular and Molecular Pharmacology, University of Miami, Dept. of Cellular and Molecular Pharmacology; *robkozol@bio.miami.edu*

Investigating conserved developmental processes and genetic networks of Autism Spectrum Disorders genes in Yeast and Zebrafish.

Development of an organism is defined by the interactions among gene and protein networks. However network interactions are hard to functionally investigate, especially in vertebrates due to characteristics such as genetic complexity and long generation times. This network complexity is exemplified by the genetics of Autism Spectrum Disorders, a group of neuropsychiatric diseases for which the diversity of genetic and developmental components complicates our understanding of genotype/phenotype relationships. To address this complexity, we are using two experimentally amenable animal models in yeast and zebrafish. The strengths of these models are complimentary because we can address both common developmental processes and gene network interactions affected by ASD. First, we are developing zebrafish mutant models of the ASD genes SHANK3 and SYNGAP1 to identify neurodevelopmental processes affected by gene disruption. Second, we have recently established a method called Yeast Augmented Network Analysis (YANA) that couples yeast interaction assays with previously published protein−protein interaction data to identify disease susceptibility networks. Together these two models will help to identify common cellular processes affected by ASD gene mutations and the underling developmental gene networks that are susceptible to perturbations. Our goal is to exploit the evolutionary conservation of eukaryotic genetic interactions and cellular mechanisms to identify genetic or molecular modifiers that can ameliorate developmental disruptions in ASD.

P3.23 KRAJNIAK, KG*; VU, C; Southern Ill Univ Edwardsville; *kkrajni@siue.edu*

The effects of oxytocin/vasopressin family of peptides on the circular smooth muscle of earthworm gizzard

Previously we showed that annetocin, an earthworm member of the oxytocin/vasopressin family of peptides, caused an increase in the contraction rate and amplitude of the isolated crop−gizzard from the earthworm *Lumbricus terrestris*. Since this experiment examined the response of longitudinal muscles in these organs we decided to examine the effects of these peptides on the circular muscles in the gizzard for comparison. After removal from the worm the gizzard was cut into rings which contained intact circular muscle. One end of the ring was attached to a support in a tissue bath and the other end was connected to a force−transducer. Mechanical contractions were recorded on a computer using an Iworx A/D converter and Labscribe 2 software. Increasing concentrations of peptide were added to the bath and changes in contraction rate and amplitude were used to create log−concentration curves. Annetocin caused an increase in both rate with a threshold of 10^{-8} M and amplitude with a threshold of 10^{-9} M. Oxytocin caused an increase in rate with a threshold of 10^{-7} M and no change in amplitude. Vasotocin caused an increase in both rate with a threshold of 10^{-8} M and amplitude with a threshold of 10^{-9} M. Both arg−vasopressin and lys−vasopressin caused an increase in rate with a threshold of 10^{-6} M and no change in amplitude. These data suggested the following rank in potency: oxytocin>anntecoin =vasotocin>arg−vasopressin=lys−vasopressin. This is similar to the potency rank for the longitudinal muscle of the crop−gizzard: anntecoin>oxytocin> vasotocin =lys−vasopressin=arg−vasopressin. In both cases the receptor prefers the oxytocin like peptides more than the vasopressins. The slight differences in potency may be due to the fact that longitudinal muscle study used both the crop and the gizzard combined.

P1.107 KRAMER, M.Y.*; MCNABB, N.A.; GUILLETTE, L.J.; KOHNO, S.; Yeshiva Univ. , College of Charleston; Medical Univ. of South Carolina, Medical Univ. of South Carolina, Medical Univ. of South Carolina; *melissa.kramer@mail.yu.edu*

Drugged Wildlife: The Potential Impacts of Environmental Endocrine Disruptors on Reproductive Development

The growing use of oral contraceptives and hormone therapeutics prompts concerns that estrogenic and progestogenic compounds are present in wastewater at concentrations that may affect the reproductive health of aquatic animals as well as humans who consume affected animals. In this study, potential endocrine active compounds were extracted from effluent produced by the Charleston Water System wastewater facility at Plum Island according to EPA method 1694. The extract, when concentrated 100 times, activated the human nuclear estrogen and progesterone receptors in an in vitro transactivation assay. This provides a mechanism for the alterations in secondary sex characteristics that have been reported in fishes exposed to effluent at other locations. Bioaccumulation of some synthetic hormones has also been reported in teleost fishes. There is, therefore, potential for humans to be exposed to endocrine active compounds through consumption of these fishes. To explore the potential biological consequences of human exposure to these endocrine active compounds during sensitive windows of development, we also evaluated the effects of neonatal exposure to progestogens on the reproductive development of mice. Quantitative RT−PCR analysis of target genes from adult mice treated with the synthetic progesterone 17±−hydroxyprogesterone caproate (17PC) as neonates suggested that developmental exposure to progestogens decreases sensitivity to E2 at the uterine transcriptome level. These data indicate a need for further exploration of the long−term impacts of neonatal progestogen exposure on reproductive development.

74.1 KRASNOV, B.R.*; KHOKHLOVA, I.S.; Ben−Gurion University of the Negev; *krasnov@bgu.ac.il*

Ability to Discriminate Between Hosts and Reproductive Performance in Ectoparasites of Small Mammals

Selection of an appropriate habitat with necessary and exploitable resources is one of the main tasks for any living organism. If an organism succeeds in fulfilling this task, its reward is translated into an increase or, at least, non−decrease of its fitness. The evolutionary motivation of parasites does not differ from that of free−living organism. Parasites have to carefully select their host organisms at both evolutionary and ecological scales. An individual parasite has to be able to locate and identify an individual of an appropriate host species, sex and age and to distinguish it from individuals of often similar but less appropriate or even inappropriate cohorts. Here, we report the results of investigation of the ability of fleas (Siphonaptera) parasitic on rodents to distinguish between hosts of different species, genders or age categories presumably using odour cues. We will demonstrate that the ability to distinguish and to select an appropriate host individual results in fitness reward.

39.2 KRAUSE, JS*; MEDDLE, SL; WINGFIELD, JC; Univ. of California, Davis, The Roslin Institute, Univ. of Edinburgh; *jskrause@ucdavis.edu*

Seasonal modulation of prolactin and corticosterone secretion in response to acute stress in a short lived arctic breeding bird

Breeding is considered one of the highest energetically challenging stages within the annual cycle. Environmental disturbances during the breeding season can influence an individual's decision to breed or continue with an initiated breeding attempt. The general reproductive effort model attempts to predict the resources that will be allocated to a current reproductive bout or to future survival by aborting the current reproductive attempt. Life history theory predicts that short lived species should devote more resources towards a reproductive event because brood value is far greater than compared to that of long lived species that have multiple opportunities to breed. Previous bird studies have used endocrine correlates to understand the regulation of parental investment in response to stress. The two hormones investigated have been prolactin, which promotes parental investment, and corticosterone which promotes nest abandonment. Work in long lived sea birds has shown that prolactin levels decrease in response to a stressor but the magnitude of the decline was positively correlated with future reproductive potential. Here we present corticosterone and prolactin data collected following a standardized stressor, acute restraint handling, from a short lived arctic breeding, migratory songbird the white−crowned sparrow (*Zonotrichia leucophrys gambelii*) at multiple stages of the breeding and non−breeding seasons. These data show that both prolactin and corticosterone are modulated seasonally. Prolactin levels do not change in response to a standardized stressor which may be a physiological mechanism for maximizing parental investment in a harsh environment with a short breeding season.

113.2 KREDIET, CJ*; LEHNERT, EM; PRINGLE, JR; Stanford University School of Medicine, Stanford University School of Medicine, University of Wisconsin, Madison; *ckrediet@stanford.edu*

Gene expression under thermal stress and the potential for thermal acclimation in a symbiotic cnidarian

Despite its central importance for coral−reef ecosystems, the cnidarian−dinoflagellate symbiosis remains poorly understood at the genetic, molecular, and cellular levels. To explore the mechanisms underlying this symbiosis and their responses to stress, we used RNA−Seq to identify genes that are differentially expressed under thermal stress, using the small sea anemone *Aiptasia* as a model system. The clonal stock CC7 (containing a Clade A *Symbiodinium* symbiont), an aposymbiotic stock derived from CC7, and the stock CC7−SSB01 (aposymbiotic CC7 reinfected with a clonal Clade B *Symbiodinium* strain) were thermally stressed at 34° at 25 µE (12:12 L:D) and sampled at intervals for 10 d. We observed a strong upregulation in the mRNAs for heat−shock and other stress−response proteins at early time points (0−12 h) but distinct expression patterns when the symbiotic stocks began to bleach (e48 h). The overall expression patterns were similar in all three stocks, indicating that most, at least, are not related specifically to the presence of the endosymbionts. Further analysis of these expression patterns is in progress. We are also examining how prior thermal history influences the tolerance of symbiotic *Aiptasia* to subsequent thermal stress, finding that acclimation at elevated but sub−bleaching temperatures (30−32°) decreases the rate and severity of bleaching during subsequent thermal stress at 34°. Future studies will vary the acclimation temperatures and durations and analyze gene expression in thermally acclimated animals, in order to detect genes that influence thermal tolerance.

95.1 KRENTZEL, D*; ANGIELCZYK, K; Univeristy of Chicago, Field Museum; *dkrentzel@uchicago.edu*

Functional trade−offs and innovations in the evolution of the rodent masticatory system

Mastication in rodents is highly derived, being composed of quasi−independent gnawing and chewing systems and a complicated array of adductor muscles. The masseters are arranged in four qualitatively different configurations, with two anterior masseter units evolving rostral attachments multiple times independently, and these define the three derived forms sciuromorphy, hystricomorphy, and myomorphy. Since the Eocene, masseter configurations have remained qualitatively static despite the massive diversifications and ecomorphological disparification. We sampled 3D linear measures of muscles attachments, lever arms, and dental measures from 140 species across all major rodent groups to analyze functional differentiation and versatility within and across qualitatively different muscle configurations. We found a trade−off between incisor gnawing proficiency and the occlusal area of the cheekteeth, suggesting few rodents are well specialized for both gnawing and chewing simultaneously. Additionally, our data demonstrate different roles for the temporalis in chewing and gnawing depending upon masseter configuration. The temporalis is correlated with cheekteeth size in sciuromorphs and myomorphs, but negatively correlated in hystricomorphs. Additionally, the temporalis is strongly positively correlated with incisor depth across both sciuromorphs and hystricomorphs, but shows no relationship whatsoever with incisor depth in myomorphs, which show reduced incisor disparity despite high muscular and ecological diversity. Our results indicate previously unknown functional trade−offs between gnawing and chewing adaptations across rodents, and imply that the qualitatively different muscle systems perform in fundamentally different ways, even for muscles like the temporalis, that lack qualitative differentiation in morphology.

25.3 KRESS, D*; LENTINK, D; Stanford University, Stanford; *dkress@stanford.edu*

How Birds Change their Gaze to Accommodate Rapid Transitions Between Flight Modes

Diurnal flying animals such as birds depend primarily on vision to coordinate their flight path during goal−directed flight tasks. To extract the spatial structure of the surrounding environment, birds are thought to use retinal image motion (optical flow) which is induced by motion of their head. During straight flight phases, proximity information can be obtained from optical flow, which is inversely proportional to the relative distance between surrounding objects and the head of the bird. In contrast, during turning flight, optical flow of surrounding objects is independent of proximity. It is unclear what gaze behaviors birds perform to support depth perception as they switch between flight modes. To analyze this, we measured the gaze behavior of rapidly turning lovebirds in a goal−directed task: take−off and fly away from a perch, turn on a dime, and fly back and land on the same perch. High−speed flight recordings revealed that rapidly turning lovebirds perform a remarkable stereotypical gaze behavior with saccadic head turns of up to 3000 degrees per second, as fast as insects. In between saccades, gaze orientation is hold constant. By comparing saccade and wing beat phase, we find that these superfast saccades are coordinated with the upstroke. During straight flight before the turn, lovebirds keep a high contrast edge in their visual midline. This visual behavior can be interpreted as object fixation. Similarly, before landing, the lovebirds fixate the landing perch. Our observations thus show that rapidly maneuvering birds use stereotypic gaze behaviors, including feature fixations to optimize visuo−motor flight control.

S6.11 KROCHMAL, A.R*; ROTH, T.C.; Washington College, Franklin and Marshall College; *akrochmal2@washcoll.edu*
Climate Change, Conservation, and Cognition: An Integrative Approach to Conserving Biodiversity in a Changing World
Climate change is of intense interest because it has direct and indirect effects on all biota. Predicting impacts of environmental change on the distribution and abundance of species classically centers on physiological principles to the near exclusion of other biological disciplines. Physiology is an appropriate starting point for such models as predicted impacts of climate change both influence and can be mediated by physiology. However, climate change is rapid (in evolutionary terms), and often extreme, thereby potentially limiting the efficacy of physiological response as a means of "escape" from climate change. Indeed, animals interact with their environments in other important ways. For example, behavioral and cognitive responses (e.g. movement, perception, and learning) give animals a fast and often plastic response to current conditions, thus potentially offering a more time−appropriate and flexible response to environmental change. We will highlight the importance of incorporating learning and cognition into future efforts to predict the impact of and response to climate change, assess the status of behavioral and cognitive processes in recent conservation and climate change research, and offer a mechanistic approaches for integrating studies of animal behavior with climate change studies and conservation efforts. We contend that integrating behavioral and cognitive processes into our understanding of how animals respond to climate change is essential for conserving biodiversity, and therefore, we propose methods for integrating studies of animal behavior.

P2.60 KRUEGER, A. J.*; SHELDON, K.S.; DILLON, M.E.; University of Wyoming; *akruege1@uwyo.edu*
Thermal tolerance of Bombus impatiens after dietary exposure to Imidacloprid
The agriculture industry relies on pesticides for crop production, but growing evidence suggests that sublethal effects of pesticides are a primary factor in the worldwide decline of insect pollinators. Neonicitinoids are a widely−used, advanced class of insecticides that are highly toxic to bees. Even at low levels, neonicitinoids can have pronounced sublethal effects, with new research linking exposure to impaired winterization, a distinct trait of Colony Collapse Disorder. However, the physiology underlying sublethal thermal effects in bees is largely unknown. We investigated the effects of imidacloprid on critical thermal minima and maxima of *Bombus impatiens* to better understand the effects of this class of insecticides on thermal physiology. We assessed and quantified these limits using a new high−throughput assay to test how critical thermal limits vary after exposure to field−realistic imidacloprid concentrations.

P1.70 KUCERA, A.C.*; HEIDINGER, B.J.; North Dakota State Univ; *aurelia.kucera@ndsu.edu*
Relationship between erythrocyte and sperm telomere lengths in house sparrows
Telomere dynamics (length and loss rate) are highly conserved mechanisms that have been shown to be predictive of longevity. In humans and in birds, individuals with longer telomeres and slower rates of telomere loss live longer. Telomerase, an enzyme that can restore telomere length, is expressed throughout the body during embryogenesis. It is down−regulated in most somatic tissues after fetal development, but remains active in germ cells throughout life. In human males, sperm telomeres have been shown to be longer than, but positively correlated with, blood cell telomere length. However, it is currently unknown whether sperm and blood cell telomere length covary in other organisms. Here we investigated the relationship between sperm and red blood cell telomeres in n = 30 free−living, adult male house sparrows (*Passer domestics*). We also compared blood and sperm telomeres with badge size and wing chord within the same individuals. The results will be discussed within the context of life history theory.

20.2 KUO, C−Y*; IRSCHICK, DJ; Univ. of Massachusetts Amherst; *chiyun@bio.umass.edu*
Combining modeling and empirical approaches to study the variation in a costly antipredator trait: tail autotomy in lizards
Trait variation among populations often reflects differing selective optima, especially those that are expensive to express or maintain. Autotomy, the voluntary shedding of appendages, is a costly antipredator strategy with high degrees of variation among populations. Unlike classical inducible morphological defenses, the ability to autotomize doesn't require energy to develop. Instead, the animal incurs the costs after the fact. In addition, an animal can only autotomize a limited number of times due to anatomical constraints. The cost−benefit dynamics behind the variation in autotomy therefore can be different from that of inducible defenses. Using tail autotomy in the side−blotched lizard *Uta stansburiana*, we first developed a model to understand how predation intensity, food availability and the frequency of male−male fighting jointly determined the variation in tail autotomy. Our model suggested that high predation intensity and moderate male−male fighting selected for higher propensity for autotomy. When fightings between males became more frequent, however, low propensity would be favored instead. Food availability, despite significantly affecting survival, did not change the joint effect of predation intensity and male−male fighting on the propensity for autotomy. Data from the field corroborated our model. Propensity for tail autotomy peaked at intermediate frequency of male−male fighting and exhibited a negative correlation with predation intensity in females. Our study provided a useful framework with which to study variation in autotomy from a cost−benefit perspective in other taxa, as well as to answer further questions such as the conditions favoring the evolution/maintenance of autotomy in nature.

80.3 KURTH, J. A.*; KIER, W. M.; University of North Carilona, Chapel Hill, University of North Carolina, Chapel Hill; *jkurth@live.unc.edu*

To burrow or not to burrow: Differences in scaling and morphology between lumbricid earthworm ecotypes

Many soft−bodied invertebrates are remarkably effective burrowers despite their reliance on a flexible, fluid−filled hydrostatic skeleton. The aim of this study was to compare the shape and ontogenetic scaling of surface−dwelling and burrowing earthworm ecotypes to explore adaptations for burrowing in hydrostatic skeletons. We compared the external morphology of adult lumbricid earthworms across species and ecotypes to examine aspects of shape that are significantly associated with ecotype. We also compared the ontogenetic scaling of internal and external morphology of a burrowing species, *Lumbricus terrestris*, and a surface dwelling species, *Eisenia fetida*, using glycol methacrylate histology. We found that burrowing species had higher length−to−diameter ratios than surface dwellers, and that *L. terrestris* was thinner at any given body mass compared with *E. fetida*. We also found the differences in the size and development of the musculature between the two species that are likely correlated with surface crawling or burrowing. Our results suggest that adaptations for burrowing in soft−bodied animals include: a disproportionately thin body, robust anterior segments, and elaborate longitudinal musculature.

48.4 KUTCH, I.C.*; FEDORKA, K.M.; University of Central Florida; *kutch.bio@knights.ucf.edu*

Implications for Y chromosome variation on immune system evolution

Recent research in *Drosophila melanogaster* suggests that the Y−chromosome influences autosomal gene regulation; particularly, immune−related genes. This effect was detected by introgressing Y−chromosomes from independently evolving populations into an isogeneic background. In order for the Y−chromosome to fundamentally shape immune system evolution however, we must first determine if Y−chromosome regulatory variation (1) exists within a population and (2) translates into functional immune response variation. To this end, we collected 30 wild lines of D. melanogaster and placed their Y−chromosomes into an isogenic background. Males and females were then assayed for variation in immune gene expression and survival against a gram−negative pathogen. Our data indicates that males (who were isogenic except for their Y−chromosomes) exhibited significant variation in immune gene expression and survival while females (who were entirely isogenic) did not. In short, our data suggest that Y−chromosome regulatory variation exists within a population and translates into functional immune differences. Our next step is to determine the nature of the Y−chromosome variation. If this variation is largely additive, then the Y−chromosome could facilitate the evolution of sexually dimorphic immune systems. However, if the variation is largely epistatic, then males may be a fundamental constraint to immune system evolution.

53.6 KVALHEIM, M*; REVZEN, S; U Michigan; *shrevzen@umich.edu*

Better models of rhythmic systems: predicting locomotion from phase alone

Many animal locomotion behaviors consist of repeating stereotyped body motions in a rhythmic fashion. When these rhythmic motions are recovered after the body encounters a disturbance, one may consider the characteristic motion to be a limit cycle of a stable nonlinear oscillator. We show, under the assumption that our data set consists of a collection of N trials each containing M cycles, that partitioning the data into cycles based on a distinguished event such as heel−strike (often used for human motion studies) and averaging the cycles produces statistically inferior model of typical motions to averaging based on an estimate of dynamical phase. The improved accuracy of the phase based model can enable effects to be detected that would otherwise require many more trials. Examples from several locomotion experimental datasets will be provided

P1.175 KVISTAD, D.K.*; GILLIS, G.B.; EKSTROM, L.J.; Wheaton College, MA, Mount Holyoke College, MA; *kvistad_daniel@wheatoncollege.edu*

Is Visual Feedback Necessary for Coordinated Landing in Hopping Toads?

Cane toads, *Bufo marinus* , are exceptional at landing. Using their forelimbs to decelerate the body after impact, they are capable of modulating both the timing and intensity of pre−landing muscle recruitment in relation to hop length. Muscles are typically activated later in longer hops, and pre−landing recruitment intensity in forelimb muscles is also usually higher. To modulate muscle activity patterns, toads likely use sensory feedback to make predictions about the timing and magnitude of impact. To begin to understand the importance of visual feedback on landing preparation, we investigated the ability of cane toads to modulate pre−landing muscle activity appropriately after vision was removed. Specifically, we first recorded landing forces and muscle activity patterns in the coracoradialis and anconeus muscles from seven cane toads as they hopped a variety of distances with vision intact. The optic nerves were then severed and the recordings were repeated. We found that muscle activity patterns were not affected by the optic nerve treatment. Although variability was present across animals, toads typically exhibited later muscle onsets and greater pre−landing recruitment intensity in longer hops, regardless of visual input. Similarly, force profiles from landing toads before and after treatments did not differ greatly. Our results indicate that cane toads, like mammals, are not exclusively reliant on vision to coordinate landing after a jump. Instead, animals can use other sensory modalities, like proprioceptive feedback from the hindlimbs and/or vestibular information collected during takeoff as critical cues to ensure safe, controlled landings.

P1.35 LABERGE, T/L*; BARIS, T; CRAWFORD, D/L; OLEKSIAK, M/F; Rosenstiel School of Marine and Atmospheric Science, University of Miami; Miami−Dade College, Rosenstiel School of Marine and Atmospheric Science, University of Miami; *tlaberge@rsmas.miami.edu*

Genomic affects of selected survival to hypoxia in Fundulus heteroclitus

Severe environments can affect the survival of individuals. Survivors could be a random genetic sample of the population or could represent selectively resistant genotypes. This study examined the effect of severe hypoxia on genome wide genetic variation in the teleost fish *Fundulus heteroclitus*. Two hundred and forty individuals were exposed to hypoxia that resulted in 43 survivors (18% survivorship). Using genotyping−by−sequencing we determined nucleotide divergence in the hypoxic survivors relative to the parental population. For approximately 12,000 single nucleotide polymorphisms (SNPs), 125 SNPs were evolutionarily significant after multiple test correction ($p < 0.01$, 0.01 FDR). These data suggests that exposure to severe hypoxic selects for specific genotypes.

S6.3 LADAGE, L.D.; Penn State Altoona; *ldl18@psu.edu*

The relationship between hippocampal neurogenesis, stress, and aspects of environmental change

Previous to the 1990's, it was thought that no new neurons were produced in the brains of adult animals. We now understand that neurogenesis is a common and plastic process in the adult brain, although researchers have not come to a unified understanding of the functional significance of neurogenesis. Several factors have been shown to be significant modulators of hippocampal neurogenesis including stress and aspects of environmental change, but questions still remain. How do these modulating factors overlap? Which aspects of environmental change induce a stress response? Is there a relationship between hippocampal neurogenesis, stress, and environmental change? Can this relationship be altered when taking into consideration other factors such as perception, predictability, and novelty of the environment? Finally, are results from neurobiological research on laboratory rodents applicable to wild systems? Here, we attempt to address some of these questions in order to integrate research from the fields of psychology and behavioral neuroscience within an ecological context.

103.2 LAHMAN, S E*; MOORE, P A ; Bowling Green State University; *slahman@bgsu.edu*

Nose blind or not? The effects of copper on chemically−mediated orientation behavior

Increases in sensory pollution within an environment can impair an organism's ability to extract information necessary to make spatial decisions regarding orientation behavior. Within an aquatic environment, many animals rely heavily on the information structured in olfactory cues for such behaviors. Anthropogenic chemical pollution in an aquatic ecosystem inhibit animals from extracting information from chemical signals by decreasing olfactory sensitivity and causing physiological damage to epithelium, before reaching lethal levels of toxicity. We investigated whether a behavioral mechanism (antennular flicking) involved in chemically mediated behaviors of the rusty crayfish, Orconectes rusticus, was altered following exposure to ecologically relevant sublethal levels of copper . The first portion of this study investigated if the success rate of locating a food source and flick rate was altered following 120 hours of copper exposure. During the next portion, we mimicked a clean−up scenario during which crayfish previously exposed to copper were subsequently placed in unpolluted water before behavioral assays. Crayfish exposed to copper were significantly less successful in their ability to orient to a food odor than crayfish living in water without elevated copper. Over the course of the experiment, crayfish previously exposed to copper and then placed in unpolluted water improved in successful location of the food odor source. Furthermore, sublethal exposure to copper altered the antennular flicking rates of crayfish and subsequent placement in unpolluted water also impacted the flicking rates of exposed crayfish. These results indicate that the mechanism by which copper impairs chemoreception in the rusty crayfish is reversible if ecosystem management and mediation practices are put into place.

72.2 LAI, P.H.*; KONOW, N.; BOERMA, D.B.; SWARTZ, S.M.; Brown University; *philhwlai@gmail.com*

Skeletal Kinematics of the Shoulder in Seba's Short−Tailed Bat

Bats move their wings in dynamic, three−dimensional patterns. These motions originate partly from complex interactions between the bones that make up the shoulder and arm. Some research has proposed transient, cyclic contact between the scapula and humerus beyond the glenohumeral joint. This might serve to transmit force, allowing muscles inserting on the scapula only to add to flight power by remotely actuating the humerus. Since these proximal elements of the wing skeleton are deeply embedded in muscle, radiographic techniques are necessary to directly explore their kinematics. We used XROMM (X−Ray Reconstruction of Moving Morphology) to reconstruct in vivo scapular and humeral motion in Carollia perspicillata at high spatial and temporal resolution. Following validation, we were able to model the glenohumeral joint as a ball and socket articulation. We found that movements of the humerus with respect to the scapula did not account for the full extent of the wing's motion in the transverse plane, indicating substantial contributions from a highly mobile scapula. While we observed periodic association between the features on the humerus and scapula, the elevation of the humerus relative to the scapula did not remain constant during these periods. This is inconsistent with a primarily force−transmitting role for the interaction. Instead, contact appeared to coincide with periods of limited long−axis rotation of the humerus. This result suggests a mechanism for constraining the humeral head, preventing translation and intermittently constraining its rotation with respect to the glenoid. Such traits may provide added stability to this crucial articulation during the downstroke. Funded by AFOSR.

10.3 LAILVAUX, SP*; KIRCHER, BK; LEIFER, J; JOHNSON, MA; University of New Orleans, University of Florida, Trinity University, Trinity University; *slailvaux@gmail.com*

The incredible shrinking dewlap: skin elasticity and secondary sexual signal size in male Anolis carolinensis lizards

The expression of male secondary sexual traits can be dynamic, with traits changing size, shape, or structure over the course of different seasons. However, the factors driving such changes are often poorly understood. For example, the size of a morphological secondary sexual signal, the dewlap or throat−fan, in male *Anolis carolinensis* lizards changes seasonally within individuals, with males exhibiting overall larger dewlap areas in the spring relative to the winter. A previous study showed that this size change is likely not due to differential resource allocation, as limiting resource availability did not affect dewlap size in young males. In this study, we tested the hypothesis that seasonal changes in male dewlap size are driven by increased use and extension of the dewlap in spring and summer, when males are breeding, relative to the winter and fall. We captured male green anole lizards in early spring prior to the onset of breeding and physically constrained the dewlap in half of them such that it could not be extended. We measured dewlap area in the spring, summer and fall, as well as the elasticity of dewlap skin relative to belly skin. We show that dewlaps in unconstrained males increase in area from spring to summer and then shrink in the fall, as seen in male green anoles in nature, whereas the dewlaps of constrained males consistently decrease in size from spring to winter. We also show that dewlap skin is significantly more elastic than belly skin. Finally, we discuss the likely importance of the mechanical properties of signalling structures for signal evolution and design.

P1.79 LAMMERS, A.R.*; GOULD, F.D.H.; OHLEMACHER, J.; GERMAN, R.Z.; Cleveland State Univ, Ohio, NeoMed, Rootstown Ohio; *a.Lammers13@csuohio.edu*

The impact of a sensory lesion on the kinematics of swallowing in an infant mammal model

The mammalian swallow is a complex reflex where the airway must be protected while passing a food bolus into the esophagus. Because of the evolutionary and embryological history of the pharynx, the functions of nerves are less than straight−forward. Although a swallowed bolus does not enter the sensory field of the recurrent laryngeal nerve, absence of this signal produces a dysfunctional swallow, with food or liquid entering the airway. We sought to determine the role of this sensory signal in determining the kinematics of a swallow. We put radio−opaque markers in the tongue, hyoid, thyroid, and epiglottis. We lesioned this nerve in 6 infant pigs, and recorded 60 swallows pre−lesion and 60 swallows post−lesion using digital videofluroscopy at 100 fps in a paired design. Post lesion, animals were able to swallow, but they aspirated milk into their airway frequently. Significant post−lesion differences in swallowing included a longer duration of the swallow and less between−cycle variation in movement. The epiglottis, hyoid, and thyroid had larger excursions of movement. There also were pre and post lesion differences in relative timing and extent of movement in the tongue, which is not directly involved in the mechanics of a swallow. These results suggest that reduced sensation changed the kinematics of the swallow so that the airway was inconsistently protected while liquid passed into the esophagus. The post−lesion slowness and greater magnitude of movements suggest that the swallowing reflex must adjust to accommodate the reduced sensory caudal to the larynx. Furthermore, the changes in movements of all structures, including the tongue, indicate a high level of brainstem coordination among at least five cranial nerves.

61.1 LANDAU, M.*; HAGER, R.; Richard Stockton College of New Jersey, Galloway; *landaum@stockton.edu*

An Overview of Marine Biology Courses

Questionnaires were mailed to 354 colleges in coastal states, and to 123 colleges in non−coastal states. Coastal schools are more likely to have field/lab components, larger classes, and offer classes more often, but non−coastal schools are more likely to have pre−requisites, like general biology. For non−coastal schools, distance to the coast is positively correlated with time in the field. Most schools don't have an oceanography prerequisite, but instructors often spend up to 20% of lecture time on this material. More than 90% of the courses use one textbook, which instructors are moderately satisfied with; in coastal schools, about 40% of the instructors would like a text that geared toward local ecosystems, while about 20% of the instructors in non−coastal schools would prefer this. In lectures, prokaryotes and fungi were covered significantly less than any other topics. The greatest discrepancies between textbook coverage and class lectures were: "other vertebrates" > "plants"> "unicellular protists".

61.7 LANDAU, M.; Richard Stockton College of New Jersey, Galloway; *landaum@stockton.edu*

Teaching "Tropical Marine Biology"

There are about 500 colleges and universities in the United States that list marine biology courses as part of their curriculum. Field courses to tropical environments have become increasingly popular for schools in non−coastal states that have limited access to the oceans, and even for schools that are in temperate coastal states. (1) A survey was conducted of colleges and universities in North America offering marine biology courses in warm water destinations. Costs, destinations, activities, and instructor preparation will be discussed. (2) For 20 years one of these classes has been offered at Richard Stockton College; an overview of this successful course will be presented.

S3.10 LANG, Jeffrey W.; Madras Crocodile Bank, Univ. Minnesota; *jeff.w.lang@gmail.com*
Behavioral Ecology of the Gharial, Gavialis gangeticus
This study followed the 2007−08 mass mortality of gharial in the lower Chambal River, n. India. From 2008−2015, 40 radio−tagged gharials have been tracked during the monsoon and dry season annually, for 2+ yrs/animal. Individuals show different seasonal movements and residency patterns, dependent on size/age. Adult females move 80−120 km post monsoon to join dry season basking−breeding groups (60+ adults), and to locate communal nest sites. In contrast, sub−adult gharials exhibit restricted movements, 10−30 km seasonally, and occupy seasonal residencies only 5−15 km in extent. Some sedentary sub−adults showed virtually no movements, upstream or downstream. Gharial feed in June−September during the monsoon, and bask daily in November−February. Large aggregations form in December−January. Mixed basking groups of all age/size classes shift to groups of large sub−adults and adults by mid−February when courting and mating commence. Nesting occurs in late March/early April when reproductive females nest on sandbanks adjacent to deep water. At nest sites, yearlings (9 months old) often remain close to a resident large male which communicates with specific displays. Nesting colonies are common, but locations shift each year, depending on monsoonal changes in river topography. Adults guard nests during incubation. Females open nests, but do not transport the young to water. Females remain with hatchlings for 1−2 months, and guard them against potential predators. Large males, with well−developed and prominent gharas, often defend young (200−1000+) from 5−25+nests. Large crèches form, and young regularly feed on small fish. Biparental care, especially paternal' guarding of young, is likely the usual condition. These studies are relevant to conservation strategies, as well as an understanding of the biology of a distinctive species within a unique crocodilian lineage.

81.2 LANG, A W*; CRANFORD, J; CONWAY, J; YODER, J; SLEGERS, N; University of Alabama, Univeristy of Alabama Huntsville, Tennessee State University, George Fox University; *alang@eng.ua.edu*
Do Butterfly Scales Improve Flight?
Butterfly scales covering the wings represent a multifunctional surface. Besides providing color to the wings and serving as a superhydrophobic surface, they may also play an aerodynamic function. The scales (approximately 0.1 mm in size) form a roof shingle pattern over the wings, and due to the fact that the scales protrude upwards from the wing a three−dimensional micro−pattern is present. We will discuss a hypothesis as to how the scales may function to alter the drag of airflow passing over the surface and will present results from flight tests of live Monarch (*Danaues plexippus*) specimens. Using the Autonomous Tracking and Optical Measurement (ATOM) Laboratory located at the University of Alabama Huntsville, 22 Vicon T40 cameras permitted millimeter level tracking at 100 fps of reflective markers placed on specimens freely flying in a 4 m x 6 m x 7 m volume. Insects first flew with their scales intact and then again after careful scale removal. The flight path, flapping frequency and wing flapping angle were recorded. Differences in these variables observed over more than 20 specimens will be discussed. Initial results indicate that without their scales some specimens appeared to compensate with higher flapping frequency for similar energetic flight, while others had reduced flight speeds for similar flapping frequencies. Both of these observations indicate a potential aerodynamic benefit due the presence of the scales, and this may be linked to the leading−edge vortex formation and induced drag.

10.1 LANGKILDE, T*; SWIERK, LN; NORJEN, CM; Penn State University, Berkley, Ohio State University; *tll30@psu.edu*
Bearded ladies: female lizards suffer fitness consequences when bearing male traits
A central assumption in evolutionary biology is that females of sexually dimorphic species suffer costs when bearing male secondary sexual traits, such as ornamentation. Nevertheless, it is common in nature to observe females bearing rudimentary versions of male ornaments (e.g. bearded ladies'), as ornaments can be under similar genetic control in both sexes. Here, we provide evidence that masculinized females incur both social and reproductive costs in nature. Male fence lizards (*Sceloporus undulatus*) discriminated against ornamented females during mate choice. Ornamented females had lower reproductive output, and produced eggs that were laid and hatched later than those of non−ornamented females. Females with experimentally elevated T levels had lower hatching success of eggs, and produced smaller offspring that survived less well. These findings support established theories of the evolution of sexual dimorphism and intralocus sexual conflict, and raise questions regarding the persistence of masculinizing ornamentation in females.

P2.146 LANZA, A.R.*; SEAVER, E.C.; University of Florida; *alexislanza@gmail.com*
Investigating an embryonic organizing signal in axis formation of the annelid Capitella teleta
Embryonic organizers are signaling centers that coordinate developmental events within an embryo. Localized to either an individual cell or group of cells, embryonic organizing activity induces the specification of other cells in the embryo and can influence formation of the body axes. In the spiralian *Capitella teleta*, organizing activity is localized to a single cell, 2d. Previous cell deletion studies have shown that 2d induces the formation of the dorsal−ventral axis. In this study, we attempt to identify the signaling pathway responsible for the organizing activity seen in 2d. Embryos at stages when organizing activity is occurring were exposed to various small molecule inhibitors, raised to larval stages, and scored for axial anomalies analogous to previously described phenotypes. We also examined the expression patterns of candidate genes to determine whether expression is restricted solely to the organizer cell or its precursor. Our preliminary results suggest that the MAPK, Notch, and ADMP pathways do not play a role in 2d's dorsal−ventral axis formation. However, the TGF Beta and Noggin pathways have yielded promising results. These and further investigations will shed light on the identity of the 2d signaling pathway involved with *Capitella* axes formation, and contribute to our understanding of the evolution of body plan diversity.

P2.131 LARDNER, CK*; SWANSON, EM; SNELL−ROOD, EC; College of William and Mary, Williamsburg, VA and University of Minnesota, Twin Cities, University of Minnesota, Twin Cities; *cklardner@email.wm.edu*

Investigating a Mechanism Underlying Sex−specific Responses to Nutrition Using the Monarch Butterfly as a Model

Many traits vary with regard to sex as well as nutrition. Yet, the mechanisms regulating this plasticity over development are not well understood. In insects, two different pathways are involved in how morphological development responds to nutrition and sex. The insulin signaling pathway informs an organism of its nutrient conditions while *doublesex* regulates sex determination. Recent evidence suggests there may be links between these pathways in regulating sexual dimorphism. In this study, we investigate the hypothesis that sex−specific responses to nutrition are mediated by insulin signaling interactions with *doublesex*. We use the monarch butterfly (*Danaus plexippus*) as a study system because high and low nitrogen leaves occur naturally on their host plant, the milkweeds (*Asclepias*), and because they have a sequenced and annotated genome and well−studied sexual dimorphism. Wild−collected larvae were raised on either a high or low nitrogen diet from the second instar to pupation. Wing and brain tissue was dissected four days after pupation and total RNA was extracted. q−RT−PCR was used to measure relative levels of expression in *insulin−like peptide 1* (*ILP−1*), *insulin−like receptor*, *FOXO*, and *doublesex*. We predicted that 1) larval diet quality would cause variation in gene expression in a sex−specific way and 2) links between pathways would be represented by concordant variation in *doublesex* expression and all insulin−pathway genes. Understanding the mechanisms that mediate the interaction of nutrition and sex during development has implications for the dynamics of sexual selection and for clarifying the molecular pathways through which organisms differentially allocate resources.

P3.34 LARSON, L.R.; JOHNSON, J.; MEDLER, S.*; Fredonia, State University of New York; *scott.medler@fredonia.edu*

Fiber type asymmetries in growing skeletal muscles

Skeletal muscles play integral roles in a variety of physiological processes including locomotion, respiration, and thermoregulation. Our current model of muscle organization is that whole muscles are subdivided into discrete motor units, each contributing its specific physiological properties. This model conveys the idea that whole skeletal muscles are mosaics of different fiber types, but that the fiber types themselves are discrete. Hybrid muscle fibers, co−expressing two of more myosin heavy chain (MHC) isoforms complicate this view of muscle organization. Hybrid fibers are essential intermediates in fiber type transformations that result from use and disuse, and they are also recognized as being significant components of normal muscles. Given their common occurrence, there is surprisingly little known about many aspects of the basic organization of hybrids. For example, the spatial arrangement of multiple MHC isoforms within single fibers has important implications for muscle function. The principle of muscle contraction is based on hundreds of sarcomeres shortening together in unison, so if faster MHCs are segregated into limited regions of a fiber, that part of the fiber could potentially stretch out the slower sarcomeres before they can contract. In the current study, we focused on young rat skeletal muscles during a period of rapid growth to determine how MHC isoforms are spatially arranged within single hybrid fibers. During this period, a variety of hybrid fiber types are common within several muscles of the lower limbs. We present biochemical and anatomical data demonstrating that fiber type asymmetries are common at this stage of muscle development. These patterns suggest that these asymmetries may be a normal occurrence in skeletal muscles, and that they may be more prevalent in rapidly growing muscles.

20.4 LASALA, JA*; HUGHES, C; WYNEKEN, J; Florida Atlantic University, Boca Raton, FL; *jlasala321@gmail.com*

Breeding sex ratios and relatedness of marine turtles nesting in southern Florida

Sound assessment of the status of a threatened or endangered organism depends on understanding key aspects of behavior throughout its life history. Sometimes organisms can be difficult to observe and key aspects of behavior may not be accessed directly. Alternative assessment techniques include using molecular markers to identify fundamental relationships among males and females. In the context of assessing the status of imperiled populations' sex ratios, population size and the relatedness of the individuals are important metrics. Environmental sex determination directs developing marine turtle sex so that primary sex ratios depend upon weather and climate; those sex ratios are estimated by proxies. Adult population sizes are inferred from numbers of females nesting on the beach, but numbers of males are unknown. Male breeding population size can be estimated from subtracting maternal genotypes from genotypes of offspring (exclusion analyses). The resulting adult sex ratios differ greatly from those estimated for hatchlings. To refine current adult sex ratios in ways that are relevant to production of future generations and add to our understanding of effective population size we compare the breeding sex ratios (the number of males and females contributing to a population) of three species of sea turtles nesting in Florida. We will use the same genetic data to measure relatedness of the female nesters and the male contributors and describe how that relates to genetic flow and population structure.

63.5 LASCALA−GRUENEWALD, D.E.*; DENNY, M.W.; Hopkins Marine Station of Stanford University; *dianalg@stanford.edu*

Long−term Effects of Thermal Variability on Intertidal Communities

Predicting the impacts of climate change on the abundance and distribution of organisms continues to be a focus for scientists and resource managers. For organisms in the intertidal zone of wave−swept rocky shores, temperature is a particularly powerful selective agent which can shape species distributions. In this study, we examine the effects of artificially increased temperatures on the rocky intertidal community adjacent to Hopkins Marine Station in Pacific Grove, California, over a period of twelve years. Rock settlement plates were used in concert with an insulating layer of neoprene to produce temperatures 1−10°C higher than the neighboring bedrock during afternoon low tides. In order to characterize the mature communities, biological surveys were conducted in the final year of the study. The experimental plates displayed decreased percent cover and species−level diversity in comparison to neighboring bedrock, and the communities were characterized by barnacles instead of upper intertidal algae. A mechanistic heat budget model was used with historical environmental data to recreate the minute−to−minute thermal histories of the test plates and the adjacent bedrock. It was found that average cumulative degree minutes over twelve years was negatively correlated with diversity and cover in both communities. This study provides an opportunity to observe long−term shifts in community structure under test conditions which mimic climate pressures, and verifies the potential of mechanistic heat budget models used in concert with environmental data to generate accurate and informative thermal histories.

75.4 LASKER, HR*; PORTO−HANNES, I; University at Buffalo; *hlasker@buffalo.edu*

Isolation by distance and dispersal among populations of a Caribbean octocoral

Observations of larval behavior and patterns of recruitment of the Caribbean octocoral *Antillogorgia elisabethae* suggest that its negatively buoyant larvae do not disperse over great distances. Microsatellite analyses of adults from 13 sites in the northern Bahamas and from recruits from 4 sites on the Little Bahama Bank identified a pattern of isolation by distance among the adult populations and recruits that most likely come from the same or adjacent sites. Analysis of molecular variance indicates that the source(s) of recruits were not different between years nor were the recruits different from the populations of adults at the sites. Assignment tests of recruits were unable to unambiguously assign recruits to origins from individual sites, but for each recruit the most likely source was generally the local or adjacent population. The vast majority of recruits were assigned to the Little Bahama Bank sites. Assignment tests also suggest some differences in the extent of self−recruitment between sites. Recognition of these complex patterns is important in developing management and conservation plans for *A. elisabethae* and similar species.

P1.11 LASLO, M*; HANKEN, J; Museum of Comparative Zoology, Harvard University; *mlaslo@fas.harvard.edu*

Expression of TR± and TR^2 throughout ontogeny in the direct−developing frog Eleutherodactylus coqui

Direct development is a life−history strategy that has evolved independently in at least a dozen amphibian lineages. Direct−developing frogs, including the Puerto Rican coquí, *Eleutherodactylus coqui*, typically hatch from terrestrial eggs as miniature adults. Their embryonic development is characterized by precocious formation of adult features, such as limbs, and modified features such as a highly vascularized tail used for respiration. Embryos of *E. coqui* undergo morphological changes mediated by thyroid hormone (TH) that mirror those at metamorphosis. TH also modulates metamorphosis, a fundamental amphibian life history trait, in indirect developing frogs. Because TH has widespread and diverse effects throughout metamorphosis, changes in TH signaling could underlie the evolution of direct development. Specifically, changes in temporal or spatial expression of peripheral TH regulators, such as the nuclear thyroid receptor ± (TR±) or thyroid receptor ^{2} (TR^2) could coordinate the heterochronic shift in metamorphic events observed during embryogenesis. Quantitative real−time PCR was used to quantify transcript levels of *TR±* and *TR^2* in the limbs and tail at key developmental stages. LC−MS was used to determine the corresponding thyroid hormone profile at these stages. These data inform our understanding of the role of hormones in direct development and the evolution of this successful life−history strategy.

85.7 LATIMER, MN*; NELSON, C; FROEHLICH, JM; SEILIEZ, I; GABILLARD, JC; BIGA, PR; University of Alabama at Birmingham; *mnlat@uab.edu*

The Effects of Differential Glucose Concentration on the Proliferation and Differentiation of Oncorhynchus mykiss Myogenic Precursor Cells In Vitro

As a group teleost fish exhibit glucose intolerance, which leads to persistent hyperglycemia and coincides with transient hyperinsulinemia. Insulin−deficiency cannot explain this phenomenon as teleost fishes normally exhibit high plasma insulin levels, likely due to evolutionary diet adaptation or the peripheral utilization of glucose (Moon, 2000). However commonly utilized fish cell culture techniques use classical media based on mammalian physiology. Of interest in this study, myogenic precursor cells (MPCs) from several teleost species are currently cultured in a high glucose medium similar to that used for the culture of mammalian myosatellite cells (MSCs) and the immortalized mammalian cell line C2C12. To assess the impacts of glucose concentration on cultured cells, *Oncorhynchus mykiss* (rainbow trout) MPCs were cultured in high or low glucose media over an 8−day period. Samples were collected at specific myogenic stages: D2, myoblasts; D4, differentiating myoblasts; and D8, myotubes. Preliminary results show that cell proliferation, demonstrated by PCNA expression, did not change significantly in response to glucose levels. However, myogenin expression was increased, indicating increased cell differentiation, in the low glucose media. While both media appear to be suitable for the culture of teleost primary cells, low glucose media may be used to enhance cell differentiation stimulated by incubation with 2% FBS.

18.2 LATTIN, CR*; DURANT, SE; ROMERO, LM; Yale University, Oklahoma State University, Tufts University; *christine.lattin@yale.edu*

Wounding alters blood chemistry parameters and skin corticosteroid receptors in house sparrows (Passer domesticus)

Skin is an important physical barrier against pathogens, but it can become damaged through fighting with conspecifics, predator attacks, and assaults by biting insects. Therefore, the ability to quickly and effectively heal wounds directly impacts an animal's health. The hormone corticosterone (CORT) has many complex effects on immune function and can slow wound healing. It has been suggested that CORT's role during wound healing may be to act as a "brake" on inflammation and cell proliferation. This project aimed to clarify the role of CORT in the healing process by quantifying glucocorticoid receptors (GR) and mineralocorticoid receptors (MR) in the skin of wounded (n=9) or unwounded (n=8) house sparrows (*Passer domesticus*) using radioligand binding assays. We also quantified receptors in three other tissues, and several different blood chemistry parameters using a VetScan machine. One day after wounding, plasma glucose was higher, and aspartate aminotransferase lower, in wounded birds compared to controls, which may be related to animals' changing metabolic needs in response to tissue regrowth or the immune challenge of wounding. Birds had significantly decreased MR, but not GR, in the skin on their wounded leg compared to the skin on their unwounded leg. There was also a trend towards lower MR in wounded skin compared to unwounded birds. Receptors in three other tissues (liver, spleen and pectoralis muscle) did not differ between groups. This study suggests that decreasing the skin's sensitivity to CORT immediately after wounding may be a necessary part of the normal healing process in wild birds.

S7.8 LAUDER, G. V.*; WITT, W. C.; WEN, L.; Harvard Univ., Princeton Univ., Beihang Univ.; *glauder@oeb.harvard.edu*

Hydrodynamics of Fish c−start Escape Responses Studied with Simple Robotic Models

One of the most−studied unsteady locomotor behaviors exhibited by fishes is the c−start escape response. Although the kinematics of these responses have been studied extensively, only a few studies have focused on hydrodynamic patterns generated by fishes executing escape behaviors. No study, to our knowledge, has employed robotic models of impulsive c−start escape behaviors to investigate how body stiffness changes escape hydrodynamics and to determine if simple robotic models can reproduce *in vivo* complex c−start hydrodynamic flow patterns: escape responses by bluegill sunfish have been shown generate three distinct vortex rings each with central orthogonal jet flows. In this study we used a robotic controller to impulsively move passively flexible plastic panels of three different known stiffnesses in heave, pitch, and heave+pitch motions to study the effects of stiffness on unsteady escape hydrodynamics. The heave+pitch motion imitated the center of mass trajectory used by the escape response of fish. We were able to reproduce the three−jet hydrodynamic pattern of the fish c−start using a panel of medium flexural stiffness and the combined heave+pitch motion. Both more flexible and stiffer panels resulted in non−biological flow patterns for all motions. The use of simple robotic models is a promising approach for studying the dynamics of unsteady fish behavior which can be difficult to manipulate experimentally in live animals.

94.5 LAUMER, CE*; BEKKOUCHE, N; KERBL, A; HEJNOL, A; DUNN, C; GIRIBET, G; WORSAAE, K; Harvard University, University of Copenhagen, Sars International Centre for Marine Molecular Biology, Brown University; *claumer@oeb.harvard.edu*

Diurodrilus is an annelid: evaluating the phylogenetic status of three rare interstitial worms within Spiralia using RNA−seq

Despite rapid advances in the study of metazoan phylogeny, the significance of several rare interstitial taxa remains unclear. The longest−known such taxon is *Diurodrilus*, widely considered a member of the phylum Annelida. However, *Diurodrilus* shares none of the common apomorphies of Annelida, instead presenting many morphological autapomorphies, as well as characters reminiscent of other animal phyla (especially Gastrotricha). A similar conundrum is presented by *Lobatocerebrum*, bearing some "turbellariform" characters, but also some characters reminiscent of Annelida and Gastrotricha. Finally, the genus *Limnognathia* has been posited as a member of Gnathifera due to its complex jaws; however, the limited available molecular data do not support this position, and morphological similarities to *Diurodrilus* have also been discussed. Here, we address these challenges using high−throughput sequencing, mining orthologous genes from RNA−seq data. Results from a phylogenetic analysis of cDNA and genome sequences from 90 taxa consistently position *Limnognathia* as sister to Syndermata within a monophyletic Gnathifera. Furthermore, the monophyly of Annelida, with both *Lobatocerebrum* and *Diurodrilus* as deeply−nested members, is robustly recovered under all but the simplest phylogeny reconstruction methods, consistent with the hypothesis of a progenetic origin of these interstitial taxa. However, both taxa are among the longest−branched annelids in our dataset, and their precise position within Annelida varies among analyses. This study also speaks to the status of Platyzoa, having added several additional deeply branching taxa from Gastrotricha, Platyhelminthes, and Gnathifera. Under unpartitioned ML the taxa of "Platyzoa" form a clade with "Polyzoa". However, under the site−heterogeneous CAT+GTR+G4 model, Platyzoa is recovered as paraphyletic, with Gnathifera as the earliest−diverging branch; a clade of Lophophorata is also recovered under some conditions. Among the most prominent signals in this dataset is the high substitution rate of both the interstitial and colonial higher taxa ("Platyzoa" and "Polyzoa"); we discuss these rate variations both from the effect of their impact on phylogeny reconstruction, and from the standpoint of their biological provenance.

99.5 LAVALVA, S.*; LOIACONO, M.; THOMPSON, J.T.; Franklin and Marshall College; *joseph.thompson@fandm.edu*

The morphology and mechanics of a gliding joint in a soft−bodied invertebrate

We investigated the morphology and mechanics of what appears to be a gliding joint in Atlantic longfin squid (*Doryteuthis pealeii*). The joint, which is formed by the nuchal cartilage and the chitinous pen, has several novel features. First, it isn't clear what holds the nuchal cartilage and pen together. The joint is not encapsulated in connective tissue but is, instead, open to the seawater in the mantle cavity. Indeed, the joint can be "snapped" apart and then reconnected in anesthetized squid without impairing function (i.e., the joint will still slide over the normal range once the squid recovers from anesthesia). Second, the nuchal cartilage and pen do not touch directly because a thin layer (1−2 mm thick in adults) of tissue covers the pen in the region of the joint. Standard histological methods showed the layer to be a muscular hydrostatic organ with muscle fiber trajectories running longitudinal and transverse to the long axis of the pen. The role of the muscular hydrostatic layer is unclear because relative to controls, the force required to snap apart the joint does not decline in animals anesthetized in an isosmotic $MgCl_2$ solution that prevents muscle contraction. Furthermore, if the muscular hydrostatic layer is slit longitudinally with a scalpel but remains *in situ* in an anesthetized animal, the force required to snap apart the joint does not decline. If the tissue layer is removed, then force declines significantly. From our preliminary results, we hypothesize (1) that the joint is held together by hydrogen bonding interactions between the pen, the muscular hydrostatic layer, the nuchal cartilage, and the thin film of seawater that covers all three structures, and (2) that the role of the muscular hydrostatic layer is to conform to the shape of the nuchal cartilage and facilitate hydrogen bonding. Funded by NSF grant IOS−0950827.

20.1 LAW, CL*; MEHTA, RS; Univ of California Santa Cruz; *cjlaw9@gmail.com*

Divergence times and diversification rates of Musteloidea (Carnivora: Mammalia)

With 84 putative species in 33 genera, Musteloidea is the most speciose Carnivoran clade. Equally impressive is the great ecomorphological diversity found across Musteloidea, where species exhibit diverse arboreal, fossorial, or aquatic lifestyles as well as a variety of diets ranging from the generalist diets of raccoons, skunks, and badgers to the specialized diets of the herbivorous red panda, hypercarnivorous weasels, and piscivorous otters. Despite their great ecological diversity, the lack of a time−calibrated phylogeny consisting of all musteloid genera has prevented further analyses investigating the macroevolutionary processes that underlie this diversity. Here, we present a complete generic−level time−calibrated phylogeny of Musteloidea using a 46 mitochondrial and nuclear gene dataset from 75 putative musteloid species (88% of Musteloidea) and 11 fossil constraints. Additionally, to test the hypothesis that mustelids exhibit greater rates of diversification relative to the background rates across Musteloidea, we reconstruct the dynamics of musteloid speciation and extinction using BAMM (Bayesian Analysis of Macroevolutionary Mixtures), a relatively new model that quantifies heterogeneity in evolutionary rates with a reversible jump Markov chain Monte Carlo. Our results confirm the monophyly within the four musteloid clades Mustelidae (badgers, martens, otters, and weasels), Procyonidae (raccoons and allies), Ailuridae (red pandas), and Mephitidae (skunks and stink badgers) in congruence to previous phylogenetic analyses; however, certain clades remain paraphyletic. Mean speciation rate for Musteloidea is 0.214 lineages/million years, and mustelids exhibited greater diversification rates then procyonids and mephitids. Our analyses will allow for future research on how ecomorphological diversity contributes to musteloid diversity and why species diversity is so unevenly distributed within Musteloidea.

82.1 LE PABIC, P*; SCHILLING, T; Univ. of California, Irvine; *plepabic@uci.edu*
Regulation of vertebrate jaw shape and size by planar cell polarity signaling
The genetic and developmental mechanisms underlying the tremendous morphological diversity of the vertebrate jaw apparatus remain poorly understood. Skeletal progenitors may coordinate their morphogenetic behaviors via planar cell polarity (PCP) signaling − a system best known for its role in propagating consistent hair/bristle orientation across mammalian skin/insect cuticle. Two main pathways regulate PCP independently in Drosophila: the Frizzled (Fz) pathway and the Fat/Dachsous (Dchs) pathway. Here we use the accessibility and miniature organization of the zebrafish jaw skeleton to show that cartilage morphogenesis depends upon both pathways. Using in vivo time−lapse imaging, we show that cartilage elongation results from oriented cell−cell intercalations and that this collective behavior involves both Fz− and Fat/Dchs signaling. Cell transplantation analyses show that Fat3 and Dchs2 are required non−cell autonomously and over several cell−diameters for cartilage intercalation, consistent with activation of a secondary signal that regulates polarized cell−cell intercalation. Interestingly, additional chimaeric experiments show that a member of the Fz pathway − the diffusible signal Wnt5b − is also required at long−range, suggesting that it may be activated downstream from Fat3/Dchs2 signaling to control intercalation of skeletal progenitors. Ultimately, modulation of cell−cell intercalation by the Fat3/Dchs2− and/or the Fz pathway constitutes an attractive evolutionary mechanism regulating the diversification of jaw shape and size.

P2.160 LE PABIC, P*; SCHILLING, T; Univ. of California, Irvine; *plepabic@uci.edu*
Morphological analysis of craniofacial divergence between two utaka cichlids with distinct feeding behaviors
Cichlid fishes of the East African rift lakes have produced the most remarkable adaptive radiations in vertebrate feeding morphology ever described. Intermediate in age between Lake Victoria and Tanganyika, Lake Malawi contains cichlid species with tremendously diverse head morphologies, but also the potential to hybridize and produce viable offspring. These conditions make Malawi cichlids ideal for the discovery of novel loci regulating vertebrate head morphology and their adaptive variants. While previous genetic studies of trophic divergence in Lake Malawi focused on the rock−dwelling *mbunas*, we selected two open−water dwelling cichlids − *utaka*, with distinct head shapes to produce a mapping cross. The sire represents *Dimidiochromis compressiceps* − a piscivorous species with a long and laterally compressed head, which feeds on smaller fish. The dam represents *Copadichromis azureus* − a planktivorous species with a shorter head more typical of utaka species. These species were selected for their extreme craniofacial morphological differences, which genetic basis is unknown. As an initial step in our quantitative trait locus mapping project, we will present a quantitative morphometric analysis of head elements of *D. compressiceps*, *C azureus* and their F1 progeny to determine which morphological traits most strongly differentiate these two species. Our preliminary observations indicate that greatest morphological differences are seen in the oral jaw skeleton and neurocranium, and that these differences have already appeared at larval stages.

P1.160 LE POGAM, A*; DUBOIS, K; HALLOT, F; MILBERGUE, M; PETIT, M; LOVE, O; VEZINA, F; Université du Québec à Rimouski (Québec), Canada, Université de Windsor (Ontario), Canada; *Audrey.LePogam@uqar.ca*
MIGRATORY SNOW BUNTINGS INCREASE FAT RESERVES AND MUSCLE SIZE BUT SHOW LITTLE CHANGE IN METABOLIC PERFORMANCE WHEN WINTERING IN EASTERN CANADA.
Snow buntings *(Plectrophenax nivalis)* are arctic breeding migratory passerines that spend their winters on exposed snowy and windy plains of southern Canada. Although these cold environment specialists migrate "south" for the winter, they are nevertheless exposed to relatively harsh wintering conditions that are known to require significant increases in metabolic performance in resident species wintering at the same latitudes. In this study, we tested whether outdoor captive snow buntings would respond to winter conditions by expressing physiological changes typically seen in northern resident species. From November 2013 to April 2014, we measured body mass, muscle size, fat score and metabolic performance (maximal thermogenic capacity, and basal metabolic rate) once a month on 15 individuals. Results indicated that birds increased fat reserves and muscles size during the coldest months, as would be expected in resident species having to support cold conditions through shivering thermogenesis. However, changes in metabolic performance were not those expected. Basal metabolic rate did not change significantly over the course of the winter, suggesting little influence of temperature on physiological maintenance costs. Thermogenic capacity changed between months but did not show a seasonal increase culminating at the peak of cold as typically found in wintering non−migratory species, perhaps as a result of good thermal insulation from the plumage.

P1.71 LEANZA, A*; DAVIDSON, B; HWANG, A; Swarthmore College; *aleanza1@swarthmore.edu*
Conservation of heart enhancers and cardiac gene expression patterns in Corella inflata and Ciona intestinalis.
Enhancers are key regulators of gene expression; yet, the relationship between the structure of these important regulators and their evolution is little understood. To investigate this relationship, we studied early developmental cardiac enhancers of two species of tunicate, *Corella inflata* and *Ciona intestinalis*. Despite hundreds of millions of years of evolution and a high mutation rate, functional conservation of heart enhancers has been demonstrated between *C. inflata* and *C. intestinalis*. To determine whether the functional conservation translated to sequence level conservation of enhancers, we have begun analyzing the genome of the lesser known species, *C. inflata*. We first assembled the *C. inflata* genome using paired−end illumina data. We then isolated conserved heart enhancers, in particular we focused on *FoxF*, a gene necessary for heart progenitor cell migration in *C. intestinalis.* We performed sequence comparison of the *C. inflata* and *C. intestinalis FoxF* enhancers, and found conservation in both the composition and order of transcription factor binding sites. We tested the functionality of each of these binding sites using reporter analysis. Our results demonstrate both sequence−level and functional conservation of this enhancer. We plan to further characterize conserved heart gene expression patterns using *in situ* hybridization and to perform more sequence analysis using recently−collected RNAseq data to better characterize the relationship between enhancer function, structure and evolution.

P2.124 LEARY, C.J.; University of Mississippi;
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The effects of close−range vocal signals on the endocrine physiology of female green treefrogs

Male courtship signals often stimulate the production of sex steroids in both female and male receivers. Such effects benefit signalers by increasing receptivity in females, but impose costs on signalers by promoting sexual behavior and aggression in male competitors. We have previously shown that male green treefrogs, *Hyla cinerea*, counter these effects during close−range vocal exchanges that stimulate glucocorticoid production and suppress androgen production in rival males. We now assess whether acoustic signals produced by male *H. cinerea* also stimulate glucocorticoid production in females. The rationale for pursuing this question was based on our previous work showing that elevated glucocorticoid levels diminish female preferences for energetically costly calls. For example, we showed via dual−speaker phonotaxis experiments that female green treefrogs that were administered higher doses of corticosterone (CORT), and that possessed higher levels of CORT, were less likely to choose male advertisement calls broadcast at high rates, which females normally prefer. Unattractive males could thus increase their chances of acquiring mates if acoustic signals stimulate the production of glucocorticoids in females, as they do in males. We tested this hypothesis by examining the effects of broadcast vocalizations on sex steroid and CORT production in female *H. cinerea*. Results from this study will be presented.

P2.14 LEASI, F*; MOORE, M; WIRSHING, H; NORENBURG, JL; Smithsonian Natl. Mus Nat Hist, Univ. of Maine, Orono;
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Phylogeny and diversity of the genus Ototyphlonemertes, an iconic clade of miniaturized Nemertea

The genus *Ototyphlonemertes* is diagnosed by the presence of a pair of statocysts and is the iconic representative of the Phylum Nemertea among marine mesopsammic meiofauna. The genus comprises 26 species thought to be valid but up to 90 varieties have been reported based on morphology alone. This variety can be captured by six general morphotypes but these lack evident synapomorphies. The genus represents a paradox among nemerteans. It consists of the smallest worms in the phylum, evidently achieved by miniaturization and reduction of structures. Yet, the proboscis exhibits greater variation than is known for the remainder of the Order Monostilifera (excluding symbiotic species). A number of these characters, however, are continuous variables of relative size or proportion, and it's unknown the extent to which these are intra−specific ecological variables versus representing interspecific diagnostics. DNA sequence data allege multiple instances of sympatrically occurring cryptic species that could not be distinguished morphologically, suggesting that there are substantially more species than anticipated by morphology. One can recognize readily two apparent clades of *Ototyphlonemertes*, one with polygranular statocysts and a helically sculpted proboscis stylet, and one with oligogranular statocysts and a smooth stylet. Recent DNA evidence supports uniting these as a monophyletic clade but unpublished phylogenetic analyses with many species reveal the two groups as either reciprocally monophyletic or offer conflicting paraphyletic results. DNA sequences suggest a recently re−discovered species appears to resolve the question. We also use DNA sequence data to test monophyly of the six morphotypes.

P2.157 LEBEL, E*; CLOUTIER, R; University of Quebec at Rimouski, Canada; *emilie.lebel01@uqar.ca*

How to Split a Spine: Insights on the Chondrichthyan Condition of Axial Regionalization

Axial regionalization is one of many skeletal modifications that allowed tetrapods to make the transition from water to land. The presence of five morphologically distinct regions along the vertebral column (i.e., cervical, thoracic, lumbar, sacral and caudal) has frequently been linked to the demand of weight−bearing and walking on land. This condition has long been thought to be restricted to tetrapods. While osteichthyans have long been characterized by a column divided solely into two regions (i.e., abdominal and caudal), recently, five regions were described in a Carboniferous actinopterygian fish, *Tarrasius*. Furthermore, a cervical region has recently been identified in some extant actinopterygians. Although rarely investigated, chondrichthyan axial regionalization has been suggested in the anterior part of the column (e.g., synarcuum of chimaeras and rays). Considering these facts, the regionalization of the chondrichthyan vertebral column has been investigated using an ontogenetic series of cleared−and−stained specimens of black dogfish (*Centroscyllium fabricii*). At least three axial regions have been recognized based on the chondrification and mineralization of vertebral components (e.g., centra, ribs, arches, spines) as well as on specific conditions (e.g., size and shape, fusion). Description of the axial regionalization in sharks provides insights on the apparition of axial patterning in early gnathostomes.

P1.118 LEDESMA , V.G*; SCHMESKI, S.M; JURKOVIC, J; MONZON, R; KROHMER, R.W; Saint Xavier University;
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Effect of Season and Sex Steroid Hormones on Dendritic Spine Formation and Spinophilin Production in the Male Red−Sided Garter Snake Forebrain

Male red−sided garter snakes (Thamnophis sirtalis parietalis) have been shown to exhibit seasonal changes in the morphology of the forebrain. This neuronal plasticity appears to be due to changes in dendritic spine formation. The current study is designed to examine seasonal and hormonal influences on neuronal plasticity and how it might relate to the regulation and control of sexual behavior. Since the number of actual dendritic spines/synapses is immense, quantifying changes can pose a serious challenge. Spinophilin, a specific scaffold, cytoskeletal protein is essential for the proliferation of dendritic spines. Subsequently, measurement of spinophilin offers a method for quantifying regional changes in neuronal plasticity. In a previous study, we found that dendritic spines were significantly increased during the breeding season and in response to testosterone and estrogen implants, with estrogen causing a greater effect than testosterone. Therefore, we hypothesize that, in the male red−sided garter snake, estrogens will have a greater effect on the production of spinophilin in regions critical for the control of reproductive behavior. Using western immunoblots, we examined regional variations in the concentration of dendritic spinophilin in the brains of male red−sided garter snakes; 1.) collected in an out of the breeding season and 2.) following implantation with either estrogen or testosterone.

65.2 LEE, J.S.*; HALDANE, D.; FEARING, R.; FULL, R.J.; University of California, Berkeley; *jessica−lee@berkeley.edu*

Biologically inspired collapsible spines increase performance in legged robot

Studies on insects and spiders have shown that in cluttered environments or those having a low probability of foot contact, collapsible leg spines can increase performance. Anisotropic properties of spines permit engagement of complex terrain during thrust, but are easily removed during swing because they collapse toward the leg. We used this architectural advantage as biological inspiration for increasing the performance of a legged robot. We developed a simple way to manufacture collapsible spines for a legged robot and used the collapsible spines to increase the robot's running and climbing ability. Our leg spines were manufactured using fiberglass with skewed triangle cuts that project outward naturally when attached to the curved robot leg. When engaged, spines could support five times the robot's body weight (1.72 N), but could be released with only one−third body weight of force, a 15:1 ratio between engagement and releasing force. We applied our manufactured, collapsible spines to a six−legged, insect−inspired robot named VelociRoACH (33g), one of the fastest terrestrial robots relative to its size, but with very limited ability to negotiate sloped terrain. Leg spines approximately doubled the slope climbed (15 to 30°) and the speed on a 20° slope (5.5±1.4 to 8.1±0.7 cm/s). Development of manufacturing techniques for these collapsible spines can provide future designs for the next generation of robots. Moreover, manufactured spines can serve as physical models to test hypothesis for animals that take advantage of collapsible spines and scales, not only on their legs, but also on their ventral surface and tail.

81.3 LEE, A.H.*; SIMONS, E.L.R.; Midwestern University; *alee712@gmail.com*

Wing bone laminarity is not an adaptation for torsional resistance in bats

Torsional loading is a common feature of skeletal biomechanics during vertebrate flight. The importance of resisting torsional loads is best illustrated by the convergence of wing bone structure (e.g., long with thin walls) across bats, birds, and pterosaurs. Whether or not such a convergence occurs at the microstructural level is less clear. In volant birds, the humeri and ulnae often contain abundant laminar bony tissue in which primary circumferential vascular canals course concentrically about the long axis of the bone. These circumferential canals and the matrix surrounding them presumably function to resist the tissue−level shear stress caused by flight−induced torsion. Here, we assess whether or not laminar bone is a general adaptive feature in flying vertebrates using a histological analysis of bat bones. We sampled the humeri from six adult taxa representing a broad phylogenetic and body size range (6 − 1000 g). Transverse thick sections were prepared from the midshaft of each humerus. Bone tissue was classified based on the predominant orientation of primary vascular canals. Our results show that humeri from bats across a wide phylogenetic and body size range do not contain any laminar bone. Instead, humeri are poorly vascularized with occasional longitudinal to slightly radial canals in large bats and are essentially avascular in bats below about 100 g. In contrast, humeri from birds across a comparable size range (40 − 1000 g) are highly vascularized. Phylogenetically−informed scaling analyses reveal that the difference in vascularity between birds and bats is best explained by higher somatic growth rates in birds. The presence of wing bone laminarity in birds and its absence in bats suggests that laminar bone is not a necessary biomechanical feature in flying vertebrates.

P1.141 LEE, JH*; KIM, AR; KIM, KR; YOON, TH; LEE, SR; KIM, HW; Pukyong National Univ., Busan; *ellen3235@gmail.com*

Two cDNAs encoding clottable proteins (Liv−CPs) in white leg shrimp, Litopenaeus vannamei; isolation, transcriptional analysis and their RNAi effects on molting, reproduction, and immunity

The clottable protein (CP) is molecules involve in the blood coagulation systems and an essential immune mechanism of crustaceans. Interestingly, CPs in decapod crustaceans exhibit high sequence similarity to vitellogenins (Vgs) in other invertebrates. Previously, single copy of CP (Liv−CP1) was isolated in *L. vannamei*. In the present study, we identified the additional full−length cDNA encoding the putative CP (Liv−CP2) from the same shrimp by the combination of next−generation sequencing (NGS) and typical PCR−based cloning strategy. Obtained Liv−CP2 exhibited the highest similarity to CP from *Marsupenaeus japonicus* (33%) and *L. vannamei* (33%). The newly obtained Liv−CP2 contained the special regions involved in the clotting reactions: Lys−rich and Gln−rich regions, Ser−Lys−Thr repeats, conserved N−glycosylation sites suggesting it may exhibit similar function to Liv−CP1. Phylogenetic analysis showed that the CPs from decapod crustaceans were clustered together with Vgs from insects and vertebrates. Transcriptional analysis of three genes (Liv−CP1, Liv−CP2, and Liv−Vg) was also determined according to the molting cycle and maturation stages by qualitatively and quantitatively. In order to estimate the functions of the newly identified Liv−CP2, RNAi experiments with sequence−specific dsRNA were performed and its physiological effects were also determined.

P1.142 LEE, SR*; KIM, AR; JEON, JM; KANG, HE; LEE, WS; KIM, HW; Pukyong National Univ.; *dltnfls87@pknu.ac.kr*

Molecular characterization of cDNA encoding arylalkylamine N−acetyltransferase in white shrimp, Litopenaeus vannamei

Arylalkylamine N−acetyltransferase (aaNAT) is the enzyme that catalyzes the transacetylation of acetyl−CoA to arylalkylamines. In mammals, aaNAT is a rate−limiting enzyme for the synthesis of melatonin from serotonin regulating circadian rhythm. In insects, aaNATs are involved in multiple physiological responses including melatonin synthesis, aromatic neurotransmitter inactivation and cuticle sclerotization. In the present study, a cDNA encoding putative aaNAT (Liv−aaNAT) was identified as a differentially expressed gene from white leg shrimp, *Litopenaeus vannamei* after the low−salinity (120) stress. The full length cDNA (639 bp) of Liv−aaNAT encoded a protein with 213 amino acids. End−point RT−PCR showed that the hepatopancreas is the major production site. In order to estimate biological functions of Liv−aaNAT, RNA−silencing technique was applied using Liv−aaNAT−specific double−stranded RNA (dsRNA). We injected 1, 10, 50 pmol of the dsRNA into the abdominal muscle of each shrimp and level of its knockdown were measured at 1, 3, and 5 days after injection. Injection of 50 pmol dsRNA effectively suppressed Liv−aaNAT expression (96 %) and dopamine level in hemolymph was also measured after Liv−aaNAT RNA interference. In order to know the effects of Liv−aaNAT knockdown, 50 pmol of dsRNA were injected for and several stress were challenged and mortality was measured. This study will help us to extend knowledge about biological roles of Liv−aaNAT in the immune response in decapod crustaceans.

S11.5 LEE, Carol Eunmi; University of Wisconsin, Madison; *carollee@wisc.edu*

The Walk onto Land: Evolutionary Mechanisms of Osmoregulatory Function during Independent Arthropod Invasions onto Land

Arthropods are the most successful animal phylum on the planet, both in terms of number of species and total biomass. While arthropods evolved originally in the sea, they have become extraordinarily successful across an extremely wide range of habitats and ecological niches. Arthropods now dominate many marine, freshwater, hypersaline, and dry environments across the globe. While most marine invertebrates have no need to osmoregulate, invading freshwater habitats requires the active uptake of scarce ions, whereas invading land adds the additional challenge of also regulating water (at times to reduce water loss). Yet, arthropods have invaded freshwater and terrestrial environments multiple times independently. Within arthropods, at least three major independent invasions of land took place in the three major lineages, the crustaceans (Pancrustacea, e.g. insects, land crabs), chelicerates (e.g. spiders, ticks), and myriapods (e.g. centipedes, millipedes). With respect to morphology and physiology, the independent adaptations onto land have been surprisingly similar. Hypotheses based on morphology posit that osmoregulatory and respiratory structures of marine, freshwater, and terrestrial arthropods are homologous. Here I focus on the evolution of arthropod appendages and their linkages to the evolution of osmoregulatory and respiratory functions (e.g. epipodites and other leg organs of "lower crustaceans," gills of decapods, and tracheal systems of terrestrial arthropods) during independent evolutionary events.

19.7 LEIGHTON, GM; University of Miami; *gleighton@bio.miami.edu*

Genomic Relatedness Predicts Investment in a Public Good

Although communal resources, i.e. public goods, are often critical to society, they are simultaneously susceptible to exploitation, and are evolutionarily stable only if mechanisms exist to curtail exploitation. Mechanisms such as punishment and kin selection have been offered as general explanations for how public goods can be maintained. Evidence for these mechanisms comes mostly from humans and social insects, leaving their generality in question. To assess how public goods are maintained in a novel taxon we observed cooperative nest construction in sociable weavers (*Philetairus socius*). We observed cooperative nest construction and also collected blood samples, performed next−generation sequencing, and isolated 2,358 variable SNPs to estimate relatedness. We find that relatedness predicts both the amount of time devoted to cooperative nest construction and the number of items inserted into the nest superstructure, while no other morphological characters significantly explain cooperative output. We argue that indirect benefits are a critical fitness component for maintaining the cooperative behavior that maintains the communal nest.

P3.12 LEMA, SC*; CARVALHO, PG; EGELSTON, JN; KELLY, JT; MCCORMICK, SD; Cal Poly, San Luis Obispo, Univ of New Haven, USGS, Conte Anadromous Fish Res Cen; *slema@calpoly.edu*

Transcriptional dynamics of ion transporters and aquaporins in the gill of a desert pupfish following abrupt salinity transfer

We examined ionoregulation when Amargosa pupfish (*Cyprinodon nevadensis amargosae*) acclimated to brackish water (7.5 ppt) experienced a shift to fresh water (0.3 ppt), seawater (35 ppt), or hypersaline (55 ppt) conditions. Fish transferred to 35 ppt or 55 ppt exhibited elevated plasma osmolality and Cl^- levels by 8 h, which gradually recovered to baseline levels within 14 days. This recovery of plasma ionic status corresponded to an increase in Na^+/K^+−ATPase activity and elevation in relative mRNA levels for several gill Na^+ and Cl^- transport proteins including cystic fibrosis transmembrane conductance regulator, $Na^+/K^+/2Cl^-$ cotransporter−1, and $Na^+/HCO3^-$ cotransporter−1. Osmotic transcription factor−1 (ostf−1) transcript abundance also exhibited a brief elevation in fish transferred to 55 ppt, suggesting that ostf−1 may mediate transcriptional responses to elevated salinities. In contrast, pupfish transferred from 7.5 ppt conditions to 0.3 ppt exhibited a decline in plasma osmolality and elevations in relative mRNAs encoding Na^+/H^+ exchanger isoform−2 and V−type H^+−ATPase in the gills within 8 h, which was subsequently followed by increased mRNA levels for Na^+/H^+ exchanger isoform−3, carbonic anhydrase−2, and aquaporin−3 within 24 h of salinity transfer. A gradual increase (by 14 days) in relative mRNA levels for a Na^+/Cl^- cotransporter was also observed in fish shifted to 0.3 ppt. These results confirm the high euryhalinity of this species and elucidate the mechanisms by which the gill epithelium of euryhaline desert pupfishes maintains ionic and osmotic balance under rapidly shifting salinity conditions.

91.5 LENTINK, D.*; HASELSTEINER, A.F.; INGERSOLL, R.; Stanford University; *dlentink@stanford.edu*

In Vivo Recording of Aerodynamic Force with an Aerodynamic Force Platform

Flapping wings enable flying animals and biomimetic robots to generate elevated aerodynamic forces. Measurements that demonstrate this capability are based on tethered experiments with robots and animals, and indirect force calculations based on measured kinematics or airflow during free flight. Remarkably, there exists no method to measure these forces directly during free flight. Such *in vivo* recordings in freely behaving animals are essential to better understand the precise aerodynamic function of their flapping wings, in particular during the downstroke versus upstroke. Here we demonstrate a new aerodynamic force platform (AFP) for nonintrusive aerodynamic force measurement in freely flying animals and robots. The platform encloses the animal or object that generates fluid force with a physical control surface, which mechanically integrates the net aerodynamic force that is transferred to the earth. Using a straightforward analytical solution of the Navier−Stokes equation, we verified that the method is accurate. We subsequently validated the method with a quadcopter that is suspended in the AFP and generates unsteady thrust profiles. These independent measurements confirm that the AFP is indeed accurate. We demonstrate the effectiveness of the AFP by studying aerodynamic weight support of a freely flying bird *in vivo*, which demonstrates that its upstroke is inactive.

66.1 LEONARD, J.B.K.*; CROSS, R.; Northern Michigan University; *jileonar@nmu.edu*

Movement−related life history variation in brook trout (Salvelinus fontinalis) in Lake Superior tributary streams

Life−history variation in salmonid fishes related to movement behavior represents intraspecific biodiversity important for species resiliency and ecosystem functioning. We used RFID/PIT telemetry in two Lake Superior tributaries to assess movement behaviors expressed in brook trout (*Salvelinus fontinalis*). Using a dataset of 650 fish tagged over four years, we detected 9−44% emigration from the streams, which likely represented the migratory (coaster) life history. Coasting behavior was not related to fish size or condition, but was predicted by a tagging location nearer to the mouth of the stream. Of the 506 fish (78%) that remained within the stream following tagging, the majority (55−60%) remained stationed close to their tagging site; however, the remainder exhibited other types of movement behavior ranging from unidirectional up− or downstream movements (20−40%) to nomadic roving (8−10%) within the study section. Mobile fish occurred throughout the streams, with a trend toward greater numbers of nomads tagged near the mouth; there was no relationship between size/condition and likelihood of mobile behavior. The proportions of fluvial movement behaviors were similar between streams and suggest more variability in movement behavior than is suggested by the migrant/resident dichotomy typically attributed to salmonids.

100.2 LEONARD, J.B.K.; Northern Michigan University; *jileonar@nmu.edu*

Using an intensive, semester−long collaborative project to develop student quantitative ecology skills

Ecology students require skills and training in quantitative analysis of ecological data sets, yet they are often resistant to developing these skills. One successful approach in an advanced ecology course is to combine quantitative analysis and presentation into the framework of a multipart, collaborative field site assessment expressly linked to "career−based" skills appealing to students. Placed in an active−learning enhanced ecology course, the project consumes approximately 1/3 of the course and builds complexity across three different levels: 1) field sampling techniques, 2) quantitative analysis (primarily statistical analysis), and 3) scientific presentation of quantitative information. For the quantitative analysis, students collect data on different aspects of a field site (physical environment, flora, and fauna) with data that grows in complexity from basic descriptive statistics to designed data sets that fit common statistical tests easily to complex data sets where students must identify appropriate approaches and recognize data limitations. The collaborative nature of the assignment, with individual reporting responsibility, as well as a requirement for revision helps ensure development of core skills while the personal linkages to "real" data collected by students, field work, and career development enhance engagement. Experimental design skills, statistical expertise, and ability to present quantitative information have shown marked improvement as has student confidence.

69.2 LESSIOS, N*; COHEN, JH; RUTOWSKI, RL; Arizona State University, University of Delaware College of Earth, Ocean and Environment; *nicolas.lessios@asu.edu*

How do natural light environments maintain multiple−pigment Pancrustacean visual systems? An answer from branchiopod crustacean vision and behavior in desert ephemeral pools

Branchiopod crustaceans have a unique phylogenetic position to make inferences about both insects and crustaceans (Pancrustacea). All branchiopods express four or more visual pigments. This brings up the question: what selective forces maintain these multiple−pigment visual systems, especially considering branchiopods have secondarily−reduced optic ganglia in comparison to "higher" order crustaceans and insects? We show that two species of branchiopods found in ephemeral pools throughout Southwestern North America use light for vertical positioning. They use multiple visual pigments for phototactic behavior. *Triops longicaudatus* are benthic foragers, while *Streptocephalus mackini* are suspension feeders that swim higher in the water column. Due to a seasonal "monsoonal" wet period in Arizona, we have described light environments of ephemeral pools over the life cycle of these branchiopods in two regions. Light within these pools attenuates rapidly with depth and is wavelength−specific to soil region. We find that regional light environments have shaped the spectral sensitivity of behavioral responses. We also find that *S. mackini* males may use a single photoreceptor type for positive phototaxis to maintain position in the water column above females. We compare phototactic behavior to visual system electrophysiology (extracellular ERG recordings). Using a maximum−likelihood approach, we use data from extracellular recordings to generate hypotheses about visual pigment parameters and place these results in the phylogenetic context of the ancestor of insects, which had three visual pigment classes, homologous to three of those expressed in branchiopods.

100.3 LEUPEN, S*; HOFFMAN, K; HANSEN, S; DOWELL, K; LEIPS, J; University of Maryland Baltimore County (UMBC); *leupen@umbc.edu*

Use of Quantitative Modules in Introductory Biology Courses Improves Quantitative Proficiencies

The increasingly quantitative nature of biology has led to calls for a revolution in undergraduate biology education in which data analysis and quantitative skills receive greater emphasis. We sought to integrate quantitative thinking into our two−semester introductory biology courses through the development and use of 11 quantitative modules, presented in weekly 50−minute active−learning class sessions, which apply mathematical thinking to biological problems covered concurrently in the course, ranging from ecology and evolution to cellular and molecular biology and physiology. Each module presents a particular biological context followed by a series of questions through which students quantitatively analyze the premised situation. Modules also include pre−class exercises designed to review the mathematical concepts needed to successfully complete the module. Modules were assessed using a pretest/posttest design; the test assessed students' quantitative competencies as well as attitudes. Student attitudes were largely unchanged by our modules due to a ceiling effect in which over 90% of incoming students felt that quantitative approaches were important for biology. Students showed significant performance gains in all semesters in quantitative numeracy; significant gains in all semesters in their ability to interpret data presented in both table and figure form; and significant gains in 3 of 4 semesters in their ability to make inferences about natural phenomena using mathematical models. The improvements seen in our study support the use of stand−alone modules to improve quantitative proficiency among students. Our modules are freely available and we invite interested instructors to use them.

38.5 LEVIN, I I*; ZONANA, D; BURT, J; SAFRAN, R J; University of Colorado − Boulder, Encounternet LLC and University of Washington; *Iris.Levin@colorado.edu*

Measuring social interactions in barn swallows (Hirundo rustica) using Encounternet proximity tags

Accurate quantification of social interactions remains one of the great challenges for understanding animal behavior. Recent advances in digital radio tag technology enable the collection of large amounts of data useful for the construction of social networks. We are using Encounternet digital transceiver tags that function as proximity loggers, detecting ID pulses and received signal strength of other tags. We deployed Encounternet tags on barn swallows for four days and recorded close (<5m) interactions during three hour morning and three hour evening sampling periods. This system allows us to reconstruct the social network based on dyadic interactions of tagged birds weighted by the number of interactions or the time spent interacting. The proximity tags record the signal strength of the interacting tag, so with knowledge of the relationship between distance and radio signal strength, we are able to construct networks based on close encounters (e.g., body contact) vs. loose spatial affiliations. We quantified social contacts in one population of tagged barn swallows and tested how phenotypic and physiological variation, as well as variation in reproductive performance, is associated with network structure.

9.6 LEVIN, ERAN*; DAVIDOWITZ, GOGGY; Univ. of Arizona, Tucson; *levineran1@gmail.com*

Effect of male feeding on female fecundity in hawk moth

Age and experience of some male Lepidoptera has an effect on female fecundity. In many insects males transfer energy resources to the females with the spermatophore, so it is assumed that spermatophore size reflects male investment. In this study we examined the effect of male feeding and mating experience on the number of his offspring in the semi capital breeder hawk moth *Manduca sexta*. Females mate only once in their early life, whereas males can mate multiple times. Even without feeding as adults, females can lay 100−400 eggs. On each of 3 consecutive days, we mated fed and starved males with a newly emerged virgin female. Females were allowed to oviposit and laid eggs counted every day until their death. Females mated with virgin fed males laid 20% more eggs then females mated with virgin starved males. In a choice test, females mated more frequently with fed males than with unfed males. Females mated with unfed experienced males laid significantly fewer eggs then females mated with fed males that have mated two or three times. Spermatophore size of virgin males was not affected by feeding. Second and third spermatophores were much smaller than the first, but a reduction in egg number was observed only in females mated with experienced starved males. The 2th and 3rd spermatophores produced by fed males were 50% bigger compared to starved ones. By feeding males labeled ^{13}C glucose, we found a significant contribution of the labeled glucose to the spermataphore but no evidence for resource transfer to the female or eggs. Using labeled amino acids fed to *M. sexta* in the larval stage, we assessed the importance of adult male body proteins for female reproduction. We suggest that male foraging success directly affects his fitness, but not through traditional "nuptial gifts".

63.3 LEVY, O*; BUCKLEY, LB; KEITT, TH; ANGILLETTA, MJ; Arizona State University, Tempe, University of Washington, Seattle, The University of Texas at Austin, Austin; *levyofi@gmail.com*

From extreme events to population dynamics: how environmental tolerances affect biological predictions

Models of population dynamics have been used to infer the impacts of climate change on the distributions of species. The predictions of these models depend greatly on parameters that characterize the studied organisms as well as the environment. In widespread group of lizards (*Sceloporus undulatus* complex), behavioral thermoregulation buffers environmental extremes that would otherwise decrease performance. However, embryos do not have the capacity for thermoregulation as well as mobile life−stages, and therefore at greater risk under climate change when extreme events will become more frequent. Based on lethal temperatures of embryos and highly resolved projections of past and future climates, we modeled how (1) incorporating embryonic survival in population models will affect populations' fitness predictions and (2) how oviposition decisions and reproductive period may shift to avoid exposure to environmental extremes under climate change. Ignoring either environmental extremes or their impact on embryonic survival causes one to overestimate population growth rates and underestimate the impacts of climate change. Although lizards can extend their reproductive period in future climates, rate of embryonic survival will decrease at many locations. Accurate predictions will require detailed knowledge of environmental conditions and thermal tolerances at each stage of the life cycle.

P3.201 LEYS, SP*; KAHN, AS; HAMONIC, L; LUDEMAN , DA; BANNISTER, RJ; University of Alberta, Institute of Marine Research, Norway; *sleys@ualberta.ca*

Filtration and cost of filtration in Geodia barretti, a high microbial abundance sponge inhabiting Norway's deep fjords.

Sponges are bacterivores, removing picoplankton from the water column with high efficiency, and thereby affecting water column properties. Bacterial supply in deep−water is limited, yet kilometre−long reefs of glass sponges occur on the shelf of Pacific Canada. Meter−large *Geodia barretti* also form beds of thousands of individuals in fjords and on the continental shelf of the North Atlantic. *Geodia* (Demospongiae, Astrophorida, Geodiidae) is a high microbial abundance' sponge whose tissues are packed with bacterial symbionts. We asked what supports such large populations in deep, bacteria−poor fjords and shelves, and whether *Geodia* filters bacteria with high or poor efficiency? In waters with high dissolved organic carbon sponges can live heavily off DOC via symbionts. We used direct measures (inhaled−vs−exhaled water) to study feeding and excretion in a population of *Geodia* inhabiting fjords in southern Norway. We used microscopy to describe the structure of, and to model the resistance through, the canals and collar filter. We also carried out experiments to determine whether 1µm fluorescent beads can bypass the choanocyte filter. Ambient TOC (bacteria and DOC) were low, and although *Geodia* filtered bacteria with 91% efficiency, no particles were found to bypass the filter. *Geodia* removed nitrite and released nitrate, but not ammonium. Electron microscopy showed the filter has a gasket' that envelops all collars, much like the secondary reticulum of the Hexactinellida. The tightness of the collar filter suggests high resistance to flow and a relatively high cost to feeding in this sponge. The role of symbiotic bacteria in reducing the cost is suspected.

60.1 LI, C.*; WÖHRL, T.; LAM, H.K.; FULL, R.J.; University of California, Berkeley, University of Jena; *chen.li@berkeley.edu*
Fast, flipping cockroaches: dynamic, self−righting behavior
Righting oneself from an upside−down orientation is one of the most prevalent locomotor transitions terrestrial animals perform to survive. Previous studies in crustaceans and insects described a diversity of self−righting strategies. Recent studies in turtles and robots begin to hypothesize self−righting mechanisms in the transverse or sagittal plane. However, few quantitative measurements exist on animals' self−righting performance to test these hypotheses, particularly in three dimensions. Here, we study self−righting on a flat, rigid ground in three species of cockroaches differing in body size, shape, and availability of wings. We found that animal righting is a complex, dynamic, three−dimensional maneuver using multi−degree−of−freedom bodies and appendages. All three species self−righted successfully (75 ± 20 % righting probability) and quickly (as low as 140 milliseconds and typically within 2 seconds). However, their morphological differences result in distinct dominant behavioral strategies. The smallest, most agile, and winged American cockroach primarily kicked its legs against the ground (95% relative frequency) to self−right (0.7 ± 0.2 s). By contrast, the mid−sized, relatively agile, winged discoid cockroach most often used wings coupled with body flexion (62% relative frequency) to self−right (1.6 ± 1.0 s). The largest, least agile, and wingless Madagascar hissing cockroach hyperextended its body (90% relative frequency) and then rubbed its legs on the ground to self−right (1.2 ± 0.4 s). Results suggest that when appendages alone cannot generate a sufficient impulse, the ability to transform into an unstable body shape when upside down is critical to self−righting capability. Our study provides inspiration for robotics as many current terrestrial robots have rigid, cuboidal bodies which hinder self−righting.

77.5 LI, G*; MüLLER, U K; VAN LEEUWEN, J L; LIU, H; Chiba University, Japan, California State University Fresno, USA, Wageningen University, The Netherlands; *reagan@graduate.chiba−u.jp*
On the propulsive role of finfold in larval fish swim: a computational study
Larval fish swimming differs from adult swimming in its kinematics, morphology and fluid mechanics. Compared with adults, larvae swim at lower Reynolds numbers and rely on drag−based mechanisms to generate most of their propulsive force. They use body undulations with a larger amplitude and frequency. They have a finfold rather than a pronounced tail fin. In this study, to develop a mechanical explanation that relates larval swimming morphology and kinematics to larval flow regime, we simulated forward cyclic swimming using a three−dimensional computational fluid dynamics approach that simulates free swimming by coupling hydrodynamics and body dynamics. Our three−dimensional, high−resolution map of the thrust and drag distribution on the body shows that thrust is generated not just at the tail tip, but along the entire body posterior to the centre of mass. By examining both horizontal and vertical cross−sections of the flow, we found that vertical flow elements contribute considerably to thrust production at Reynolds numbers in the 100 order of magnitude: the flow separates at the finfold and forms strong and complex vortex structures at the upper and lower edges of the finfold. Thrust generation is concentrated at these edges, indicating a causal relationship between edge vortex and thrust generation. Aside from finding that the finfold has a significant propulsive function in larval fish, this study shows show that larval fish generate a substantial proportion of their propulsive forces by flows that manifest in vertical rather than horizontal cross−sections. Hence, thrust estimates based solely on horizontal cross sections will underestimate total thrust production.

94.3 LI, Y*; KOCOT, KM; SANTOS, SR; HALANYCH, KM; Auburn University; *yzl0084@auburn.edu*
Phylogenomics and species−tree analyses reveal deep−sea family Siboglinidae (Annelida) relationships
Deep−sea tubeworms (Annelid, Siboglinidae) have drawn considerable interest in ecology and evolutionary biology. As adults, they lack a digestive tract and rely on endosymbionts for nutrition. Moreover, they are important members of chemosynthetic communities such as hydrothermal vents, cold seeps, muddy sediments and whale bones. Four lineages within Siboglinidae have been recognized: Frenulata, Vestimentifera, Sclerolinum and Osedax. Despite their importance, evolutionary history within this family has been debated due to conflicting results from morphological and molecular phylogenetic studies. In particular, placement of the bone−eating Osedax worms has been unclear mainly due to their distinctive biology, including harboring heterotrophic bacteria as endosymbionts, displaying marked sexual dimorphism and exhibiting a distinct body−plan. Here, we reconstruct siboglinid phylogeny using two phylogenomic datasets: one contained 553 nuclear genes (on average 75% genes were sampled per taxa) while the other possessed 186 nuclear genes (strict dataset, on average 93.3% genes were sampled per taxa). Both datasets strongly supported Osedax being most closely related to the Vestimentifera+Sclerolinum clade, rather than the Frenulata, as previously reported. Additionally, several species−tree approaches were also conducted in order to evaluate the effects of gene incongruence when inferring phylogeny from large concatenated datasets.

P2.9 LI, J*; PAGUIO, D; VILLARREAL, F; KüLTZ, D; Univ. of California, Davis; *joli@ucdavis.edu*
Molecular phenotype differences in gills of resident marine versus landlocked limnetic three−spined sticklebacks (Gasterosteus aculeatus)
Three−spined stickleback (Gasterosteus aculeatus) are a globally widespread species that is capable of residing in marine and limnetic habitats. Its geographical distribution and potential to adapt to an anadromous life history make it a suitable candidate in providing insight into the mechanisms underlying salinity tolerance in teleosts. To analyze the influence of marine versus limnetic habitats on three spined sticklebacks, we compared a resident marine (Bodega Harbor, CA) with a landlocked limnetic (Lake Solano, CA) population. The marine population ecotypes were classically fully plated whereas the limnetic population were classically low−plated. Morphometric parameters were measured after staining fish with Alizarin Red, and the Bodega population were significantly larger and more plated. To gain insight into differences of gill function between these ecotypes, label−free quantitative proteomics was performed. Specific proteins of interest were validated by targeted proteomics based on multiple reaction monitoring and analysis using Skyline software. Proteins that were significantly different in abundance were then analyzed by gene ontology and pathway analyses. PANTHER (Protein Analysis Through Evolutionary Relationships) was used for protein enrichment and overrepresentation analyses. The current study provides a network based analysis of proteins and compares consistent differences in the stickleback gill proteome in both populations. These analyses delineate specific branchial pathways involved in ionic regulation, proteosomal degradation, and molecular chaperoning that different between the two populations. We conclude that these pathways are under strong selection pressure when marine sticklebacks invade limnetic habitats. Funded by NSF Grant IOS−1355098

101.1 LIAO, JC*; AKANYETI, O; The Whitney Lab for Marine Bioscience, U. Florida Gainesville; *jliao@whitney.ufl.edu*
Using 3−D printing technology to investigate the function of cranial lateral line canals in fishes during rheotaxis
The cranial lateral line canals (CLLC) of fishes are a mechano−receptive sensory system that can detect pressure gradients caused by changes in flow velocity. The CLLC is phylogenetically conserved, exhibiting a stereotyped, three branch arrangement on each side of the head consisting of a supraorbital branch above the eye (SO), an infraorbital below the eye (IO) and an operculo−mandibular along the lower jaw (OM). Simultaneous recordings from a comprehensive population of lateral line units in behaving animals is currently out of our reach, which has made advancing functional evaluations of CLLC organization challenging. Here we fabricated fish heads from 3D scans of rainbow trout (*Oncorhynchus mykiss*) to investigate the contributions of each CLLC branch when faced with oncoming flow. We placed pressure sensors in the location of the pores for each CLLC branch and measured the pressure as we varied the yaw and pitch angle of the head from −20° to +20° at 10° intervals. Our results show that the signal to noise ratio of the pressure gradient (PG) across the head is larger than that on the same side of the head. In contrast, pitch angle can be detected only by the PG on the same side of the head. We found that the $PG_{SO} > PG_{IO} > PG_{OM}$ when the pitch angle was positive (e.g. the model was facing down) and that the $PG_{OM} > PG_{IO} > PG_{SO}$ when pitch angle was negative. We also analyzed how pressure varied with head size (14 cm and 8 cm, corresponding to body lengths of 49 and 18 cm, respectively) and flow speed (55 cm s^{-1} and 26 cm s^{-1}), and found that the signal to noise ratio of the PG increases with head size and flow speed. Our results show that each CLLC branch can provide distinct information during rheotactic behaviour.

88.2 LIBBY, T*; JOHNSON, A.M.; FULL, R.J.; Univ. of California, Berkeley; *tlibby@berkeley.edu*
SCALING OF EFFECTIVENESS FOR INERTIAL REORIENTATION
Swinging tails, flailing limbs and bending spines all produce inertial forces through which animals can control orientation, enabling aerial righting among other feats of agility. To compare inertial reorientation (IR) ability across diverse taxa and appendages, we developed the simplest possible model (a template) that captures the salient behavior underpinning IR in both animals and robots. The model features a body and an appendage pinned at their shared center of mass and equipped with a velocity−dependent actuator to capture the effect of limited power on performance. Owing to its linear dynamics, the template is analytically integrable for an optimal reorientation, revealing the link between performance (rotation in finite time) and morphology (parameterized by range of motion, specific power, maximum rotation speed and IR effectiveness, defined as the body rotation produced by a differential shape change). More detailed planar rigid−body models for each appendage type reduce to the template, allowing direct comparison of the effect of size and morphology. Effectiveness depends only on inertial properties, which may be measured directly or estimated through morphometrics, enabling characterization of both extant and extinct animals. Power needed for reorientation is inversely proportional to effectiveness, favoring long tails over smaller appendages for fast maneuvers. Effectiveness scales isometrically, but the specific power to reorient in one body length of vertical fall scales as the square root of size. A small increase in mass dedicated to a tail was needed to retain righting performance across a 50−fold increase in mass for two biologically inspired robots. Animals capable of effective IR likely span a larger range, from 3 gram geckos to 20 kilogram theropod dinosaurs and beyond.

86.6 LIDDY, A.*; MILLER, A. L.; University of Tampa; *angelina.liddy@spartans.ut.edu*
Sex specific behavioral responses to pheromones in the scorpion Paruroctonus boreus
Differences between the sexes are well known across taxa and are due to how males and females maximize their reproductive success differently. Generally, females tend to be the limiting sex because of the higher cost of their gametes, as well as growing and rearing the young. This has led to many examples of sexual dimorphism in size and color, which often stems from the competition males have with each other in obtaining a mate. Further males often exhibit a greater tendency to expose themselves to predation risk by spending more time searching for a mate. Male scorpions are no different, as they are known to be the more vagile sex. Research has shown males reduce their risk by recognizing substrate pheromones of females, thus directing their search and limiting their exposure to predation. In the current research, it is unknown if females have the ability to locate males or other females as a way to facilitate sex and reduce competition in these solitary animals. We tested the female response to substrate pheromones of conspecific males and females. Females were placed in an experimental chamber and allowed to roam between areas exposed to conspecific pheromones and control areas, not exposed to pheromones. Total time spent in each area was compared and behavioral movements noted. Our findings show that males and females respond differently to pheromones and we suggest this can be attributed to different reproductive strategies. Further, our findings give insight into the observed sexual dimorphism of their sensory organs, known as pectines, and suggest that selection pressure on these organs may be greater in males than females.

17.1 LIGHTON, JRB*; TREAT, MB; SCHOLER−MCFADDEN, L; RICHARDSON, J; VAN BREUKELEN, F; Sable Systems International, Univ. of Nevada, Las Vegas; *lighton@sablesys.com*
Torpor in Tenrecs: Insect−like gas exchange and zombie−esque behavior in a basal protoendothermic mammal
The tenrec, *Tenrec ecaudatus*, also known as the tailless tenrec, is a basal endothermic mammal resident in Madagascar. The animal's basal status is emphasized by poor temperature regulation and anatomical plesiomorphisms including a cloaca. During the austral winter, they enter into a state akin to hibernation in 1−2m long burrows plugged with soil. We measured O2 consumption, CO2 production, respiratory exchange ratio, evaporative water loss, position and activity in the X and Y planes using a Promethion−C continuous metabolic phenotyping system, plus cutaneous temperature, at ambient temperatures ranging from 11−26°C at intervals of approximately 1 to 2° C for 24 hours in nominally hibernating tenrecs (body mass range 180−450 g, N = 7−8 at each temperature). The animals spontaneously aroused more frequently at higher temperatures, but the arousal duration was typically less than 20−40% of the 24 hour recording; thus we were able to obtain good hibernation data. The tenrecs were capable of basic ambulatory activity when their heart rate was < 30 BPM and their body temperature was practically indistinguishable from ambient temperature, even at 11° C. The temporal structure of the metabolic records during hibernation was anomalous and reminiscent of the insect DGC. Periods of apnea, or near−apnea, lasted approximately 15−30 minutes across the temperature range up to 20° C, interrupted by discontinuous gas exchange corresponding to a few breaths. Metabolic rates (Q10 of 3.0 across the temperature range) were exceedingly low. We hypothesize that this unusual ventilatory strategy may be adaptive in hypercapnic, hypoxic underground conditions (cf. the "chthonic hypothesis").

97.3 LIN, Y.F.*; HORNER, A.M.; DUMONT, E.R; University of Massachusetts, Amherst, California State University, San Bernardino; *yifenlinOEB@gmail.com*

Do moles burrow like Michael Phelps? The stroke pattern of Eastern moles

Forelimb strokes are used to propel animals through substrates in many forms of locomotion, including flying, swimming, sculling and burrowing. Moles, one of the most specialized mammalian diggers, are thought to burrow through the earth with swimming−like lateral strokes, but the kinematic details of the mole's lateral stroke remains unclear. In this study, we analyzed the 3D pattern of 83 lateral strokes from 3 Eastern moles using biplanar video radiography combined with model−based motion analysis (XROMM). We allowed the animals to burrow in couscous and traced the movement of the tips of the third digits. We found that the path of the lateral stroke has much more of a lateral component than a posterior component. The stroke ends with the two hands parallel to the body axis with palmar surface facing outward. This contradicts the previous view that lateral strokes end with the hands facing posteriorly as in swimming. We also found that the stroke span, the maximum distance between claw tips, is somewhat wider than body width. 77% of the strokes have a span that is 90−140% of body width, but only 2% of the strokes are over 160% of body width. Finally, we found that moles alternate their right and left hands during burrowing. 65% of the strokes we surveyed were asymmetric: one hand moved the substrate laterally while the other hand braced against the substrates. Our findings suggest that the lateral stroke of Eastern moles is unlike any type of swimming stroke and is also distinct from the stroke used by scratch diggers.

57.4 LINDSAY, S.M.; University of Maine, Orono; *slindsay@maine.edu*

Injury, infaunal activity and soft sediment community ecology: New insights and new directions

In 1984, Sally Woodin reported the effects of injury (posterior segment or feeding palp loss) on activity of arenicolid, maldanid and spionid polychaetes [Biol Bull 166:558−573]. Tissue loss reduced defecation by all three species, and tube−building by the spionid. Thus, Woodin demonstrated an important link between browsing predators and biogenic sediment modification by infauna, particularly given the challenge at the time to "assess the importance of biogenic sedimentary change in determining composition of the local assemblage, as well as the chemical and physical structure of the sediment." The organizing role of infaunal activity has been an important theme in soft sediment ecological research, but what have we learned about infaunal injury, activity and soft−sediment ecology since 1984? Patterns and frequency of injury are better documented in terms of taxa, geography, and energy flow. We know more about how injury impacts growth and reproduction for more taxa, and new approaches examine how the type of tissue lost and environmental conditions affect regeneration. Studies of the regenerative process have intriguing implications for sensory and evolutionary biology. Research examining the effect of repeated injury on infaunal activity suggests that not all injury is equal, and that food availability and environment may modify responses. Relatively few studies have modeled population consequences of interactions between predation, infaunal activity, and sediment disturbance. And despite advances in understanding how infauna act as hydraulic engineers, incorporating the effects of injury into biogeochemical models is also challenging. Some of the newest research investigates how injury affects infaunal hydraulic activity in an attempt to improve such models.

86.3 LINKEM, CN*; BUTLER, MA; University of Hawaii at Manoa; *cnlinkem@hawaii.edu*

What is the meaning of different color signals to the colorful Megalagron damselfly?

One commonly known characteristic of Odonates is that they possess a great variety of color polymorphisms both within and between species and sexes. The visual system should then be appropriately adapted through the process of natural selection to receive these color signals and the individual should act accordingly. The Blackline Hawaiian Damselfly, *Megalagrion nigrohamatum nigrolineatum*, is in contention for possessing the most color polymorphisms of any odonate. We show here that the wide variety of chromatisms displayed by M.n.n reaches to nearly 20 different color combinations. Are these differences in coloration of any ecological significance? Are damselflies using the colors they perceive to make an informed decision on what behavioral response they should elicit? We tested these questions by presenting artificial stimuli that mimicked conspecific males and females to perching male damselflies in the field and noting their behavioral response which was classified as either attack, track, avoid, or no response. The results here show that this damselfly does in fact respond differently to the variety of colors that were presented to them, suggesting that body coloration is a meaningful, important signal.

P1.156 LINVILLE, M.C.*; KAUR, M.; DAVIS, J.E.; Radford University; *mlinville3@radford.edu*

The Effects of Vespa Amino Acid Mixture on Swimming Endurance of Musca domestica

This study was designed to test the actions of Vespa Amino Acid Mixture (VAAM) on energetically expensive activities such as swimming, in an insect model. VAAM is a product isolated from the saliva of Japanese giant hornet (*Vespa mandarinia japonica*) larvae. This product has been used in a Japanese sport and health drink marketed by VAAM Power, which claims that it increases endurance via the breakdown of fat and the suppression of lactic acid formation in the muscles. However, it is notable that no other studies on VAAM's efficacy have been conducted on insects other than the giant Japanese hornets. *Musca domestica*, more commonly known as the housefly, was used as a study animal for this experiment. Results from our study show that VAAM does in fact significantly increase swimming endurance in our test by an average of 275% ($p < .0001$), though the mechanisms of the product's effects remain somewhat unclear. Findings in this experiment also point towards a risk associated with VAAM, as experimental flies were significantly more likely to die following testing than were the control group animals, though again the mechanisms underlying this effect are currently uncertain. Continuing studies regarding this remarkable mixture are ongoing.

13.6 LIU, H*; LATSHAW, E; TAYLOR, B; CURET, O.M.; Florida Atlantic University; *ocuret@fau.edu*

Propulsive performance of ribbon−fin−based propulsion with flexible rays

Certain aquatic organisms propel by sending traveling waves along one or multiple elongated fins. This undulating ribbon−fin−based propulsion can provide remarkable locomotion capabilities and it has independently evolved for various fishes in both marine and fresh water environments. In this work, we studied the effect of flexibility on ribbon−fin−based propulsion using a robotic fin actuated by a series of rays. We characterized the mechanical behavior and performance of a robotic undulating ribbon fin with different ray flexibilities. We tested the physical model in a water tunnel. In a series of experiments, we measured the propulsive force, power consumption and swimming speed of the robotic fin for different ray flexural stiffness, wave frequencies and flow conditions. We found that an increase in flexibility can either decrease or increase the propulsive force depending on the frequency of the traveling wave. In addition, an increase in flexibility decreased power consumption. Thus, flexible rays could improve or worsen the propulsive performance compared to a rigid counterpart depending on the actuation parameters. We present the result concerning the performance and kinematics of rigid and flexible ray fins.

31.1 LIWANAG, H E M*; DICKSON, M M; ZIMMERMANN, S A; WOLFMEYER, T; ESPINOZA, R E; Adelphi University, California State University, Northridge; *hliwanag@adelphi.edu*

Rapidly Adapting to the Neighborhood: Physiological Responses of Mediterranean House Geckos to their Introduced Climates

Introduced species are likely to rapidly adapt to local climates because of small founder populations and strong selective pressures in their new environments. Ectotherms may be particularly sensitive to climatic challenges, requiring swift adaptive change. To test these ideas, we compared thermal tolerances (critical thermal minimum, CT_{min} and panting threshold, T_{pant}) and temperature−dependent rates of evaporative water loss (EWL) and resting metabolism (RMR) of Mediterranean House Geckos (*Hemidactylus turcicus*) from different climates. These "porch light" geckos have been widely introduced throughout the New World since their first appearance in Florida in 1910. Eight populations of geckos were collected from the southern USA, representing three climates: desert (hot/dry; n = 2 populations), Mediterranean (warm/dry; n = 2), and subtropical (hot/humid; n = 4). We hypothesized that geckos would exhibit physiological differences consistent with adaptation to their local climates. Geckos from climates with cooler daytime temperatures had lower CT_{min} compared to those from hotter climates. However, we found no statistical difference in T_{pant} among populations. Compared to geckos from humid regions, those from arid climates had lower rates of EWL at higher temperatures, which is explained by correspondingly lower RMR. Interestingly, a recently founded (~3 yr) Mediterranean population did not show evidence of local adaptation. Future studies will include sprint performance and testing for developmental plasticity. Ultimately these data will be used in a mechanistic niche model to predict the future range expansion of this species in the USA.

47.4 LOGAN, M. L.*; DURYEA, M. C.; MOLNAR, O.; KESSLER, B.; CALSBEEK, R.; Stellenbosch University, Lund University, University of Brazil, Dartmouth College; *mike.logan1983@gmail.com*

Gene flow−selection balance and the response of metapopulations to climate change

Most models for the response of organisms to climate change implicitly assume that populations occur in isolation. However, most local populations are nested within broader metapopulations, united by the immigration and emigration of individuals. If a metapopulation is distributed over a broad geographic region, selection on physiological traits may vary such that gene flow among populations alters extinction probabilities. For example, gene flow from populations that are adapted to cooler climates may reduce the ability of other populations to adapt to a progressively warming environment. Alternatively, local selection may be strong enough to overwhelm gene flow, generating and maintaining phenotypic diversity that may increase a species' resilience to climate change. Here, we examine the degree to which 7 populations of the lizard *Anolis sagrei* occurring on different islands in The Bahamas exhibit local thermal adaption in the face of gene flow from geographically disparate populations. Islands varied significantly in their thermal regimes, and despite extremely high gene flow among populations, the thermal optimum for sprint performance was strongly correlated with both the mean and maximum environmental temperature of each island. These data suggest that local selection on thermal physiology has overwhelmed the effects of gene flow from maladapted populations, and that metapopulation structure may increase the resilience of *A. sagrei* to a rapidly changing climate.

64.3 LOLAVAR, A.*; WYNEKEN, J.; Florida Atlantic University; *alolavar@fau.edu*

Experimental Assessment of the Effects of Moisture on Loggerhead Sex Ratios

Nest sand temperature strongly influences development of sea turtle embryos and sex differentiation; however in nature eggs experience temperature along with other environmental factors. We tested the hypothesis that moisture affects sea turtle hatchling sex ratios. We studied the relationships among humidity, temperature, and loggerhead (*Caretta caretta*) sex ratios in an experimental study. Eggs were incubated in sterile nest sand in the laboratory under different moisture regimes to test the role of humidity at a constant incubation temperature. Incubator temperature was set at 29.4 degrees C, which is slightly above the temperature that should yield a 1:1 sex ratio. Nest moisture was maintained by daily DI water treatments and high relative humidity was maintained with the aid of a mist humidifier throughout incubation. All hatchlings were collected, raised for several months and sexed laparoscopically to establish sex ratios for each treatment. The experimental treatments tested the effects of (i) very high moisture, (ii) moisture with potential for evaporative cooling, and (iii) moisture added at average rain temperatures plus the potential for evaporative cooling. The nests were expected to produce a moderate female bias if moisture played no role. We found 87−93% males across all experimental treatments. The results support our hypothesis that moisture impacts hatchling sex ratios. High moisture conditions can produce shifts in developmental response from that expected based on temperature alone.

P2.188 LOMAX, JJ; CROFTS, SB*; Univ. of South Florida, Univ. of Washington; *jeremylomax@mail.usf.edu*

Importance of being Organized: the Effects of Changing Tooth Arrangement on Durophagous Predation

The many lineages of hard prey specialists have a variety of robust tooth morphologies. The variation in tooth morphology is complicated by variation in the arrangement of teeth between species. The arrangements include the familiar linear array, zig−zag patterns, and tightly packed irregular and regular patterns. To better understand how tooth pattern affects the predator's ability to crush prey, we created a series of tooth plate models based on arrangements seen in nature. In addition, we tested for interactions between tooth morphology and tooth arrangement. We measured the force required by different models to break ceramic tubes, a proxy for shelled prey items. These tubes have standard dimensions and reduce much of the variability seen in live organisms due to their natural history. We found that changing tooth arrangements from linear to more complex patterns does not decrease the force required to fracture a prey item and in some cases changing arrangement and morphology served to increase force to fracture. Because changing tooth arrangement does not appear to confer a functional advantage when crushing prey, we suggest that the benefit of less linear tooth arrangements may lie elsewhere, for example, in resistance to failure in teeth.

P3.42 LONEY−WALSH, K*; DUBOSE, L; CATAPANE, E,J; CARROLL, M,A; Medgar Evers College; *catapane@mec.cuny.edu*

p−Aminosalicylic Acid (PAS) Reverses the Neurotoxic Effects of Manganese on Dopamine Post−Synaptic Receptors

Manganese (Mn) causes Manganism a disease disrupting dopamine (DA) neurotransmission. The mechanism of action is not fully resolved. It's thought Mn toxicity is more related to dysfunction of DA D2 receptors (D2DR) than degeneration of DA neurons. Gill lateral cells of *Crassostrea virginica* are innervated by a DA nerves from the ganglia. We showed Mn treatment blocks cilio−inhibitory effects of DA, and the post−synaptic DA receptors in gill lateral cells are D2 type. We also showed treating animals with Mn in the presence of the drug p−Aminosalicylic acid (PAS) prevented the toxic effect. We hypothesize PAS could reverse Mn toxicity when applied after Mn. We treated *C. virginia* 3 days with Mn (500 mM) followed by 5 days with PAS (500 mM). Gills were excised, fixed, exposed to 1º antibodies against D2DR and FITC−linked 2º antibodies, embedded and sectioned. We viewed D2DR in gill cells on a fluorescence microscope showing bright FITC fluorescence in lateral and other gill cells. Fluorescence intensity of lateral cells was quantified using ImageJ software from NSF. Intensity in sections from Mn treated animals was 40% less than controls. Animals treated with PAS after Mn exposure did not show reduced fluorescence, showing PAS reversed the Mn induced lose of post−synaptic D2DR. This study shows positive correlation between loss of D2DR fluorescence in gill lateral cells in Mn treated animals vs controls and PAS reverses toxic effects of Mn on D2DR after 3 days of Mn treatment.

P1.73 LONG, K*; NOSSA, C; SEWELL, M; PUTNAM, N; RYAN, J; Whitney Laboratory for Marine Bioscience, University of Florida, St Augustine, FL, Rice University, Houston, TX, Univeristy of Auckland, NZ; *kalong91@gmail.com*

Increasing resolution of Hox evolution with whole−genome sequencing from three echinoderm species

Hox genes are a group of transcription factors known to be important in patterning the primary body axis of most animals during development. Unlike other animals, the echinoderm body plan incorporates a pentaradial adult form built upon a bilateral larval plan. It has long been suspected that changes in the presence/absence, arrangement, and expression of Hox genes in stem ancestors of echinoderms have contributed to their unique adult body plan. Although the genome of *Strongylocentrotus pupuratus* has been fully sequenced and studied extensively, genomic information from other echinoderms remains scarce. We have sequenced and assembled the genomes of three echinoderm species from three of the remaining four classes: *Ophionereis fasciata* (brittle star), *Patiriella regulars* (sea star), and *Australostichopus mollis* (sea cucumber). In this study we characterize 361 previously unidentified homeobox genes. We report the first evidence of the presence of Hox2 in Asterozoa, which had been previously thought to be absent. The absence of Hox4 within holothuroids was also confirmed. Hox4 had previously been shown to be absent in echinoids, meaning that Hox4 was most likely lost in Echinozoa. We identified a novel family of posterior−class hox genes, Hox11/13d, in each of the three species, suggesting that this might also be present within Crinoids and Echinoids. The increased resolution of echinoderm hox genes will aid further studies of the role of Hox genes in echinoderms and shed light on the role Hox genes in echinoderm body patterning.

79.3 LONGO, SJ*; WAINWRIGHT, PC; Univ. of California, Davis, Univ. of California, Davis ; *sjlongo@ucdavis.edu*

NOVEL SUCTION FEEDING KINEMATICS RESULTS IN AN UNUSUAL FORM OF PREY CAPTURE IN SYNGNATHIFORM FISHES

Suction feeding across the vast diversity of acanthomorph fishes is thought to involve a highly stereotyped sequence of movements. Yet, previous research suggests that seahorses and pipefish may be an exception. They use their long snout in a unique form of ram prey capture whereby rapid dorsal head rotation brings the mouth close to prey. In addition, it has been shown that they power amplify their strikes, making them some of the fastest fish feeders in the ocean. But how different are the strikes of seahorses and pipefish compared to their close relatives and other acanthomorph suction feeders? To address this, high−speed videos of strikes on live prey were collected from lineages across the syngnathiform tree (pipefish, trumpetfish, snipefish, and razorfish) and compared to typical suction feeding outgroups. The contributions of head rotation, body ram, jaw protrusion and suction to prey capture were quantified using vector analysis, and timing of key events in suction feeding were compared. We find that syngnathiform strikes rely on dorsal head rotation to bring the mouth close to prey; this is the largest component of movement toward prey in all syngnathiforms, while it is near zero in typical suction feeders. In syngnathiforms, onset of hyoid rotation occurs simultaneously with (or even just before) onset of head rotation, a pattern that has never been reported in any other teleost. Rearrangement of kinematics across syngnathiforms points to a novel roll of the hyoid in the suction feeding mechanism that is not unique to seahorses and pipefish but most likely evolved at the base of the syngnathiform tree. In addition, we propose that simultaneous onset of hyoid rotation with head elevation supports the role of the hyoid as a potential trigger for fast head rotation in syngnathiforms.

86.4 LOPES, PC*; KOENIG, B; Univ. Zurich, Switzerland; *patricia.lopes@ieu.uzh.ch*

What does the mouse say? USV as an honest signal of condition in house mice

Male mice produce ultrasonic vocalizations (USV) during sexual encounters and these appear to act as secondary sexual characters. To understand whether these signals convey information about a male's condition, we handicapped wild−derived house mice (*M. musculus domesticus*) males by making them experience sickness and then assessed their ability to vocalize. To do this, we housed brother pairs in separate recording chambers connected to a common central chamber by mesh−covered windows. One of the males was injected with lipopolysaccharides (LPS) to induce sickness behaviors, while the other was injected with saline. Both males were then exposed to the same female stimulus and their behaviors and vocalizations were recorded overnight. Before exposure to the female, males in both treatments produced virtually no vocalizations. When presented with a female, mice treated with LPS emitted significantly fewer syllables then the control. Females discriminated between control and LPS−injected males, spending more time with the former. The amount of time females spent close to a certain male could not be explained by the number of syllables emitted by that animal. Finally, we combined this with data on expression of urinary proteins to understand how these might interact with auditory cues in facilitating female choice. Our results suggest that USVs produced by males in the context of courtship may function as an honest signal of current condition, although not necessarily the only signal females use to make their decisions. Our experiment helps understand how animals integrate information from different sensory modalities, similar to that which animals experience in their natural environment.

100.5 LOUDON, C*; MACIAS−MUÑOZ, A; Univ. of California, Irvine; *cloudon@uci.edu*

Multiple−choice testing: are we providing too many alternative answers per question?

Different versions of multiple−choice tests were administered to undergraduate students as part of normal testing in order to evaluate whether the number of alternative answers per question affected the effectiveness of assessment. All versions of the test were equally long, with a total of 30 questions, in which ten questions had three alternative answers, ten questions had four alternative answers, and ten questions had five alternative answers (in all cases one correct answer plus distractors). Each question appeared in all three versions of the test, but with a different number of alternative answers. The point biserial statistic was used to evaluate the discrimination ability of each question. The class was an advanced undergraduate class in human physiology with two sections of >300 students each; three tests were given to each of the two sections during the academic quarter (for a total of six tests). There was no measurable improvement in assessment of student learning (using the point biserial statistic) when more than three alternative answers were provided. Therefore, there appears to be little advantage in providing more than three alternative answers per multiple−choice question, and there are disadvantages, such as needing more time for a test in which students need to consider a larger number of incorrect answers. (Partial funding for AM provided by NSF BEACON DBI=0939454)

P3.166 LU, JS*; HALE, ME; Univ. of Chicago; *mhale@uchicago.edu*

Locomotor−respiratory uncoupling in pectoral fin development of zebrafish.

As organisms develop, morphological growth coincides with transitions in functional demands on the body. Little is known about how organisms adapt behaviorally through this process. In larval zebrafish, pectoral fin movements during swimming serve a respiratory function by drawing oxygenated fluid to the skin for cutaneous respiration. Pectoral fins are no longer needed for respiration by 21 days post−fertilization (dpf) when the gills have fully developed. As adults (>70 dpf), pectoral fins assume a locomotor role, raising the question of how zebrafish transition between these two different pectoral fin functions. We examined the swimming of zebrafish 6−90 dpf in order to understand how pectoral fin behavior is modified from rhythmic, alternating fin beats in larvae to adult movements. In adults, we observed that fin movements during forward swimming typically consist of a single, synchronized fin beat at initiation of swimming. The transition between these two behaviors begins at 14 dpf, when oxygen intake is dependent on both gill and cutaneous respiration. We observed a gradual decrease in number and amplitude of fin beats following initiation of swimming. The transition from larval to adult fin movements stabilizes at 20 dpf, when gills have fully developed and are necessary for respiration, but before major developmental changes in pectoral fins occur. These results demonstrate that modifications in pectoral fin motor control coincide with a gradual loss of their respiratory function and precede the fin's morphological transformation. They support the idea that gill and fin development are tightly linked. This example of locomotor−respiratory uncoupling provides a model for better understanding the development of interacting motor systems.

65.1 LUCAS, KN*; THORNYCROFT, PJM; GEMMELL, BJ; COLIN, SP; COSTELLO, JH; LAUDER, GV; Harvard Univ., Univ. of Texas at Austin, Port Aranas, Roger Williams Univ., Providence College; *klucas@fas.harvard.edu*

Effects non−uniform stiffness on the swimming performance of a passively−flexing flapping foil model

Simple mechanical models like passively−flexing foils have been used recently to study specific aspects of fish locomotion without the confounding complexity of the entire fish body. Yet, unlike these uniform−stiffness foils, fish are notable for non−uniform material properties along the body length. In particular, passive flexural stiffness of fish decreases along the anterior−posterior body axis. Thus, to expand upon previous models, this study examined the role of non−uniform stiffness in swimming propulsion. We studied four foil configurations made by sandwiching layers of plastic to produce discrete regions of high and low stiffness. This resulted in two uniform control foils and two foils with high−stiffness anterior and low−stiffness posterior regions. With a mechanical flapping foil controller, we measured forces and torques in three directions and quantified swimming performance under both heaving and constant zero angle of attack motion programs. Foils swam at Reynolds numbers of 45,000−80,000 and Strouhal numbers of 0.20−0.30. Self−propelled speeds (SPS) of the foils increased with frequency, but did so in different manners across stiffness distributions and motion programs. Non−uniform foils often achieved SPS, thrust coefficients, and efficiencies similar to or greater than uniform foils, but often required more power to do so. We also evaluated cost of transport during the two motion programs. Future research will seek to understand the fluid mechanics driving these differences and will evaluate swimming performance of more advanced models with continuous stiffness gradients.

S10.7 LUNCEFORD, B.E.*; PADOVE COHEN, S; BLOOMQUIST, R; NAGLE, M.P.; SHIN, C; MCCARTY, N.A.; KUBANEK, J; Georgia Institute of Technology, Emory University and Georgia Institute of Technology, Emory University; *blunceford3@gatech.edu*

Aversive chemoreception in predatory fish

Chemoreception is necessary for the survival and reproduction of all organisms. Thus, the molecular mechanisms of chemoreception are of vital importance to the evolution of a species. These mechanisms help mediate an organism's interaction with its environment, including the detection of potentially harmful compounds. While much is known about the identity of chemical defenses produced by many prey species, not much is known about the chemoreception mechanisms used by predators to detect prey chemical defenses. In one system, the marine generalist *Thalassoma bifasciatum* (bluehead wrasse) and the model organism *Danio rerio* (zebrafish) are both deterred from eating foods laced with triterpene glycoside defense compounds produced by the marine sponge *Erylus formosus*. We have identified a small membrane bound co−receptor, known as RL−TGR, which is involved in this system of aversive chemoreception in both bluehead wrasse and zebrafish. In addition, other species of fish have RL−TGR orthologs in their genomes. We seek to characterize the mechanism of action of this novel chemoreceptor by localizing its expression in zebrafish and bluehead wrasse and mapping the ligand binding site of RL−TGR using mutagenesis studies. We also seek to determine the breadth of RL−TGR signaling in various fish species by utilizing bioinformatic approaches. A better understanding of this mechanism will give insight into the evolution of aversive chemoreception in fish and its potential role in speciation events.

P2.98 LUOMA, R.L.*; HOLCOMB, L.M.; STAHLSCHMIDT, Z.R.; Georgia Southern University; *zstahlschmidt@georgiasouthern.edu*

Context−dependent effects of complex environments on behavioral plasticity

Adaptive animal behavior must often balance the rigidity of behavioral type (a.k.a., animal personality or consistent inter−individual variation in behavior) with the flexibility of behavioral plasticity. Although individual environmental factors influence behavioral plasticity across taxa, animals live in complex environments wherein multiple environmental factors vary simultaneously. Thus, we investigated the independent and interactive effects of temperature and energy intake on the boldness and feeding behavior of juvenile corn snakes (*Pantherophis guttatus*) in the context of global climate change (GCC). Unlike previous studies that imposed constant or fluctuating temperature regimes on animals, we manipulated the availability of preferred thermal microclimates (control vs. warmer−than−preferred regimes) for eight weeks and allowed individuals to behaviorally thermoregulate among microclimates. By also controlling for energy intake and each animal's initial (pre−study) behavior, we demonstrate context−specific effects of temperature and energy on behavioral plasticity. Temperature and energy intake independently affected feeding behavior where snakes reared in warm regimes and those with high energy intake exhibited a greater feeding propensity. Yet, temperature and energy interactively affected boldness in an open arena. Clearly, complex environments can exert multifaceted effects on behavior after accounting for inter−individual differences in behavior (e.g., behavioral type). Therefore, we advocate for continued investigation into the consequences of GCC−relevant, complex (multi−factorial) environments on behavioral plasticity.

102.1 LUTTERSCHMIDT, D.I.*; LUCAS, A.R.; Portland State University; *d.lutterschmidt@pdx.edu*

Trans−seasonal activation of brain GnRH: Mechanisms underlying temperature−induced reproduction.

All animals use environmental cues to accurately time life−history events. How the brain decodes information about the environment to produce adaptive changes in physiology and behavior, however, is poorly understood. We asked if low temperature dormancy activates seasonal reproduction by altering the synthesis and release of gonadotropin−releasing hormone (GnRH) in the brain. We used the well−studied red−sided garter snake (*Thamnophis sirtalis parietalis*) for this study, as 4 weeks of low temperature exposure is both necessary and sufficient to induce reproduction in northern populations of this species. Male and female snakes were collected from the field and hibernated at 4 or 10°C in complete darkness. At 0, 2, 4, 8, and 16 weeks, plasma was collected from a subset of 8 snakes for steroid hormone assay; brains were processed for immunohistochemistry. The total number of GnRH cells within the forebrain was quantified for each individual. We also measured GnRH soma size to assess changes in the relative activity of GnRH neurons during dormancy. In males, GnRH cell number ($P = 0.004$), GnRH cell area ($P = 0.015$), and plasma androgen concentrations ($P = 0.024$) increased significantly over time. In addition, males hibernated at 4°C for 16 weeks tended to have a higher number of GnRH cells ($P = 0.064$), a larger GnRH cell area ($P = 0.052$), and higher plasma androgens ($P = 0.024$) than males hibernated at 10°C. Intriguingly, female snakes showed no changes in GnRH cell number or soma size during winter dormancy at either temperature, a finding that corroborates known sex differences in the timing of reproductive activities in this species. Collectively, these data provide critical insight for understanding the environment−organism interactions that govern differences in reproductive timing.

S5.6 LUTTRELL, S.; SWORE, J.J.; FODOR, A.; SWALLA, B.J.*; Univ. of Washington; *bjswalla@u.washington.edu*

Evolution of Deuterostome Nervous Systems: A nerve cord runs through it

Morphology and nervous systems are tightly linked in animal evolution, yet the development of nerves involves similar gene networks. Nerve nets are adaptive in marine environments, while nerve cords tend to predominate in land animals. Deuterostome animals show nerve nets and nerve cords in different configurations, depending on their environment and life history. For example, ascidians have a dorsal central nervous system, but this is found only in swimming tadpoles. After metamorphosis, the adult develops a nerve net, and in some species the central nervous system can be extirpated entirely after the nerve net is established. Tailless ascidians have lost their notochord and muscle, yet develop a nerve cord as larvae. Vertebrates have a central nervous system but have reduced or lost their nerve nets and have evolved neural crest that contribute to the nervous system. Hemichordates have an extensive nerve net and also a central nervous system as adults. We will discuss the results of our studies on neural development and regeneration in hemichordates. By studying the process of regeneration in hemichordates, we have identified several new cell types that appear to facilitate regeneration and may contribute to the nervous system. We are actively working to define this unique cell population. We will present our results in a robust phylogenetic framework and discuss hypotheses of loss vs. gain in the evolution of deuterostome nervous systems.

P2.114 LUTTRELL, SAM*; GREENBERG, R; University of Maryland Baltimore County, Smithsonian Migratory Bird Center; *manor.sarah@gmail.com*

A digital photograph technique for comparing overall body color in highly patterned animals

Color plays an important role in animal signaling and sexual selection, and as such is frequently used as a metric for identifying homotypic and heterotypic populations. However, quantifying color differences among individuals or populations can be challenging. Historic techniques for quantifying color rely on the visual system of the observer, and therefore are biased, difficult to evaluate statistically, and not necessarily applicable to the behavior of the animal. An excellent tool for eliminating these biases has been the use of spectrophotometers. However, spectrophotometers work best on uniform patches of color, quantify only a small portion of the body at once, and can perform poorly when the area of interest is highly patterned. We developed a standardized digital photography method that allowed us to quantify differences in highly patterned plumage of phenotypically variable populations of songbirds quickly and account for color and patterning of the entire body of the bird. This method is quantifiable, repeatable, lends itself to statistical analysis, and is independent of observer visual bias.

39.4 LYNN, SE*; KERN, MD; The College of Wooster; *slynn@wooster.edu*

Mothering matters: interactions of temperature, corticosterone, and hypothalamo−pituitary−adrenal axis development in wild chicks.

In vertebrates, exposure to stressful stimuli or elevated glucocorticoids early in development may have fitness consequences later in life. In altricial species, parental brooding behavior may prevent temperature−induced elevations in glucocorticoid secretion by their chicks. To investigate this, we studied eastern bluebirds (*Sialia sialis*) with three goals. First, we measured the surface temperature of chicks during the first week post−hatch to determine the extent to which they cooled in the field. Second, we determined if a brief, experimental drop in body temperature within the range that occurs when a brooding female is off the nest was sufficient to stimulate glucocorticoid secretion in young chicks. And, third, we examined how experimentally induced bouts of cooling within an ecologically relevant range affected their hypothalamo−pituitary−adrenal (HPA) axis function in response to handling just prior to fledging. Chicks in 25% of broods experienced repeated, natural bouts of cooling in the nest, and experimental reduction of their surface temperatures within this cooling range significantly elevated their corticosterone secretion. Chicks that were experimentally subjected to four 20−min bouts of such cooling during the first week post−hatch had a reduced corticosterone response to restraint prior to fledging (more than 1 week later) compared to control chicks. Our data suggest that natural variation in maternal brooding patterns, and hence natural variation in chick temperature, can result in differential exposure of offspring to glucocorticoids early in development, with impacts on HPA function that extend well beyond the brooding period.

71.2 MAAS, AE*; BERGAN, AJ; LAWSON, GL; TARRANT, AM; Woods Hole Ocg. Inst. and Bermuda Inst. Ocean Sci., Woods Hole Ocg. Inst.; *amaas@whoi.edu*

Response of the thecosome pteropod Limacina retroversa to CO_2 on seasonal time scales.

Dissolution of excess anthropogenic CO_2 into the ocean is causing the marine environment to decrease in pH. This ocean acidification' is predicted to threaten a broad variety of marine organisms, particularly calcifying animals such as the thecosome (i.e., shelled) pteropods. Due to spatial and seasonal variability in carbonate chemistry within the Gulf of Maine, pteropods in this environment may already be exposed to under−saturated, and hence corrosive, waters during certain seasons. To understand the implications of this variability we have explored the physiological response of the local population of thecosome pteropod, *Limacina retroversa*, to CO_2 over the course of a year. Sampling for pteropods was done at four time points and was followed by four 7−14 day laboratory exposures to CO_2 (ambient, 800, 1200 ppm). Using an integrated set of metabolic, gene−expression and shell quality studies, we examined whether pteropods vary seasonally in their sensitivity to CO_2 exposure on time−scales relevant to acclimation responses. Similar to previous work with this species and others, there were pronounced changes in shell quality that were discernible after less than 3 days of exposure, while changes to metabolic rate were not pronounced. Our previous study of the transcriptomic response of the thecosome species *Clio pyramidata*to short term CO_2 exposure (10 h, 800 ppm) revealed that despite a lack of change in respiration rate, expression of genes associated with biomineralization was affected by CO_2 exposure. Directed studies of biomineralization−associated gene families and a differential expression analysis of the transcriptome of *L. retroversa*, in combination with both metabolic and shell quality metrics, will provide a complete picture of the effect of CO_2 on this sentinel species.

P1.56 MACIEL, E.I.*; GEORGE, S.B.; University of California, Merced, Georgia Southern University, Statesboro ; *sgeorge@nsf.gov*

The frequency of low salinity waters affects protein expression and growth of sea star larvae

Surface waters around the San Juan Islands in the Pacific North West are directly affected by Arctic ice melt via the Fraser River, the second largest in the region. Data collected in these waters by the Friday Harbor Labs weather station to the south of the river reveal an increase in the frequency of low salinity waters (21) into the area during the spring and summer months when echinoderm larvae are developing. The present study investigated whether protein profiles of eggs and larvae from sea stars (*Pisaster ochraceus*) from a location directly exposed (Cantilever Point, CP) to the Fraser River and a location less exposed (Snug Harbor, SH) differed. Greater expression of high molecular weight (HMW) proteins was observed in the eggs produced by CP females than for those produced by SH females. CP larvae exposed to 4 salinity fluctuations (low salinity 21−22) during development, expressed HMW proteins (404, 271, and 166kDa) not present or faintly expressed by those in the controls (30 ppt). CP larvae in 21 ppt. did not differ significantly in size from those in 30; while SH larvae in 21ppt. were significantly smaller. Interestingly, proteins expressed by SH larvae in low salinity differed from those expressed by CP larvae under similar conditions. In instances were larvae from both locations expressed similar proteins (e.g. 244, 135, and 77kDa) the expression of these proteins was significantly higher for CP larvae. As global warming continues to increase the rate of glacial melting, females from sites exposed to the Fraser River might invest specific proteins in their eggs that ensure optimal physiological conditions (e.g. active transport of ions with the help of Na^+/K^+ ATPase, $Ca2^+$ ATPase, and organic anion transporters) for larval growth and development.

P1.102 MACK, Z.E.*; FOKIDIS, H.B.; Rollins College; *zmack@rollins.edu*

Analysis of the embedded cortisol signature in the nail of the domestic dog (Canis lupus familiaris)

Cortisol is a glucocorticoid steroid hormone that is released from the adrenal gland in response to stress in most mammal species; other vertebrates use the structurally similar corticosterone. There is currently no method to measure cortisol levels from the nail of an animal, which would allow a more accurate analysis of long−term cortisol secretion in relation to current techniques such as measures of blood and saliva. In this study, we proposed a novel technique to analyze cortisol within the nail of the domestic dog (Canus familiaris). Nail was homogenized through exposure to liquid nitrogen and use of an attrition mill. Cortisol was then recovered through solid phase extraction and recovery was determined through enzyme−linked immunoassay. We have found that cortisol is present within the nail at a measurable level. Validation of this technique is currently being completed to determine effectiveness as a diagnostic tool. This research will lay the groundwork for advancing technology available surrounding cortisol testing.

S2.1 MADLIGER, C.L.*; LOVE, O.P.; University of Windsor, Ontario; *madlige@uwindsor.ca*

The power of physiology in changing landscapes: considerations for the continued integration of conservation and physiology

The field of conservation physiology employs physiological measures (e.g., metabolites, glucocorticoids, immune factors, etc.) to understand how organisms and populations respond to changes in their environment. Although the discipline is growing rapidly, there are a number of opportunities that will allow for improved application of physiological knowledge to conservation goals. We will introduce the major themes of the symposium by highlighting five considerations for the continued integration of ecological, evolutionary, and applied endeavours: i) recognizing opportunities for applied components in ecological and evolutionary physiology studies; ii) combining multiple measures of physiology and behaviour; iii) taking into account the context−dependency of physiological variables; iv) combining a within−individual and population−level approach; v) considering the temporal and logistical limitations of working with populations of conservation concern. Drawing on evidence from a range of taxa and physiological systems, and our own work on baseline glucocorticoids in Tree Swallows (*Tachycineta bicolor*), we will demonstrate how current theoretical and empirical approaches in physiology can contribute to a diversified conservation toolbox.

31.5 MAHON, AR*; HAVIRD, JC; SANTOS, SR; HALANYCH, KM; Central Michigan University, Auburn University; *mahon2a@cmich.edu*

Thermal adaptation and differential gene expression in Antarctic sea spiders (Pycnogonida)

Current knowledge of the transcriptomic effects of temperature on Antarctic organisms is limited to vertebrates (antifreeze proteins, oxidative stress genes, heat shock mechanisms) or to upper thermal limits. Few if any studies to date have utilized transcriptomics to directly focus on functional and differential responses to Antarctic benthic marine invertebrates to temperatures approaching lowest survivable limits. Technological advances allow molecular genomic studies to investigate functional genomics as they relate to the physiological mechanisms and responses of organisms to lower temperature extremes. In this study we examine the transcriptomes of the widespread Antarctic sea spider Nymphon australe to identify candidate genes involved in its ability to thrive at low temperatures (i.e., below 0C) and how they respond to rapid, short−term thermal increases. In this, we completed a series of experimental trials where the sea spiders were exposed to different temperature regimes and monitored changes over an ecologically relevant time period. Due to the rapid pace of climate change in regions of Antarctica, there is urgency to more fully understand physiological responses of temperature on Antarctic organisms such as Nymphon australe, not just over longer time periods, but for scenarios that the organisms would see on a daily basis. This study tests major dogma about Antarctic invertebrates having novel mechanisms for dealing with freezing temperatures and it has significant implications for how researchers understand the function of species under adverse and changing conditions.

P3.52 MAI, E*; LOPEZ, M; FUSE, M; San Francisco State University; *emai@mail.sfsu.edu*

The ecdysteroid agonist RH 5992 reduces developmental delays that arise after tissue damage in the hornworm, Manduca sexta

The developmental timing and progression of growth in insects is controlled by neural and endocrine signaling. In particular, the release of 20−hydroxyecdysone (20−HE) from the brain into the hemolymph (blood) stimulates molting at the larval, pupal, and adult stages. It is hypothesized that the release of the endocrine signal that drives development, 20−HE, is inhibited when an insect's tissue is damaged. Specifically, damage to the imaginal disc tissues of the fruitfly *Drosophila melanogaster* appears to cause a delay in the release of 20−HE and thus a delay in development. This has not yet been demonstrated in the hornworm *Manduca sexta*. We hypothesized that injection of a synthetic 20−HE analog (RH 5992) would reduce the developmental delay noted after tissue damage. The hornworm imaginal discs were damaged by exposure to 10 kRads of X−ray irradiation. At a time point when the levels of ecdysteroids were expected to be elevated, hornworms were injected with 2 ul of either 100% ethanol (vehicle) or 0.3mM to 30mM doses of RH 5992 (tebufenozide), a long−acting 20−HE agonist, in control and irradiated larvae. Following treatment, time−lapse photography was used to record timing of pupation. As expected, pupation delays were noted after irradiation in the ethanol−injected irradiated animals. However, irradiated animals that were treated with 0.3 mM − 3mM RH 5992 showed shortened developmental delays, although not to the level of control larvae. Animals that were treated with higher doses of RH 5992 also failed to pupate and eclose correctly. This shows that damage induced development delays can be reduced to some extent by increasing the abundance of ecdysteroids in the hemolymph.

101.3 MAIA, A*; EATON, M; PROBST, B; ELMUTI, S; Eastern Illinois University, Charleston High School; *amresendedamaia@eiu.edu*
Form and Function of the Spiny Dorsal Fin in Sunfishes
In fish fin evolution there is a trend towards a higher range of motion and flexibility, but little attention has been given to the spiny and less flexible fins of Acanthomorpha. In some Centrarchidae fishes, the spiny portion of the dorsal fin reaches similar sizes to the soft dorsal fins and is thought to have a role in predatory defense and/or in locomotion. We sampled green, redear and bluegill sunfish from Illinois tributaries and analyzed dorsal fin morphometrics. We also collected kinematics data during steady swimming, hovering, routine maneuvers and fast starts, as well as in response to hydrodynamic stimuli delivered to the dorsal fin. Geometric morphometrics separated the three species into two groups but was not effective in separating the green sunfish from the bluegill. The main variables driving the differences were relative position along the cranio−caudal axis and height of the spiny and soft dorsal fins. In terms of ontogenetic changes, we found that the soft dorsal fin grows faster in height than the spiny dorsal fin. This suggests that the fins are under selective pressure, although not necessarily as a predatory deterrent. There were no significant differences in escape responses between green sunfish and bluegill sunfish of similar sizes, but the spiny dorsal fin was deployed by both species. Bluegills are able to detect hydrodynamic stimulus delivered to the fin and respond by temporarily collapsing and then re−erecting the spiny dorsal fin while moving the soft dorsal fin laterally. These results seem to indicate that the dorsal fin is capable of detecting flow and provide stability in different locomotor behaviors. Stability demands are likely to have played a role in the evolution of spiny fins in Acantomorpha.

68.3 MAIE, T; Lynchburg College; *maie.t@lynchburg.edu*
Effects of contaminated water due to mining activities on the vertebrae in fishes: material testing and functional morphology as assessment tools for environmental risks
Changes in aquatic environments associated with mining activities (e.g., historic iron mining) may have tremendous impacts on aquatic organisms, ecosystems, and natural resources. Currently, mining companies are working to develop open−pit copper−nickel mining operations in Minnesota. Although not yet operational, environmental risks would be predicted. Lakes and rivers in Minnesota linked to waters that have previously been influenced by mining (e.g., iron ore pits) may already have direct or indirect impacts on the vertebrae in fishes. Using the material testing system (the TA.XT Plus Texture Analyzer), I evaluated a series of force−bearing capacities (strength, Young's modulus of elasticity, and yield strength) of the vertebrae from four body regions of yellow perch (*Perca flavescens*), which have been exposed for years to mining−influenced water, as well as from yellow perch from water free from mining influence. The vertebrae of *P. flavescens* from a mining−influenced lake produced much more elevated level of strength than those from a spring−fed lake. However, the vertebrae of *P. flavescens* from the mining−influenced lake had substantially reduced Young's modulus, as well as yield strength. The degree of deformation that the vertebrae could resist and recoil back from was greatly reduced in *P. flavescens* from the mining−influenced lake. These results suggest that the vertebrae might mineralize differently and contribute differently to locomotor function, particularly in varying environmental contexts.

9.5 MAJORIS, J.E.*; FRANCISCO, F.; ATEMA, A.; BUSTON, P.M.; Boston University, Universität Konstanz; *jmajoris@bu.edu*
Hatching plasticity in a coral reef fish: causes and consequences of early hatching
In many taxa, embryos adjust the timing of hatching in response to intrinsic and extrinsic environmental cues. Here we investigated the effect of parental and mechanical cues on the timing of hatching and hatchling morphology in the neon goby *Elacatinus colini*. We established a breeding population of *E. colini* in the lab, and observed the timing of embryo hatching under parental and artificial incubation conditions. Artificially incubated clutches were divided into two treatments: i) mechanically induced clutches that were shaken every 8 hrs to determine the earliest onset of hatching competence, and ii) non−induced clutches that were allowed to hatch undisturbed. Larvae from each treatment were photographed and preserved for morphological analysis. When incubated with parents, male *E. colini* were found to induce hatching by actively removing embryos with their mouth and spitting the hatched larvae into the water column. Mechanically induced clutches hatched approximately 20% earlier (134 hours−post−fertilization, HPF), had a smaller propulsive area, and larger yolk sac area than parentally induced clutches (169 HPF). Our results suggest that *E. colini* embryos are capable of hatching early in response to environmental cues, and provide the first evidence of paternally induced hatching in a coral reef fish.

19.6 MAKOWICZ, A*; SCHLUPP, I; University of Oklahoma; *amber_makowicz@ou.edu*
Kin Recognition in an Asexual Fish, Poecilia formosa
Kin selection theory states that individuals should favor their kin at the cost of their own fitness when the benefits of inclusive fitness outweigh the costs. In clonal species, relatedness is high and kin selection would predict stronger selection favoring identical clones when compared to other clonal lineages. I studied this theory using the clonal fish the Amazon molly (*Poecilia formosa*). Females produce daughters that are identical to themselves and each other, and are sexual parasites to their parental species. They overlap and compete in many aspects of their ecological niche, behavioral, and life history parameters. Understanding the maintenance of sexual/unisexual species is a challenge because it violates competition theories. Behavioral differences between sexual/unisexual species may play a prominent role in allowing these species to overlap in the same ecological niche, such as aggression regulated via kinship. To test these theories, several, genetically confirmed, mono−clonal lineages of Amazon mollies were raised. Using these populations, I demonstrate that these females can recognize and prefer sister clones over non−sister clones. Familiarity was ruled out as viable explanation. Furthermore, I found that Amazon mollies could even adjust their aggressive behaviors between different clonal lineages. Together, this data suggests that Amazon mollies are able to identify identical clonal sisters and regulate their aggressiveness towards them when compared to non−sister clones and their sexual host.

P1.57 MAKRIS, P.*; WALTERS, L.J.; PHLIPS, E.J.; University of Central Florida, Orlando, University of Florida, Gainesville; *panayiotamakris@knights.ucf.edu*
Harmful Algal Blooms and Recruitment of the Eastern Oyster in a Subtropical Estuary
Harmful algal blooms caused by the marine microalga *Aureoumbra lagunensis* have been associated with fish kills as well as the loss of seagrass and benthic invertebrates in New York, Texas, and, most recently, the Indian River Lagoon (IRL) system along Florida's east coast. Within the IRL, intertidal oyster reefs comprised of the eastern oyster *Crassostrea virginica* provide important ecosystem services including habitat for commercially important fishes, erosion protection, and water filtration. To determine if blooms of *A. lagunensis* negatively impact *C. virginica*, recruitment was monitored monthly beginning in May 2013 to the present on 10 oyster reefs within Mosquito Lagoon (northern IRL). Recruitment occurred continuously from May to December 2013, resuming again in February 2014. During the 2013 warm water months of April to November, maximum recruitment occurred during October (392 ± 168 live oysters/m2) and minimum recruitment during July (80 ± 48 live oysters/m2). A one−way ANOVA showed statistical significance in 2013 oyster recruitment ($p<0.0001$) with Tukey's posthoc test indicating less recruitment during months with *A. lagunensis* present. As of September 2014, no blooms of *A. lagunensis* have been reported for Mosquito Lagoon. Additionally, salinity became more suitable for oyster recruitment in 2014 (H30 ppt) than in 2013 (>40 ppt). 2014 recruitment for the month of May (the month of peak *A. lagunensis* densities in 2013) increased by 300% from the previous year. Depressed oyster recruitment rates were associated with presence of *A. lagunensis*; however, oysters in Mosquito Lagoon settled and spat (juvenile oysters) survived under brown tide conditions.

2.4 MANAFZADEH, AR*; ANGIELCZYK, KD; Univ. of California, Berkeley, The Field Museum; *armita@berkeley.edu*
Morphological integration in the mandibles of living reptiles and fossil synapsids
The co−option of mammalian middle ear ossicles from the postdentary jawbones of their ancestors is a classic example of exaptation, and is documented in the fossil record by a number of "transitional forms." Over the course of synapsid evolution, the articular and quadrate bones migrated from the jaw joint into the middle ear where they function as part of an impedance−matching system for hearing airborne sound. The angular bone evolved into the ectotympanic, which supports the tympanic membrane, and the other postdentary bones were reduced and lost. On the contrary, sauropsids retained a full complement of postdentary bones. Despite an increase in studies of the capacity of systems to evolve, the potential influence of modularity as a precursor for evolvability in this transition has not been investigated. To explore this possibility, we collected two−dimensional landmark−based morphometric data from mandibles of 446 living reptiles across a wide range of families, as well as a fossil synapsid test case, to examine whether all the bones of the mandible form a single integrated unit or if subgroups of bones form distinct modules. We then used the RV coefficient to test the *a priori* hypothesis of dentary versus postdentary modularity. We did not find a strong signal of modularity for all modern reptiles. However, modularity is apparent in some clades (Lacertilia and Serpentes), likely correlated with jaw kinesis. Comparison with fossil synapsids proved difficult, with findings biased towards high levels of integration due to the effects of preservational artifacts. While our results do not allow for a prediction of the basal character state for sauropsids, evidence of modularity in some squamates demonstrates that the modularity we predict for synapsids is not unprecedented among amniotes.

S8.10 MANEY, Donna L.*; ZINZOW−KRAMER, Wendy M.; Emory University; *dmaney@emory.edu*
Estrogen Receptor Alpha: A Mediator of Life History Trade−offs?
In many vertebrates, tradeoffs between competitive and parental strategies are well−understood to be mediated by sex steroids. Disruptive selection leading to alternative behavioral strategies may thus act on the mechanisms underlying steroid signaling and metabolism. White−throated sparrows exhibit two color morphs with different responses to territorial intrusion; white−striped (WS) birds sing more than tan−striped (TS) birds. Although WS males have higher levels of plasma testosterone (T) and estradiol than TS males, experimental equalization of these hormones does not abolish morph differences in singing. We recently showed that the expression of estrogen receptor alpha (ER±) in the brain, which could confer sensitivity to sex steroids, differs between the morphs and may drive the behavioral polymorphism. First, the ER± promoter region contains fixed polymorphisms that affect transcription efficiency *in vitro*. Second, in a free−living population, local expression of ER± depends strongly on morph and predicts territorial singing. Differential ER± expression is particularly striking in the medial amygdala; WS birds have three times more ER± mRNA than TS birds. This difference persists during the non−breeding season and is unaffected by exogenous T treatment. Finally, weighted gene co−expression analysis of the medial amygdala identified one module of genes significantly correlated with both morph and song. Within this module, the gene most highly correlated with territorial singing was ESR1, which encodes ER&alpha. Together, these results suggest that ER± plays a pivotal role in territorial displays and may be a target of disruptive selection leading to alternative behavioral strategies. Our future directions include a more detailed analysis of the ER± promoter regions to determine the molecular basis of differential expression.

P3.98 MANGER, MA*; GARDELL, AM; BUCK, CL; VON HIPPEL, FA; PETERSEN, AM; CRESKO, WA; POSTLETHWAIT, JH; Georgetown University, Washington, DC, University of Alaska, Anchorage, University of Oregon; *mam525@georgetown.edu*
The effects of perchlorate, iodide and thyroid hormone on the kidney and gonad morphology of the threespine stickleback
Perchlorate is a contaminant and endocrine disrupting compound found throughout the United States that affects the production of thyroid hormone and thyroid morphology as well as sexual development in many species including the threespine stickleback (*Gasterosteus aculeatus*). We investigated the effects of perchlorate, iodide (I^-) and thyroxine (T_4) on the kidney and gonad morphology of stickleback. Following fertilization, fish were chronically exposed to nine treatments with three perchlorate concentrations (0, 10, 100 ppm) and three supplementation options (no supplement, I^-, or T_4). Fish were euthanized, fixed, sectioned and stained in order to perform histology measurements. The area and epithelial cell height of the kidneys were measured as was the testis area and stage and the number of oocytes per stage. We found that hypertrophy in the kidney caused by perchlorate was prevented by both exogenous I^- and T_4, although I^- exerted a stronger effect. For the gonads, we found that T_4 led to testis hypertrophy, and that oocyte development was delayed by perchlorate. These results suggest that effects of perchlorate are mediated through the thyroid, however, since iodide exerted stronger effects than T_4 and oocyte development was not ameliorated by either supplement, it is possible that although the main pathway through which perchlorate functions is thyroidal, crosstalk with other endocrine axes, such as the hypothalamus−pituitary−gonadal axis, is also causing effects in the gonads and kidney. Future work should further investigate this possible crosstalk by analyzing the levels of thyroid and sex hormones (including estrogens, androgens, and aromatase) in relation to perchlorate.

P2.93 MANLEY, RD; New College of Florida;
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Visually Mediated Behaviors of the common mantis shrimp, P. ciliata

The eyes of the stomatopods incorporate the largest variety of visual color spectra in the animal kingdom to date. Previous studies have indicated that stomatopods have up to 16 different photoreceptors, 12 of which are for separate spectrum detection. *Pseudosquilla ciliata*'s behaviors are well studied and documented. Observational data are used in the determination of whether the visual system in *P. ciliata* is crucial in the completion of various behaviors. Behaviors tested include territorial aggression, prey detection, courtship, predator avoidance, and shelter creation. Using the base behaviors displayed, the subjects were then filmed using an infrared camera to determine if the behaviors were similar before and after the visual system was eliminated.

36.1 MANN, WT*; BRINKHUIS, V; MYDLARZ, LD; University of Texas Arlington, Florida Fish and Wildlife;
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Characterization of a new disease in the gorgonian coral Eunicea calyculata

Outbreaks of disease in marine organisms have become more prevalent over the past decades. This has been especially true in both hard and soft corals. Understanding the etiology of these diseases is important when directing conservation efforts and preservation of coral reefs. One of the most recent epizootics occurring affects the soft coral species, *Eunicea calyculata* and is causing large scale mortality among populations in the Florida Keys, Miami, and West Palm Beach reefs of Florida. Current efforts are aimed at identifying a potential pathogen and the main immunological responses occurring with this disease. In this presentation, we focus on the host immune response. Using biochemical immunoassays and transcriptional analyses we demonstrate significant changes in several immune parameters. Most notably, there was significant increase in melanin and antioxidant activity in diseased colonies versus healthy. To our knowledge, this is one of the first studies to examine the immune responses in the *Eunicea*genus as well as being the first transcriptional study of *Eunicea*. Recent survey data indicate that this disease is more prevalent in shallower waters and may be driven by the presence of environmental stressors such as elevated temperatures and/or excess UV irradiation. Therefore, further study of this disease system can contribute greatly to our understanding of how environmental stressors affect the immunocompetence of corals.

P1.64 MANZO, W.*; RIVIE, A.; MENON, J.; William Paterson University; *menonj@wpunj.edu*

A Tale of Oxidative Stress: Regression versus Restoration of the tail in tadpoles, Xenopus laevis

Xenopus laevis is a model system widely used to investigate metamorphosis, tail regeneration and regression. Aspects related to tail regeneration and regression are among the most interesting as both the processes are opposed to each other. In the present study we have investigated the role of reactive oxygen species (ROS) with emphasis on nitric oxide (NO) in both these processes. Our results on in situ staining for ROS show that during early stages of metamorphosis, tail fin showed presence of ROS in moderate amount reaching its peak in climax period. Just before the tail starts regressing, large amount of ROS were noted especially in the epidermal cells of the fin. Further increase in ROS in fin epidermal cells occurs once the regression had begun. In situ staining for mitochondrial derived NO in tail showed an increasing trend with metamorphic progress. Crucial role of fin epidermis in the process of tail regression is well established. Western blot results show decrease in expression of SOD and catalase as metamorphosis progressed indicative of lowered antioxidant defenses. In contrast, staining for ROS in the regenerate is much stronger than NO. Western blot results show increase in SOD but steady expression for catalase in regenerating tail compared to un−amputated tail during different stages of metamorphosis. This indicates increase in hydrogen peroxide as a salient feature of regeneration. It is possible that high levels of super oxide and hydrogen peroxide may inactivate NO. Thus, it appears that ROS signaling is vital to both the processes which may modulate signaling but disparity in type of ROS produced characterize subtle differences between regression versus restoration of the tail.

47.2 MARCOS, C C*; PEARSON, L E; BURNS, J M; LIWANAG, H E M; Adelphi University, Univ. of Alaska, Fairbanks, Univ. of Alaska, Anchorage; *candicemarcos@mail.adelphi.edu*

From ice to ocean: thermal function of harp seal fur in water

Pinnipeds (seals, sea lions, walrus) are a unique group of mammals that feed in the ocean but return to land for breeding and molting. Harp seals (*Pagophilus groenlandicus*) live in the frigid Arctic and rely on thick insulation to maintain thermal homeostasis. Adult harp seals primarily use blubber for insulation, but newborn harp seals rely on a fur coat as their blubber layer develops. After harp seal pups are weaned at 12 days old, they must learn to swim and dive in Arctic waters on their own. This study examined ontogenetic changes in the thermal properties of harp seal fur in water. Thermal conductivity, thermal resistance, and fur thickness were compared in air and water for pelts of harp seal neonates (1d old, N=7), thin whitecoats (4d old, N=3), fat whitecoats (9d old, N=4), molting pups (2w old, N=4), molted pups (3w old, N=5), and adults (N=4). Fat whitecoat pelts had significantly higher thermal conductivity in air ($P<0.001$), whereas thin whitecoat pelts had significantly higher thermal conductivity in water ($P=0.014$). Thermal resistance of the pelt in air decreased with age ($P<0.001$), with a significant reduction just prior to the molt. Thermal resistance of the pelt was significantly reduced in water compared to air, across age classes ($P<0.001$). In older pups and adults this decrease in thermal function was balanced by a thick blubber layer. The lanugo hairs of pre−molt pups increased in height rather than flattening underwater, a phenomenon that has never been reported. This unusual occurrence may create a buffer in water, similar to a wetsuit. Overall, fur represents an important component of thermoregulation for harp seal pups on land, whereas the development of a thick blubber layer is key to their transition to a predominantly aquatic lifestyle.

89.1 MARION, ZH*; CAMPANGA, SR; TESTER, A; FORDYCE, JA; FITZPATRICK, BM; Univ. of Tennessee, Knoxville; *zmarion@utk.edu*

Species identity and life−history explain chemical defense complexity in North American fireflies

Fireflies (Coleoptera: Lampyridae) are a diverse family of beetles best known for their bioluminescent mating displays. Fireflies are also chemically defended with complex blends of cardiotoxic steroids called bufadienolides or lucibufagins, yet the chemistry of only a few species has been described. Here we describe the diversity and complexity of the chemical defenses for ten North American firefly species collected from Tennessee and Pennsylvania. Whole body extracts were analyzed via liquid chromatography−mass spectrometry (LC−MS). We quantified both qualitative and quantitative aspects of the chemical variation using traditional multivariate approaches and a novel method we developed to hierarchically partition phenotypic complexity. For the first time, we show that much of the variation in firefly chemistry can be attributed to species identity and lifestyle strategy (i.e., bioluminescent vs. pheromonal signaling vs. aggressive mimicry).

P2.181 MARMOL−GUIJARRO, AC*; TORRES−CARVAJAL, O; Pontificia Universidad Católica del Ecuador, Quito−Ecuador; *adcamagu@gmail.com*

Clinging ability in ecuadorian anoles. A case study of mainland vs. island evolution.

Anolis lizards offer a great opportunity to study how evolutionary processes take place in mainland and island faunas. These two groups often show differences in behavior, morphology, and life history. Previous studies have shown that Caribbean anoles have proportionally bigger toe pads than mainland anoles, and that clinging ability is directly related to perch height and toe pad area. The present study focused on the functional relationship of clinging ability with toe pad area and perch height in seven mainland anole species from Ecuador. Contrary to what has been observed in Caribbean taxa, our results showed that toe pad area and perch height have no significant influence in clinging ability. These findings suggest that different traits affect clinging ability in mainland and island taxa. Our results also support the idea that mainland anole populations suffer different evolutionary pressures than Caribbean anoles. Further information on how toe pad microstructures work is necessary to understand clinging ability.

P1.51 MARQUES, E*; ROSSI, T; University of North Florida; *e.marques@unf.edu*

Effects of the red imported fire ant (Solenopsis invicta) on the growth and survival of the threatened hooded pitcher plant (Sarracenia minor)

Carnivorous plants are found all across the world and have evolved various adaptations for capturing and consuming their prey. It has been hypothesized that carnivory in plants has evolved independently six times primarily due to a lack of nutrients in the environment. However, recent research has shown that other selective pressures such as the need to defend against herbivory may also contribute or have greater strength in directing these plants towards carnivory. In this study, we look at the interaction between the exotic *Solenopsis invicta* (RIFA) and the threatened *Sarracenia minor* (hooded pitcher plant). We are specifically looking at RIFA because it is a highly aggressive exotic species found throughout the southern half of North America. RIFAs aggression is much higher than native ants, which may lead to RIFA having a more robust impact on deterring herbivores from the host plant. We are testing to see if RIFA has an effect on the growth and survival rate of the hooded pitcher plant by conducting a manipulated field study, where the presence of RIFA is excluded or included in the environment of the hooded pitcher plant. Measurements currently being taken include pitcher mortality, pitcher height and width, proportion of pitchers with herbivory present, and the capture rate of *Solenopsis invicta*. This data will provide some insight if multiple selective pressures caused by *Solenospsis invicta* are acting upon *Sarracenia minor* and it will also give an understanding into what organisms are beneficial to have around the threatened plant to prevent its extinction, even exotics such as RIFA.

P3.102 MARSHALL, CD*; CULLEN, JA; AL ANSI, M; DUPONT, J; Texas A and M University, Qatar University, ExxonMobil Research Qatar; *marshalc@tamug.edu*

Iconic Marine Vertebrates of the Qatari Arabian Gulf: Preliminary Data on Sea Turtle and Dugong Morphometrics, Movement, and Strandings

The marine environment of Qatar is ideal for supporting large populations of dugongs and sea turtles. In fact, Arabian dugongs (*Dugong dugon* constitute the world's 2nd largest population. However, little is known regarding their natural history in the region. Therefore, we have begun collecting life history data that will provide information to wildlife managers within Qatar. Dugong work focused on beach surveys for stranded animals where we collected morphometrics, determined gender, and collected tissues for reproductive staging and genetic analyses. Dugongs range from Saudi Arabia to the UAE. The region between Qatar and Bahrain has been reported as particularly important for dugongs. Our data shows a high frequency of strandings on the northwest Qatari coast and supports this observation. All strandings have been female, including one pregnant dugong. Longer−term studies have been ongoing in the region on hawksbill (*Eretmochelys imbricata*) and green sea turtles(*Chelonia mydas*). Turtles were captured, fitted with satellite tags and released after morphometrics and tissue were collected. Morphometrics of mature hawksbill sea turtles suggest they are among the smallest of their species worldwide. Hawksbills use both coastal and shallow offshore habitats throughout the southern Arabian Gulf. Green sea turtles were young juveniles, stayed within coastal waters, and are likely using Qatar as developmental habitat. Interestingly, sea turtle telemetry suggests a strong affinity of sea turtles for this same area off the Qatari northwest coast that is known to be important for dugongs. This region may be a hotspot for both sea turtles and dugongs and warrants further investigation.

P1.18 MARSON, KM*; MILLER, G; BARRON, E; EARLEY, RL; Univ. of Alabama; *krismars02@yahoo.com*

Reproductive timing varies seasonally and geographically in mangrove rivulus fish

Seasonal environments exert strong selection on reproductive timing. Certain seasons may preclude investment in gametes, limit fitness returns of such investment, or provide favorable conditions for reproduction. Seasonality and reproductive timing might interact to drive selection on processes like developmental plasticity and phenotypic flexibility, which mediate fitness in variable environments. The mangrove rivulus fish (*Kryptolebias marmoratus*) is a self−fertilizing hermaphrodite that exhibits remarkable phenotypic plasticity and flexibility and exists from tropical to temperate climates. We conducted field and laboratory studies to investigate variation in reproductive timing among populations that experience varying degrees of seasonality. We hypothesized that selection would drive local adaptation in reproductive timing, with restricted reproduction in populations from highly seasonal environments and year−round reproduction in populations from less variable environments. Rivulus are being collected from nine populations in Florida and at four seasonal intervals for two consecutive years. Reproductive status has been determined by the presence/abundance of vitellogenic eggs in the gonad. Also, 398 distinct rivulus genotypes derived from 53 populations spread across their geographical range have been housed under common garden conditions. Fecundity was assessed for each genotype each week for over one year. We found different patterns of reproductive seasonality across major geographical regions. Retention of seasonality in the laboratory supports the hypothesis that selection has driven local adaptation in reproductive timing. This research establishes a foundation for generating predictions about the relative fitness advantages of developmental plasticity and phenotypic flexibility in rivulus populations.

P2.200 MARTIN, G/G*; BAILEY, A; COHEN, S; Occidental College; *gmartin@oxy.edu*

Morphology and Functional Properties of the Skin covering the Giant Keyhole Limpet, Megathura crenulata.

The giant keyhole limpet *Megathura crenulata*, is a marine gastropod of commercial interest because its blood contains the respiratory pigment Keyhole Limpet Hemocyanin (KLH), which is the focus of clinical trials hoping to capitalize on its ability to stimulate our immune system to help fight cancer. We are using the giant keyhole limpet as a model marine gastropod to address the effectiveness of the skin and associated mucus layer in providing protection against microbial infections. By "skin" we refer to the simple columnar epithelium that covers the foot, the sidewall of the foot and the inner and outer surfaces of the mantle. We will present morphological descriptions of the cells making up the epithelium including ciliated cells (only abundant on the foot), pigmented cells (containing carotenoids on the foot and melanin in other locations), and secretory cells (both epithelial and sub−epithelial) which differ at each location. The lack of cilia at locations other than the foot indicates that the mucus layer does not behave like the mucus involved in airway clearance in vertebrates. The variety of secretory cells and differences in the physical properties of the released mucus on the foot and other regions is reflected in different abilities of the mucus to bind foreign bacteria and other foreign particles.

S6.7 MARTIN, LB*; LIEBL, AL; University of South Florida, University of Exeter, Cornwall; *lbmartin@usf.edu*

The role of glucocorticoids on range expansion behaviors in Kenyan house sparrows

Traits that mediate vertebrate range expansions are only just being revealed, and such information may help mitigate the negative impacts of pest species on native communities as well as the challenges of global climate change on the distributions of endemics. Here, we summarize recent work we have conducted on the house sparrow (*Passer domesticus*) in Kenya. The species was introduced about 1950 to the coastal city of Mombasa, but has since spread across much of the country. We have found that range expansion was apparently mediated by adjustments in the regulation of the stress hormone, corticosterone, and the receptors integral to its effects (glucocorticoid (GR) and mineralocorticoid (MR)). Moreover, we have found that variation in stress hormone regulation is related to variation in behaviors relevant to range expansion. Birds at the range edge release much more corticosterone in response to restraint, and they are also much more exploratory, less neophobic (or more neophilic), and better able to consolidate (spatial) memories than birds from older sites; intriguingly though, birds at range edges are less innovative than birds from old sites. To discern whether these patterns are due directly to circulating corticosterone, we implanted individuals from one old, one new and one intermediate site with either a high or a low dose of corticosterone or a sham control, and assessed effects of the steroid treatments on some of the above behaviors. Analyses are still ongoing, but preliminary analyses indicate weak effects of corticosterone on behaviors, suggesting that any effects of this hormone might be correlated to behavior for unknown reasons or organized early in life.

103.6 MARTIN, K.L.M.*; QUACH, V.V.; PIERCE, E.R.; Pepperdine Univ., Malibu, CA; *kmartin@pepperdine.edu*

Effects of Animal Predators and Human Hunters on Runs of a Beach−Spawning Fish

Famous for unique spawning behavior, California Grunion *Leuresthes tenuis* surf onto sandy beaches to lay eggs out of water. This endemic silverside fish, found only off California and Baja California, shares critical spawning habitat with millions of beach goers along one of the world's most heavily populated coastlines. Spawning occurs during spring and summer, the times of heaviest human use. Although regulations offer some protection, anthropogenic impacts include a recreational fishery with bare−handed catching. Natural predators from land and sea prey on the distracted fish flopping on shore. The stock cannot be assessed with traditional fisheries methods, so evaluation of population status and trends is difficult. For over a decade, the spawning runs have been monitored across the habitat range with the help of citizen scientists, the Grunion Greeters. Greeters provide evaluation of the runs and other ecological features, including the incidence of animal predation and recreational fishing on the runs. Within this long term dataset, we compared runs with and without natural predators, and with and without human hunters. We found that humans disturbed the runs more than animal predators did, and that the number of humans chasing fish can be far higher than the number of natural predators at a beach during the run. In the presence of active human hunting, runs were smaller, although human observation without attempts to catch fish did not appear to disturb the runs. Highly efficient human hunting sometimes removed every fish that appeared on shore, in effect stopping the run and preventing any successful reproduction. Additional conservation efforts may be necessary, including catch−and−release and no−take reserves, to protect this vulnerable endemic species from overharvest.

S8.8 MARUSKA, K.P.; Louisiana State Univ.; *kmaruska@lsu.edu*
Social transitions cause rapid behavioral and neuroendocrine changes
In species that form dominance hierarchies, there are often opportunities for low−ranking individuals to challenge high−ranking ones, resulting in a rise or fall in social rank. How does an animal detect, process and then respond to these social transitions? The African cichlid fish, *Astatotilapia burtoni*, provides an ideal model to examine how changes in social rank rapidly impact an individual's behavior, physiology, and brain. Males form hierarchies where a few brightly colored dominant males defend territories and spawn with females, while the remaining males are subordinate, drab colored, do not hold a territory, and have minimal reproductive opportunities. These social phenotypes are plastic and reversible, meaning that individual males may switch between dominant and subordinate status multiple times within a lifetime. When the social environment is manipulated to create males that either ascend (subordinate to dominant) or descend (dominant to subordinate) in rank, there are rapid changes in behavior, circulating hormones, and gene expression levels in the brain that reflect the direction of transition. For example, within minutes, males ascending in status show bright coloration with a distinct eye−bar, increased dominance behaviors, higher plasma levels of sex−steroids and gonadotropins, and activation of brain nuclei in the social behavior network. These males also show rapid changes in neuropeptide and steroid receptor levels in the brain, as well as in the pituitary and testes. Also within minutes, descending males show faded body coloration, decreased dominance behaviors, increased subordinate behaviors, and higher circulating levels of cortisol. Collectively, this work highlights how the perception of similar social cues that are opposite in value are rapidly translated into adaptive behavioral and neuroendocrine changes to promote survival and reproductive fitness.

P2.158 MASSEY, JL*; TULENKO, FJ; DAVIS, MC; Kennesaw State University; *mdavi144@kennesaw.edu*
Muscle Formation during Paired and Unpaired Fin Development in the American Paddlefish Polyodon spathula
The formation of a functionally integrated musculoskeletal system is one of the fundamental aspects of vertebrate development. In mouse and chick model systems, much work has been done to characterize the formation of appendicular musculature. These studies demonstrate that myogenic precursor cells express the transcription factor *Pax3* and its downstream targets *Lbx1* and *c−MET*, delaminate from pectoral and pelvic level somites, and undergo a long range migration into the limb buds where they mix with lateral plate derived connective tissue. Once in the limb buds, these muscle precursor cells upregulate the myogenic regulatory factors *MyoD* and *Myf5*, and differentiate into mature myofibers. Notably, a migratory mode of muscle formation has been demonstrated during paired fin formation in teleosts, and appears to be a conserved feature of osteichthyans. Median fins predate the appearance of paired fins in the fossil record, and in extant taxa express many of the same genes that pattern limb buds. Together, these paleontological and molecular data have fueled the hypothesis that the early evolution of paired fins involved the redeployment of pre−existing developmental programs from the midline to the flank. Here we use antibody labeling and *in−situ* hybridization to characterize the expression of *Pax3/Pax7, Lbx1, c−MET,* and myogenic regulatory factors during muscle formation in the paired and unpaired fins of the American paddlefish *Polyodon spathula*, a basal actinopterygian. We use these data to generate new hypotheses about the conserved, core genetic machinery underlying appendage muscularization in vertebrates and discuss potential avenues of future investigation to test these hypotheses.

P2.19 MATSUDA, SS*; GOSLINER, TM; California Academy of Sciences, San Francisco; *smatsuda@calacademy.org*
Slug life: Chemical defense and phylogenetic analysis of Glossodoris nudibranchs
Glossodoris nudibranchs (Mollusca: Gastropoda: Opisthobranchia: Chromodorididae) are brightly colored sea slugs that derive their toxic chemical defenses from their sponge prey. Sesterterpenoid compounds exhibit a wide range of biological properties that aid in organism defense including cytotoxicity, anti−microbial, and ichthyotoxicity. Nudibranch tooth morphology has traditionally been used for taxonomic classification, but with recent advances in molecular systematics, many of these relationships have changed. A recent mitochondrial phylogeny of the Chromodorididae revealed the genus *Glossodoris* to be polyphyletic. In this study, 50 individuals comprising 18 taxa were used to build a more robust phylogenetic tree of *Glossodoris*. Molecular phylogenetic analyses were performed on three loci: mitochondrial COI (658 bases), mitochondrial 16S (edited: 465 bases), and nuclear 28S (edited: 851 bases). Maximum likelihood and Bayesian statistical analyses verify the previously hypothesized evolutionary relationships within *Glossodoris*. Morphological analysis of mantle dermal formations, radular structures, and reproductive systems were used to confirm the molecular phylogeny. Additionally, preexisting chemical data has been amassed and will be used to determine if more closely related *Glossodoris* share chemical profiles. These results provide insight into the evolution of chemical defense sequestering in nudibranchs and allow for a deeper understanding of coevolution and prey choice of *Glossodoris* nudibranchs.

92.1 MATSUDA, SS*; GOSLINER, TM; California Academy of Sciences, San Francisco; *smatsuda@calacademy.org*
Slug it out: A cryptic species complex emerges from within Glossodoris cincta
Chromodorid nudibranchs are brightly colored sea slugs that live in some of the most biodiverse and threatened coral reefs on the planet. These sea slugs' vibrant colors can serve as a warning signal to predators of their toxic chemical defenses, or allow the slugs to blend seamlessly into their surroundings. Nudibranchs in the genus *Glossodoris* (Mollusca: Gastropoda: Opisthobranchia: Chromodorididae) exhibit diverse color patterns and are a model group for examining the evolution of color pattern and shape. However, a recent mitochondrial phylogeny of the Chromodorididae revealed *Glossodoris* to be polyphyletic. In this study, 50 individuals comprising 18 taxa were used to build a more robust phylogenetic tree of *Glossodoris* and related clades. Molecular phylogenetic analyses were performed on mitochondrial genes COI and 16S, and nuclear gene 28S. Maximum likelihood and Bayesian statistical analyses were conducted to support the hypothesized evolutionary relationships within *Glossodoris*. Molecular and morphological data reveal a cryptic species complex within *Glossodoris cincta*, with distinct species arising from the Indo−Pacific and the east coast of Africa. Next steps include morphological analysis of radular structures and reproductive systems to confirm the distinct new species. *Glossodoris cincta* are large, common nudibranchs with a widespread range. The molecular identification of cryptic species allows for the recognition of subtle variations in color pattern and external characters that will help with in−field identifications. The discovery of cryptic species within *Glossodoris cincta* accentuates the likelihood that more undescribed species are hiding within previously defined taxa; this has strong implications for color pattern evolution, the evolution of chemical defense sequestration, and biomedical prospecting.

P3.121 MATTERSON, K.O.*; EASSON, C.G.; THACKER, R.W.; Univ. of Alabama at Birmingham; *kenanm@uab.edu*

Variable impact of top−down forces and photosymbiont−derived nutrition on Caribbean shallow−water sponges

Recent evidence suggests that top−down factors (predation) primarily determine the diversity and abundance of sponges in reef environments. In the Caribbean, one−third of the dominant sponge species host high densities of photosynthetic cyanobacteria, with some sponges deriving significant nutritional benefit from this symbiosis. To test whether these symbioses play a role in structuring sponge communities, we examined the interactive effects of predation and irradiance on the growth of 6 sponge species. Sponges were held in a two−factor field experiment that manipulated irradiance and predation *in situ* for 6 weeks. Sponges hosting high densities of photosymbionts had significantly lower growth and cyanobacterial abundance under reduced irradiance irrespective of the presence of predators, indicating that shading had a greater impact on holobiont biomass than predation. In contrast, sponges lacking cyanobacteria displayed significantly reduced growth in uncaged treatments, supporting the contention that top−down forces influence growth of some sponge species. *Neopetrosia rosariensis*, which hosts high densities cyanobacterial symbionts, demonstrated higher growth rates under shaded conditions when predators were excluded than in uncaged treatments, suggesting that an interactive effect of irradiance and predation can influence growth. These results suggest that sponge communities in the Caribbean are likely structured by multiple factors varying in importance among species, and highlight the necessity of examining multiple ecological variables in combination when examining the forces that structure communities.

P1.84 MAURO, A/A*; JAYNE, B/C; Claremont McKenna College, University of Cincinnati ; *amauro15@cmc.edu*

branch compliance and experience affect perch choice in brown tree snakes, BRANCH COMPLIANCE AND EXPERIENCE AFFECT PERCH CHOICE IN BROWN TREE SNAKES

Animals live in complex environments, and the effects of environment on behavior are important for understanding their ecology. An essential step in gaining this understanding is examining how animals sense and respond to environmental cues. Branches in natural arboreal habitats pose discrete choices and differ in their size, which is often correlated with mechanical properties such as stiffness. Although brown tree snakes (Boiga irregularis) are known to use visual cues to choose between perches, the effects of branch stiffness on perch choice are unknown. Hence, we used cylinders with V−shaped arrays of pegs to test whether the brown tree snakes preferred artificial branches with variable diameters and compliance. We also used a repeated measures procedure to test if perch preference was altered by experience over the course of six days. When all perches were rigid and the overall width of the V−shape was constant, the snakes had no preference based on the diameters of the cylinders and pegs. By contrast, after two days snakes developed and maintained a preference for larger rigid perches rather than the compliant perches with smaller diameters. However, this preference for larger diameter perches did not persist after both perches were made rigid again. This suggests that the snakes were not able to associate rigidity (a tactile sensation) with perch diameter (a visual cue). A touching behavior, in which the snakes repeatedly tapped the compliant perch, emerged when the snakes were exposed to the compliant perch, but this was exclusive to interactions with the compliant perch. Hence, our results show that the snakes sampled their environment more when interacting with compliant perches. Overall our study shows that perch compliance alters the behavior of Boiga irregularis.

S4.5 MAYER, G; University of Leipzig, Germany; *gmayer@onychophora.com*

Prey capture, feeding and functional anatomy of jaws in velvet worms (Onychophora)

Onychophorans (velvet worms) are carnivorous, terrestrial invertebrates that occur in tropical and temperate forests of the southern hemisphere and around the equator. Together with tardigrades (water bears), onychophorans are regarded as the closest relatives of arthropods. One of the most peculiar features of onychophorans is their hunting and feeding behavior. The animals use a sticky slime secretion, which is ejected via a pair of slime papillae, to entangle their prey, such as soil−dwelling invertebrates. After the prey has been immobilized, its cuticle is punctured using a pair of jaws that are internalized appendages of the second head segment. The jaws are innervated by the deutocerebrum and, thus, homologous to the chelicerae of chelicerates, and the (first) antennae of myriapods, crustaceans and insects. They might be serial homologs of the paired claws associated with each walking limb of the trunk. The structure of the jaws is similar in representatives of the two major onychophoran subgroups, the Peripatidae and Peripatopsidae. Each jaw is characterized by an outer and an inner blade; while the outer blade consists only of a large principal tooth and up to three accessory teeth, the inner blade bears numerous additional denticles that are separated by a diastemal membrane in peripatids. The onychophoran jaws are associated with large apodemes and specialized muscles that enable their movement. In this talk, I review our current knowledge on the onychophoran jaws and provide some new insights into their composition.

4.4 MAYERL, CJ*; RIVERA, G; BLOB, RW; Clemson Univ., Creighton Univ.; *cmayerl@clemson.edu*

Swimming function in pleurodiran turtles: hydrodynamic stability and a novel gait

Novel structures have been found to convey strong functional consequences in a variety of taxa. We examined the functional significance of the fusion of the pelvis to the plastron (the ventral portion of the shell), a feature unique to pleurodiran turtles. Pleurodires are one of the two extant groups of turtles, and while Cryptodires (the other extant taxa) have invaded a variety of terrestrial and aquatic habitats, nearly all pleurodire species are highly aquatic. As with all aquatic animals, they are thus subject to a myriad of potentially destabilizing forces while swimming, resulting in both rotational (pitch and yaw) and translational (heave and sideslip) movements. These motions can decrease locomotor performance, making their minimization advantageous. We hypothesized that pelvic−plastral fusion in pleurodires might improve lateral stability by reducing potential movements of the girdle relative to the shell. We used high−speed video to compare hydrodynamic stability during swimming between a pleurodiran turtle (*Emydura subglobosa*) and previously collected data from a cryptodiran species (*Chrysemys picta*) which lacks pelvic−plastral fusion. Data were collected at similar size−normalized speeds. We found that, as predicted, extraneous lateral movements (slideslip and yaw) are reduced in pleurodires. Moreover, while pleurodires and cryptodires experience similar pitch, pleurodires exhibit lower heave. We also observed *E. subglobosa* perform a novel gait among turtles, in which it would periodically use synchronous extension of both fore and hind limbs, producing movements that resemble an underwater gallop'. Our data indicate that pleurodiran swimming may differ from that of cryptodires in a variety of parameters, which may relate to the novel pelvic construction of this group.

13.7 MAZOUCHOVA, N*; HSIEH, ST; Temple University; *nmazouch@gmail.com*

Water depth influences dynamic similarity and locomotor mode in semi−aquatic turtles

Many legged animals regularly transition between aquatic and terrestrial environments. While on land, limbs must bear the entire weight of the body; however, when moving at different water depths, body weight is buoyed by the surrounding fluid. In simulated reduced gravity conditions, during which the limbs support only a portion of the body weight, humans do not move in a dynamically similar manner. Here we test whether dynamic similarity principles apply across size and water depths in turtles. We hypothesize that similarly−sized turtles will not move dynamically similarly across different submersion levels, but that turtles of different size will move in a dynamically similar manner at similar water depths. To address these hypotheses, we filmed eleven semi−aquatic red−eared slider turtles (*Trachemys elegant scripta*) grouped into three size classes: small, medium and large (mass: 6.2 − 106.8 g, carapace size: 3.0 − 9.8 cm) while moving in different water depths: 0% (terrestrial), 25% (below plastron), 75% (half of carapace) and 100% water (fully submerged). Turtles within the same size class did not move in a dynamically similar fashion at different water depths (duty factor: $p<0.001$: mixed−model ANCOVA). At similar Froude numbers only the medium and large turtles moved dynamically similarly for 0 and 25% submergence, whereas at 75% submergence all size classes moved in a similar fashion. At 100% submergence, differences in stride frequency and duty factor revealed three distinct locomotor modes: swimming, bottom walking, and hindlimb pushing. These results show that dynamic similarity is largely preserved between different size classes within each water depth, except when the turtles are fully submerged.

76.5 MCALISTER, J/S*; GARCIA, E; CLEMENTE, S; HERNANDEZ, J/C; College of the Holy Cross, Universidad de La Laguna; *jmcalist@holycross.edu*

Egg composition and larval development of Diadema africanum from the Canary Islands: adaptations for oceanic drifting

The Canary Islands, located 100−400 km off the coast of northwest Africa, sit astride a geological hotspot amid a temperate/subtropical convergence zone. Across the archipelago, coastal waters vary in the amount of upwelled nutrients, primary productivity, and temperature, providing a unique natural experiment for examining the effects of environmental change on marine organisms. *Diadema africanum* is a newly described sea urchin species that had been considered an eastern Atlantic Ocean population of *Diadema antillarum*. In the Canaries, *D. africanum* adults play a major ecological role in the production of urchin barren habitats. In order to determine basic life−history characters for this species, we collected and spawned adults in the laboratory, preserved eggs for biochemical composition analysis, and reared larvae through to metamorphosis. We will discuss the results of egg protein, lipid, and carbohydrate assays and highlight larval developmental features. We will compare our results with similarly obtained data for other Diadematids and consider how the egg and larval characteristics of *D. africanum* may have evolved to facilitate long−distance oceanic drifting.

P1.148 MCBRIDE, S.A.*; KROGMAN, W.L.; WATSON, C.M.; Midwestern State University; *sarah.mcbride@mwsu.edu*

Optimal Feeding Frequency in the Corn Snake, Pantherophis gutattus

Snakes generally have evolved to eat relatively large prey items whole on an infrequent basis. Therefore, they tend to up−regulate their metabolism and digestive mechanisms just after a feeding event and then down−regulate once they have completed digestion. Animals in captivity are often fed on a set schedule, but in the wild feeding frequency is closely associated with prey availability. We hypothesize that snakes will more efficiently digest their prey when it is fed less frequently and may be less efficient when prey is readily available. In order to determine if snakes adjust their digestive efficiency to match feeding frequency (as a proxy for prey availability) we fed three experimental groups of corn snakes (*Pantherophis guttatus*) and rat snakes (*Pantherophis emoryi*) at different frequencies while keeping the total percentage of their body mass consumed constant. We then determined caloric content of the prey item and the feces associated with each feeding event. We find that corn snakes grow at a faster rate when fed once a week and no experimental group exhibits a difference in digestive efficiency. Because digestive efficiency remains constant while growth rate is generally curvilinear in respect to feeding frequency, an optimal feeding frequency exists for this species. Future studies will investigate this phenomenon with other species that exhibit different natural feeding frequencies.

P3.173 MCCABE, KM*; STAAB, KL; McDaniel College; *kmm005@connections.mcdaniel.edu*

How to build an intramandibular joint: the construction of Meckel's cartilage in Poecilia spp. during ontogeny

Teleosts typically have a lower jaw comprised of three fused bones: the dentary, angular, and articular. However, several unrelated teleosts have an independently derived "extra" joint between the angular and dentary: the intramandibular joint (IMJ). This decoupling of bones allows the dentary to rotate about the angular, allowing for a wider gape. Little is known about the evolution of the IMJ or its ontogenetic construction, though the Meckel's cartilage is the foundation of the joint. *Poecilia spp.* possess an IMJ, thus we studied the development of the jaw in *Poecilia* larvae to hypothesize the evolutionary construction of the IMJ. Specifically, we focused on the developmental changes to Meckel's cartilage. If Meckel's cartilage is the foundation for the IMJ, then ontogenetic changes in it could be an indicator of how the IMJ is constructed. Importantly, the cellular morphology of Meckel's cartilage in *Poecilia spp.* is non−homogenous and we asked how this changes over ontogeny. We hypothesized that Meckel's cartilage is non−homogenous throughout development; this can aid in the flexibility of the IMJ, allowing *Poecilia spp.* to have a wider gape. Specimens of black and balloon freshwater mollies (two variations of *P. latipinna*), as well as common mollies (*P. sphenops*), were cleared and stained to obtain an ontogenetic series. Histological sections for both species were generated to find patterns of ossification and allometric measurements of jaw elements. Histological sections stained with various methods were used to determine the composition of the Meckel's cartilage, and were compared among the ontogenetic series as well as to adults. Understanding the ontogenetic formation of the IMJ in individuals will contribute to hypotheses on the evolution of this joint.

P3.13 MCCAIN, S.C.*; LUTTERSCHMIDT, W.I.; FONTENOT JR., C.L.; Sam Houston State University, Huntsville, TX, Southeastern Louisiana University, Hammond; *scmccain@crimson.ua.edu*

Behavioral avoidance to salinity and physiological responses to osmotic challenge and dehydration in Amphiuma tridactylum

Coastal fresh−water habitats may experience rapid change in salinity. For the aquatic salamander, *Amphiuma tridactylum*, fluctuations in the concentration of environmental solutes offer challenges of osmotic stress, as they have limited options for avoidance and escape from their obligate habitat. A portion of the range for *A. tridactylum* is periodically subject to increased salinity due to salt−water intrusion (ca. 17 ppt salinity during storm surges) and drought (6.5 ppt salinity during natural drawdowns of water). Thus, it is probable that populations of *A. tridactylum* are euryhaline in their tolerance to salinity, particularly those populations within coastal and estuarine regions of its distribution. We investigated the threshold salinity that elicits behavioral avoidance by *A. tridactylum* and found that salamanders do not actively avoid increasing water salinity until concentrations reach 10 ppt. Such a level of environmental salinity is considerably more hyperosmotic than the normal blood plasma osmolality (250 mOsmol/kg) of *A. tridactylum*. Here we compare the typical physiological responses of amphibians to increased environmental salinity and outline the responses observed in *A. tridactylum*. We also introduce some preliminary findings on this species physiological and behavioral responses to evaporative water loss and dehydration.

P1.58 MCCANN, C/J; CHAN, KY/K; MCALISTER, J/S*; College of the Holy Cross, Hong Kong University of Science and Technology; *jmcalist@holycross.edu*

Geometric morphometric analysis of larval shape: a comparative study of geminate Echinometra spp. from tropical Central America

Geometric morphometric analysis uses Cartesian geometric coordinates of landmark features to analyze shape and has been used extensively in insect and vertebrate systems. We used MorphoJ, an integrated software package for geometric morphometrics, to examine differences in the shape of pluteus larvae during early development. We examined shape differences among the larvae of three congeneric species of *Echinometra* sea urchins that were collected from coastal waters off the Isthmus of Panama in 2005. These species vary in the length of larval food collection structures (larval arms), as well as in egg size and egg composition, which reflect pre−feeding egg energetic reserves used for morphogenesis. Our results indicate that species vary in their developmental shape trajectories, such that when normalized for size and age the overall shape differed between the congeners. These differences among species may be associated with egg size and/or composition. Shape differences may also be associated with differences in the larval feeding environment of the tropical western Atlantic and eastern Pacific oceans. This novel application of shape analysis sheds light on potential developmental, environmental, and biomechanical constraints on the evolution of larval form.

P3.125 MCCLINTOCK, JB*; GENEVIERE, AM; AMSLER, MO; Univ. of Alabama at Birmingham, Laboratoire de Biologie Integrative des Organismes Marins; *mcclinto@uab.edu*

The Mg−Calcite composition of the skeletal elements of the ecologically important sea urchin Paracentrotus lividus: implications for surviving in an acidifying Mediterranean Sea

Marine invertebrates that belong to the phylum Echinodermata are uniquely susceptible to ocean acidification (OA). This is because echinoderm skeletons are classified as high−magnesium calcite (> 4% MgCO3) rather than skeletons of other marine invertebrates that are comprised primarily of aragonite or calcite. Moreover, within echinoderm skeletal elements, the higher the ratio of magnesium to calcite the greater the potential vulnerability to OA. This vulnerability is manifest in both increased susceptibility to dissolution and potentially greater investment in production and maintenance. Among echinoids, there has yet to be a detailed comparative analysis of mg−calcite composition across all the skeletal elements of an individual. Accordingly, the present study compares mg−calcite levels measured for the ambulacral plates, interambulacral plates, genital plates, and auricles of the test, primary and secondary spines, and the teeth, epiphyses, compasses, and pyramids of the Aristotle lantern of twenty adults of the common Mediterranean sea urchin *Paracentrotus lividus*. The findings are discussed in the context of the comparative vulnerability of skeletal elements to OA and their functional implications. Supported by the Observatoire Océanologique de Banyuls sur Mer and a Endowment to JBM from the University of Alabama at Birmingham. Indirect support was provided by NSF grant ANT−1041022 to JBM.

P3.145 MCCLOUD, E.S.; DAVIS, J.L.; FIELD, B.S.; NINAD, N.*; University of Southern Indiana; *jldavis2@usi.edu*

Flexural Stiffness of Fresh vs. Dry Wings in Lycaenidae

Flexural stiffness of wings play an important role in our understanding of insect flight and behavior. The condition of the wing during testing is especially important. Of course any structural damage will play a significant role in altering the flexural stiffness. In addition, the "freshness" of the wing will also play a role. Moisture in the wing is lost over time. After several days, dissected wings become dry and brittle. Therefore testing of the wing immediately after dissection is a good way to capture a flexural stiffness that represents its in−vivo characteristics. In this study we tested 3 species from the butterfly family *Lycaenidae* with a focus on the effect of drying the wing on flexural stiffness. Wings were tested immediately after removal from the insect at intermediate times over several days, and after a longer period (ca. 50 days). Insect wing flexural stiffness does fluctuate over time, but there is a window of approximately 1 day after which there is low percentage of change in the wing stiffness. Fresh wings can be almost 50% stiffer than dry wing at certain locations along the length of the wing. In addition, change in stiffness is more prominent at the proximal portion of the wing.

77.3 MCCORKELL, FA*; DOUBE, M; BOMPHREY, RJ; TAYLOR, GK; Univ. of Oxford, Royal Veterinary College; *fergus.mccorkell@zoo.ox.ac.uk*

Tuning of flow−sensitive hairs to airflow stimuli in the desert locust (Schistocerca gregaria)

In the absence of much passive stability, flying insects rely upon active stabilisation, necessitating the provision of rich sensory feedback across a range of modalities. Mechanosensors that respond to aerodynamic flows are ubiquitous on the bodies of flying insects; in our model species, the desert locust (Schistocerca gregaria), approximately 430 flow−sensitive hairs (trichoid sensilla) on the front of the head provide a highly directional response to the oncoming flow. The directional sensitivity of these hairs may allow them to sense changes in angle of attack and sideslip, and are thus potentially important in both lateral and longitudinal flight stability. Here we characterize how the flow over each hair field varies with angle of attack and sideslip. We use computational fluid dynamics to model how the flow around the head varies with head orientation, validating our simulations against wind tunnel particle image velocimetry on a scale model. The simulations reveal that some fields of hairs are better placed to measure angle of attack, while others are better placed to sense changing sideslip. In addition we find that some hair fields could provide consistent sensing over a range of angles, whereas other fields appear to have a threshold response, with greatly reduced sensing of oncoming flow over certain head angles. We go on to compare the measured local flow directions with the directional sensitivity of each of the sensilla, measured morphologically using microCT scans. These data provide information on the curvature of each hair, which corresponds to the peak directional sensitivity of the hair to airflow. The relationships between these data allow us to identify what features of the flow certain groups of hairs might be measuring, and how this information could be used in flight control.

78.3 MCCOY, MW*; VONESH, JR; BOLKER, BM; East Carolina University, Virginia Commonwealth University, McMaster University; *mccoym@ecu.edu*

Predicting Predator Diversity Effects on Ecosystem Function

Habitat loss, over−harvesting, culling, and introductions are drastically changing predator communities, which in turn modify the structure of prey communities and affect ecosystem structure and function, with potentially large socio−economic consequences. However, we lack a general framework for predicting how changes in predator communities influence prey populations and ecosystem functions. Current methods assessing predator functional diversity are often idiosyncratic, and divorced from theoretical or statistical models. Further, current statistical models for predicting the effects of predator diversity conflate predictable nonlinear effects and context−dependent interactions. We overcome these challenges by developing models that (1) explicitly account for effects of nonlinearity in predation rates, and (2) by explicitly linking definitions of predator functional diversity to theoretical models that link predator and prey dynamics. By disentangling apparent emergent effects, nonlinear predator−prey interactions, and context dependence, which are typically conflated in current studies, we will be able to more reliably forecast how changes in predator diversity will affect ecosystem function.

17.3 MCCUE, M/D*; GUZMAN, R/M; PASSEMENT, C/A; DAVIDOWITZ, G; St. Mary's Univ, Univ Arizona; *mmccue1@stmarytx.edu*

How do insects rely on endogenous protein and lipid resources during lethal bouts of starvation? a new application for ^{13}C breath testing

Most of our understanding about the physiology of fasting and starvation comes from studies of vertebrates; however, studies that monitor vertebrates through the lethal endpoint are scant. Insects are convenient models to characterize the comparative strategies to cope with starvation because they have diverse life histories and have evolved under the omnipresent challenge of food limitation. Moreover, we can study the physiology of starvation through its natural endpoint. In this study we raised populations of five species of insects (adult grasshoppers, crickets, cockroaches, and larval beetles and moths) on diets labeled with ^{13}C−palmitic acid or ^{13}C−leucine to isotopically enrich the lipids or the proteins in their bodies, respectively. The insects were allowed to become postabsorptive and then starved. We periodically measured the δ^{13}C of the exhaled breath to characterize how each species adjusted their relative reliance on endogenous lipids and proteins as energy sources. We found that starving insects employ a wide range of strategies for regulating lipid and protein oxidation. All of the insects except for the beetle larvae were capable of sharply reducing reliance on protein oxidation; however, this protein sparing strategy was not always sustainable during the entire starvation period. At death, the crickets and cockroaches were relying extensively on protein oxidation but the other species were not. All insects increased their reliance on lipid oxidation, but while some species (grasshoppers, cockroaches, and beetle larvae) were still relying extensively on lipids at death, other species (crickets and moth larvae) allowed rates of lipid oxidation to return to prefasting levels. We conclude that starving insects exhibit a much wider range of strategies for rationing lipids and proteins than vertebrates.

16.6 MCELROY, EJ*; DE BURON, I; College of Charleston; *mcelroye@cofc.edu*

Host performance as a target of manipulation by parasites: a meta−analysis

The mechanisms underlying parasite−altered host behavior and fitness remain largely unanswered. The purpose of this review is to provide a perspective that has not been fully incorporated into the debate on how parasites manipulate their hosts. We argue that performance capacity is an important target of parasitic manipulation, and we aim to integrate the study of performance with that of parasitic manipulations of host behavior and fitness. We performed a meta−analysis from the published literature of 101 measures of the effect of parasites on host performance capacity to address the following questions. (1) Do parasites exert an important effect on host performance capacity? (2) Is that effect routinely to decrease or enhance performance capacity? And, (3) what factors explain variation in the effect sizes that have been quantified? Although negligible−small effect sizes were detected in 40/101 measures, host performance capacity was overall affected by parasitic infection, with a negative direction and medium−large magnitude in 58/101 measures and an increase in performance capacity in 3/101 measures. Host age, type of host performance, the host tissue infected by the parasite, and whether the study was experimental or based on natural infections each explained a significant amount of the variation in effect size. The significance of each factor is briefly discussed in light of the potential adaptive character of host manipulations by parasites.

54.1 MCELROY, MT; Univ. of Washington; *mtm3@uw.edu*
Gene flow and the "Bogert effect": Genes move up mountains in the Puerto Rican Crested Anole (Anolis cristatellus)
While behavior determines how organisms interact with their environment and may "drive" evolution and local adaptation in novel habitats, regulatory behaviors may actually inhibit evolutionary change. When populations inhabit different thermal environments, thermoregulatory behaviors may reduce expected differences in body temperature, and mediate selective pressures on thermal physiology. Huey et. al (2003) termed this the "Bogert effect" and predicted that divergent selection should be weak, and gene flow high, across thermal gradients for thermoregulating species, whereas selection should be strong, and gene flow low, for thermoconforming species. In this study, I use targeted Sanger sequence data and genome−wide single nucleotide polymorphisms (SNPs) to investigate population genetic structure and gene flow in *Anolis cristatellus*, a thermoregulating species that inhabits a range of thermal environments on Puerto Rico. I find multiple genetic populations of *A. cristatellus*, some of which may correlate with distinct thermal environments. Furthermore, I demonstrate uni−directional gene flow between populations that span a thermal gradient, a result that has important implications for thermal adaptation and that is only partially predicted by the "Bogert effect". These results are discussed with regards to adaptation and selection on thermal physiology, as well as to alternative "non−physiological" models.

P3.19 MCGAHERN, P.*; JORGENSEN, D.; University of Pennsylvania, Roanoke College; *jorgensen@roanoke.edu*
Hemolymph pressure is not homogeneous in the pre−gill sinus of the American lobster
Lobsters carry out gas exchange with two sets of gills each housed in a branchial chamber (BC) located on either side of the thorax. Each gill set consists of groupings of trichobranchiate gills that extend into the BC from the epipodites of the thoracic appendages. In decapod crustaceans, venous hemolymph collects in a relatively large vascular space, the pre−gill or infrabranchial (Ib) sinus, before moving through the gill circulation, and into the pericardial (P) sinus, in which the heart is suspended. We are interested in characterizing gill perfusion in resting and active lobsters. Hemolymph moves through the gill circulation down a hydrostatic pressure gradient from the Ib to the P sinuses. The Ib sinus, though geometrically−complex, is a contiguous space and our hypothesis was that hemolymph pressure should be equivalent at all points in the space. Perfusion of the different gill groupings within a gill set, driven by equivalent Ib sinus pressure, should be relatively equivalent. We measured hemolymph pressure along the length of the Ib sinus (at the base of the cheliped, and pereiopods 3 and 5) in lobsters at rest and while the animals walked at a steady rate on a submerged treadmill. We found that hemolymph pressure is not homogeneous in the Ib sinus in resting lobsters, being higher at the anterior and posterior ends of the sinus by as much as 2−fold. During exercise, we found that pressure in the sinus became more homogeneous, although we still saw substantial pressure differences along the sinus's length. These results suggest that gill perfusion may vary considerably along the length of a gill set with implications regarding gas exchange and other gill functions.

43.6 MCGEE, MD*; BORSTEIN, SR; CHANG, J; ALFARO, ME; WAINWRIGHT, PC; Univ. of California, Davis, Univ. of Tennessee, Knoxville, Univ. of California, Los Angeles, Univ. of California, Los Angeles; *mcgee.matthew@gmail.com*
Progressive functional innovation in cichlid adaptive radiations
How important is the role of time in evolution? Past research suggests that populations can rapidly evolve new dietary specializations and morphologies over extremely short amounts of evolutionary time. However, do morphological traits, particularly those related to functional innovation, evolve rapidly? We assembled the largest ever animal kinematic dataset from several of the most spectacular adaptive radiations on the planet, the cichlids of Africa's Rift Valley. The three great cichlid lake radiations each contain the same set of ecological specialists, including fish specialized on algae, snails, plankton, scales, and other fish. However, they differ widely in age: Lake Victoria and its associated satellite lakes are roughly 100,000 years old, Lake Malawi is 1−2 million years old, and Lake Tanganyika is 10−20 million years old. We filmed feeding kinematics from all three major radiations, covering all major genera and ecological specializations. We then combined our kinematic data with a time−calibrated phylogeny encompassing the cichlid radiations to generate a phylogenetically corrected principal components analysis in R. We then used the SURFACE method to generate an adaptive landscape of kinematic traits. Only in the oldest of the three radiations, Lake Tanganyika, do cichlids colonize the full set of adaptive optima, with the younger radiations of Malawi and Tanganyika occupying fewer optima. Interestingly, Tanganyika's extreme optima are characterized primarily by extreme jaw protrusion and extensive modification of cranial linkages, suggesting that while evolution can be rapid, true functional innovations require longer stretches of evolutionary time.

P2.29 MCGEE, MD*; BORSTEIN, SR; NECHES, RY; SEEHAUSEN, O; WAINWRIGHT, PC; Univ. of California, Davis, Univ. of Tennessee, Knoxville, Univ. of Bern, Switzerland; *mcgee.matthew@gmail.com*
The ecological price of evolutionary innovation
Competition is thought to play a major role in evolution, but it is difficult to observe its effects over macroevolutionary timescales. Here, we show that pharyngognathy, a classic example of evolutionary innovation, has affected niche evolution between major lineages of freshwater and marine spiny−finned fishes, including some of the most spectacular adaptive radiations on the planet. Experimental and historical evidence suggest that competition between pharyngognaths and an invasive non−pharyngognath played a major role in a recent mass extinction of fishes in Africa's Lake Victoria. Nearby Lake Tanganyika also bears the signature of competition between pharyngognathous and non−pharyngognathous fishes over the last several million years. Finally, a large comparative analysis of dietary evolution in marine fishes reveals that over tens of million of years, fishes with the pharyngognathy innovation have gained improved access to novel prey categories, but at the cost of surrendering their prowess in predatory niches to close relatives lacking the innovation. Our results reveal that the ecological effects of competition can shape macroevolutionary dynamics, and that evolutionary innovation often carries a heavy ecological price.

P3.132 MCGOWAN, K.L.*; IYENGAR, E.V.; Muhlenberg College; *iyengar@muhlenberg.edu*

Epibionts on gastropod shells in the rocky intertidal: Effects of zonation, shell rugosity, and migration

In a dynamic environment such as the rocky marine intertidal zone, the stresses experienced by epibionts and their hosts may differ when these animals are engaged in symbioses compared with when they are attached alone to the surrounding rock. We compared the species composition of the epibiotic community on gastropod shells to that of colonizers on neighboring rock surfaces to determine whether intertidal zone, wave action, or basibiont identity affected the epibionts present. We examined two tidal heights (a lower *Saccharina sessilis* zone and a higher *Fucus gardneri*/*Semibalanus cariosus* zone) at three sites of varying wave exposure (Westside Preserve, Cattle Point, and Colin's Cove) on San Juan Island, WA. In the lower tidal zone (but not in the higher), the percent of unfouled snails was much greater than predicted based on the surrounding substratum. Fewer than four algal species dominated the substratum at both tidal heights, but the identity of the dominant algae differed between tidal heights and did not match the dominant epibiotic species. Instead, small individuals of the barnacles *Semibalanus cariosus* and *Balanus glandula*, spirorbid worms, an excavating bryozoan, and diatoms were the most prevalent epibionts. Overall, while the basibiotic gastropods were less fouled than we expected, we found heavily−fouled individuals (especially limpets) interspersed among unfouled individuals. We deployed cleaned shells, with some sanded ("weathered"), of the gastropod species *Tectura scutum*, *Lottia digitalis*, *Nucella canaliculata*, and *Nucella lamellosa* for 3 to 6 weeks in the higher intertidal zone and subtidally at two sites. There was little differential settlement due to shell morphology.

P1.83 MCGUIGAN, MA*; KRAUSE, JS; CHMURA, HE; PEREZ, JH; GOUGH, L; BOELMAN, NT; WINGFIELD, JC; UC Davis, UT Arlington, Columbia U.; *hechmura@ucdavis.edu*

Spatial habitat use in post−breeding songbirds: A radio−telemetry study in Gambel's White−crowned sparrows

In migratory songbirds, behavior and habitat use during arrival and breeding has been studied intensively for decades. However, bird activities at the termination of the breeding season are less well understood. During the post−breeding period, offspring become independent and adults shift time away from provisioning young and towards self maintenance as they enter molt and prepare for migration. Additionally, as the season progresses abundance and distribution of food resources change. While terrestrial arthropod biomass peaks in early July at the time that offspring are fledging, berries ripen and aquatic arthropod biomass peaks in August which coincides with molt. Energetic demands and increased predation risk associated with molt, as well as shifts in food resources, may force individuals to alter movement patterns on the landscape. To investigate habitat use, we attached radio−transmitters to Gambel's White−crowned sparrows *(Zonotrichia leucophrys gambelii)* with known nests at the termination of the breeding season at Toolik Lake Research Station on the North Slope of Alaska. Adults were tracked using both automated and handheld receivers until departure for fall migration. Results show that most birds stayed within 100−200 meters of the nest until departure. In addition, predation rates were highest during the last week of July to first week in August when molt is most intense. Given inter−annual variation in weather and predator−prey dynamics on the tundra, additional years of data collection would be illuminating in this system

S12.5 MCHENRY, MJ; UC Irvine; *mmchenry@uci.edu*

The sensory−motor basis of evasion strategy in prey fish

Suction feeding can rapidly capture prey, but it is only effective over a limited spatial range for a brief duration. These constraints present opportunities for a prey fish to evade capture. We have examined the components of successful prey strategy by studying how larval zebrafish (*Danio rerio*) sense fish predators and coordinate evasive maneuvers. When placed in a small arena, these prey successfully evaded 70% of predatory strikes with a fast start' escape response and a majority of these evasions were initiated before the predator opened its mouth. To determine the sensory cues that direct an escape response, we built a robotic predator that moved toward prey at a fixed speed. We found that prey responded to this stimulus at distances of greater than 10 body lengths. However, these responses reduced to within 2 body lengths for experiments conducted in the dark, and ceased entirely when we chemically−ablated the lateral line system. By modeling the visual and lateral line stimuli generated by the predator, we found that both sensory systems failed to direct escape responses in an optimal direction, as predicted by game theory models. Instead, responses were consistent with feed−forward control directed on the side of the body away from the stimulus source. Therefore, the limitations inherent to the sensory and motor systems of a fish prey may constrain prey responses to a sub−optimal, but effective, strategy.

65.3 MCINROE, BM*; ASTLEY, HC; KAWANO, SM; BLOB, RW; GOLDMAN, DI; Georgia Tech, NIMBioS, Clemson Univ.; *bmcinroe3@gatech.edu*

Biological and robotic modeling of the evolution of legged locomotion on land

Many existing organisms use flipper−like limbs for both aquatic and terrestrial locomotion. In the transition from an aquatic to a terrestrial environment, early tetrapod walkers adapted to the challenges of locomotion on complex substrates (e.g. sand and mud), which can exhibit both solid and fluid−like properties. Laboratory studies of physical robot models reveal that locomotor performance on dry granular media is sensitive to variations in limb morphology and kinematics. Although previous studies have reconstructed skeletal morphologies of early walkers, the impact of kinematics on their locomotor performance, particularly the importance of the tail, remains unclear. To gain insight into how early walkers contended with complex substrates, we developed a flipper−driven physical robot model with limb−joint morphology inspired by the mudskipper fish (*Oxudericinae*), a model analog for early tetrapod walkers. We discovered that although mudskippers move effectively on level substrates with a crutching gait driven by their front fins, their locomotor ability becomes limited as substrate tilt is increased, unless they use their well−developed tails to prevent slipping and generate forward thrust. The addition of an actuated tail to the robot improved performance, simplifying the robot's control strategy: tail use made the robot more robust to variations in morphology and kinematics, such as flipper tilt and flipper insertion depth, and made locomotion on inclines possible for morphological configurations that otherwise failed. With these discoveries, we are elucidating a minimal feature set that would have allowed the first terrestrial vertebrates to adapt to life and locomotion on complex terrestrial environments.

105.1 MCKEE, A*; MACDONALD, I; FARINA, S C; SUMMERS, A P; University of California, Irvine, Northern Arizona University, Cornell University, University of Washington; *biologymajor8@gmail.com*

Body undulation frequency affects burial performance in living and model flatfishes

Flatfishes bury themselves under a thin layer of sand to hide from predators or to ambush prey. We investigated the role of body undulation frequency in burial in five species of flatfishes (*Isopsetta isolepis, Lepidopsetta bilineata, Parophrys vetulus, Lyopsetta exilis,* and *Psettichthys melanostictus*). High speed videos show that undulations begin cranially and pass caudally while burying, as in forward swimming in many other fishes. They also flick their dorsal and anal fins during burial, apparently to guide jets of fluidized sand. A physical model − a silicone model flatfish with a motorized, variable−speed actuator − was built to isolate the effect of undulation speed on burial. The model suggests that increased frequency increases the area of sand coverage. However, this benefit leveled off at higher speeds, which suggests there is an optimal range of undulation frequency that allows for the most efficient burial. The model shows undulation is sufficient to bury the animal, but the live flatfishes showed a superior ability to bury, which we attribute to the action of the median fins. We suggest that body undulations offer a means for a fish to bury itself which is enhanced through the independent action of its fins.

113.5 MCKEON, S*; OLIVER, T; Smithsonian Marine Station, University of Hawaii; *mckeons@si.edu*

High Temperature Environment Drives Cascading Fitness Effects Through Multi−party Reef Coral Mutualism

Reef corals are symbiotic assemblages that can derive up to 95% of their carbon demands from endosymbiotic dinoflagellates in the 'genus' *Symbiodinium*. The coral−algal symbiosis also relies on other inter−species interactions, including the mutualistic symbiosis between corals in the genus *Pocillopora* and crabs in the genus *Trapezia*. The exosymbiotic *Trapezia* live among branches of the coral, and benefit their host by deterring corallivores and removing sediment and debris. In return *Pocillopora* not only shelter, but also feed their *Trapezia* with photosynthetically−derived lipids translocated into tentacle tips, which the crabs clip and consume. As warming seas threaten temperature−sensitive multi−species coral assemblages, we know that genetically distinct *Symbiodinium* can confer distinct thermal tolerance upon the coral−algal symbiosis, but little work has highlighted the cascading effects of such symbionts on other coral associates. Here we show that in a high−temperature coral reef habitat, physiological distinctions between *Symbiodinium* genotypes carry effects beyond the coral−algal symbiosis and affect the fitness of associated fauna, including *Trapezia*. We show that in high temperature back reef pools with high proportions of heat−resistant *Symbiodinium* D, those *Trapezia* living with *Pocillopora* hosting the more thermally sensitive *Symbiodinium* C1 are smaller and less fecund than those associated with corals hosting the more heat−resistant *Symbiodinium* D. As smaller *Trapezia* are less effective at fending off corallivores, by not hosting thermally robust *Symbiodinium* in this high−temperature habitat a coral not only increases its risk of direct physiological effects from thermal stress, but also undermines its 'defense force', thus increasing its risk of predation.

P3.25 MCKIBBEN, T*; KRAJNIAK, KG; Southern Ill Univ Edwardsville; *tmckibb@siue.edu*

The Effects APKQYVRFamide on Contractile Activity of the Isolated Pharynx of the Earthworm Lumbricus terrestris

The isolated earthworm pharynx displays a complex pattern of contractions with both large and small peak amplitudes which can be modified by neurotransmitters. Previously we showed that FMRFamide caused changes in both the large and small amplitude contractions. Since APKQYVRFamide is a FaRP native to genus *Lumbricus* we decided to determine the effects of this peptide on the pharynx. The organ was removed from the animal, placed in a tissue bath filled with saline, and attached to a force transducer which was connected to a computer using Iworx software to record the contractions. Increasing concentrations of peptide were placed into bath and the resulting changes in contraction rate and amplitude were used to create log−concentration response curves. APKQYVRFamide caused a concentration−dependent decrease in large contraction rate with a threshold of 10^{-7} M. The peptide caused a complex response in amplitude with an increase at 10^{-10} M, a decrease in at 10^{-8} M, an increase at 10^{-7} M, and a final decrease at 10^{-6} M. On the small peaks it caused a biphasic effect on rate with an increase at 10^{-8} M and a decrease at 10^{-7} M. The effect on amplitude of the smaller peaks was complex. A decrease occurred at 10^{-8} M, an increase at 10^{-7} M, and a decrease at 10^{-6} M. These responses are different from those elicited by FMRFamide and may be due to the peptide native to *Lumbricus* acting on a separate receptor from that of FMRFamide or regulation of the receptor is controlled by a different set of cues, but more experiments need to be performed to verify these results. Future experiments include examining substitutions to the C−terminal tetrapeptide to determine their effect on contractile activity.

P1.46 MCLARTY, SJ*; COWLES, DL; Walla Walla University; *shelley.mclarty@wallawalla.edu*

Gut Content and Pigment Analysis in the Marine Isopod Pentidotea resecata

The green morph of the marine isopod *Pentidotea resecata* lives and feeds on eelgrass, while the brown morph lives on kelp. The coloration of the green morph closely matches that of its substrate. The goal of this project was to determine whether the green isopod's coloration is due to the presence of chloroplasts and/or chlorophyll. Using spectrophotometry, we analyzed isopod tissue extracts for the presence of chlorophyll *a*. The extracts did exhibit peaks near 430 and 664 nm, as expected for chlorophyll *a*. However, acidification of the extracts produced little change in the extracts' absorption spectra, indicating that they contained mostly pheophytin *a*, a degradation product of chlorophyll *a*. The digestive system of *P. resecata* consists of a mouth, esophagus, stomach, hepatopancreas, hindgut, and anus, which exits ventrally into the valve formed by the uropods. The stomach contains separate openings into both the hepatopancreas and the hindgut, which are the locations where most of the materials being digested were found on dissection. The hepatopancreas of this species consists of several tan−colored midgut glands that surround the stomach and hindgut. The hindgut contents include chunks of whole eelgrass cells and a variety of diatoms along with other debris. Although fluorescence suggests that some chlorophyll in the material within the hindgut lumen may still retain functionality, we did not find any indication of plant cells or chloroplasts within the isopod tissue itself. While it is likely that *P. resecata* derives its green pigmentation from its eelgrass diet, these animals do not appear to contain functional chlorophyll *a* within their tissues.

P3.192 MCLAUGHLIN, CJ*; WISE, TC; STAYTON, CT; Bucknell University; *cjm048@bucknell.edu*

Morphological evolution of the turtle shell and its mechanical implications, part 2: theoretical

Evolutionary biologists have considered understanding the relationship between organismal morphology and functional performance to be fundamental for understanding phenotypic diversification. Numerous studies have investigated performance and morphological evolution within lineages. However, far less attention has been paid to the relationship between performance and morphological diversification among lineages. This study develops the turtle shell as a model system for studying morphological and performance diversification within a comparative context. Original data consisted of 3D landmark coordinates digitized on 1962 turtle shells representing 254 separate species. Data were aligned using a Generalized Procrustes fit and ordinated with principal component (PC) analysis. High scores on PC1 and 2 indicate taller, more domed shells. To explore the functional implications of this variation, theoretical shell shapes corresponding to 117 evenly−spaced points in morphospace were extracted. Finite element models were built for all theoretical shapes to assess mechanical performance. Heat transfer ability was quantified using surface area to volume ratios (SA/V), and three shape indices were used to assess righting ability. Turtle shells with high PC1 and 2 scores were stronger, possessed greater righting ability, and had lower SA/V. Shells with low PC1 and 2 scores were more streamlined, and had higher SA/V. Terrestrial and aquatic turtles did not differ in shell shape (see part I), but terrestrial turtles showed a tendency to evolve towards higher PC1 and 2 scores. Similar values for all performance measures could be found in large areas of morphospace, suggesting many−to−one mapping of form onto function; thus, turtle shells can diversify morphologically without necessarily sacrificing performance for all shell functions.

P3.38 MCLEOD, A*; SEMPLE, D; CATAPANE, E,J; CARROLL, M,A; Medgar Evers College; *catapane@mec.cuny.edu*

Immunohistofluorescence Localization of Histamine and Histamine Receptors in Ganglia and Tissues of the Bivalve Mollusc, Crassostrea virginica

Histamine (HIS) is a biogenic amine serving as a neurotransmitter in nervous systems and sensory receptors in invertebrates. HIS has rarely been reported in bivalves. We previously showed it is involved in sensory−motor integration of gill lateral cell cilia beating in the bivalve *Crassostrea virginica*. We also used HPLC to show it is present in ganglia and tissues. We hypothesize HIS neurons and HIS receptors are present *C. virginica*. We used immunohistofluorescence with primary antibodies to HIS and HIS receptors, and fluorescently labeled secondary antibodies to visualize HIS and HIS receptors in ganglia, gill and mantle. Tissues were dissected, snap frozen, cryostat sectioned, fixed with EDAC (N−Ethyl−N'−(3−dimethylaminopropyl) carbodiimide hydrochloride) or paraformaldehyde, treated with blockers, and incubated with primary and secondary antibodies. Whole mounts of gill and mantle were similarly treated. Cryostat sections and whole mounts were viewed with a Zeiss epilume fluorescence microscope with a ProgRes C3 camera, as well as a Leica epilume fluorescence microscope with a Leica DFC400 camera. Both scopes had FITC and Texas Red excitation/emission filters. Results show HIS and HIS H2 receptors present in visceral ganglia gill, mantle body and sensory tentacles of the mantle rim. Of particular significance is their presence in sensory tentacles as that correlates well with our sensory physiology studies, and their presence in gill interfilamental junctions, the physiology of which has not been well described. This project confirms the identity of HIS and H2 receptors in the nervous system and innervated organs, and coupled with our other work shows HIS to be an important endogenous biogenic amine in the bivalve *C. virginica*.

P1.67 MCMAHON, J.B.*; PIRES, A.; Dickinson College; *pires@dickinson.edu*

Effects of Ocean Acidification and Nutrition on Growth and Metamorphosis in the Gastropod Crepidula fornicata

The earth's oceans are becoming more acidic due to absorption of atmospheric CO_2. Ocean acidification decreases the concentration of carbonate ions in seawater, and imposes increased energy costs on organisms that deposit calcium carbonate shells and skeletons. Larval stages of these organisms are especially vulnerable to stresses of acidification and nutrition, which may have a common energetic basis. We investigated how acidification and nutrition affected precompetent larval growth of the slipper limpet *Crepidula fornicata* during the first 8 d after hatching. We also asked if a 4 d period of food and/or acidification stress, applied to older competent larvae, affected speed of metamorphosis and juvenile growth after stresses were relieved. Treatments in both experiments used all 4 combinations of pH 7.8 or 7.4, and high or low food ($15x10^4$ or $1x10^4$ cells/ml *Isochrysis galbana*). pH setpoints were achieved by bubbling CO_2 in 0.2 ¼m−filtered seawater. Lower food level in the pH 7.8 treatments resulted in decreased growth rates for precompetent larvae (p<0.0001), while larvae failed to grow in the pH 7.4 treatments regardless of food level. Increased acidification extended the latency of KCl−induced metamorphosis in the second experiment (p<0.04), but nearly all larvae completed metamorphosis within 24 h. Juveniles were then held at ambient pH of 7.8−8.1 while being fed $10x10^4$ cells/ml *I. galbana*. Together, larval experience of acidification and low food availability decreased subsequent juvenile growth in the first 6 d after metamorphosis (p<0.01), demonstrating carryover effects of larval experience on juvenile performance.

P1.106 MCNABB, N.A.*; GUILLETTE JR., L.J.; KOHNO, S.; College of Charleston, Medical Univ. of South Carolina; *mcnabbna@g.cofc.edu*

Corexit 9500 as a Potential Endocrine Disruptor on Sex Determination of the American Alligator

The American alligator (*Alligator mississippiensis*) exhibits temperature−dependent sex determination (TSD), in which incubation temperatures during thermosensitive period (TSP) in embryonic development determine sex of the offspring. Hormone signals also play a critical role in TSD, and exposure to exogenous endocrine active compounds during TSP can override the effects of temperature. Both natural estrogens and xenoestrogens can lead to sex reversal and induce female development, even when eggs are incubated at a male−producing temperature. Since *A. mississippiensis* is a long−lived, apex predator that does not migrate far during its lifetime, it is a great sentinel species to investigate chronic exposure to environmental contaminants, including endocrine disrupting contaminants (EDCs). During the 2010 *Deepwater Horizon* oil spill in the Gulf of Mexico, the dispersant, Corexit 9500, was applied to the surface water and at the broken wellhead to dissolve the oil spill. Although studies have been conducted on toxicity, there has been limited research on the sublethal effects of Corexit 9500. We found that Corexit 9500 induced transactivation via American alligator estrogen receptor 1 (ESR1) on hormone receptor reporter gene assays *in vitro*, and could be an EDC. Further, alligator eggs were exposed to Corexit 9500 at 0.25, 2.5 and 25 mg/g egg weight during TSP to investigate the potential endocrine disruption and effects on gonadal development in the American alligator *in ovo*. Exposures to Corexit *in ovo* at these doses did not affect the viability at hatch−out. Further analyses of gonadal development in the alligators exposed to Corexit 9500 *in ovo* will be reported.

17.5 MCWILLIAMS, R*; PIERCE, B; Univ Rhode Island, Sacred Heart University; *srmcwilliams@uri.edu*

Oxidative stress associated with long−duration flights and its implications for the ecology of migrants at stopover sites.

During migration, birds use primarily fats to fuel their long−duration flights and this high rate of fat metabolism during exercise substantially increases the bird's oxidative stress. Birds may avoid the cellular damage associated with this oxidative stress during exercise by up−regulating their endogenous antioxidant capacity (e.g., liver antioxidant enzymes) and by consuming more dietary antioxidants in preparation for migration and during stopovers while migrating from wintering to summer sites. I will test a series of hypotheses related to how the physiology of migratory birds changes during endurance flights to cope with enhanced oxidative stress, and how this relates to the ecology of birds at stopover sites. Supported by NSF (IOS−0748349) and USDA (RIAES−538748).

95.6 MEHTA, R/S*; BALIGA, V/B; Univ. of California, Santa Cruz; *rmehta2@ucsc.edu*

Quantifying the Morphological Diversity of Teleost Taxa that Apprehend Prey By Biting

Biting to apprehend prey is a widespread behavioral strategy in terrestrial vertebrates, but in aquatic environments, biting can be considered a behavioral novelty. Within the last ten years, functional morphology studies focused on predatory teleost taxa that employ biting to capture prey have emerged. Through these studies, it is apparent that biters exhibit a high degree of variation in behavior, morphology, kinematics, and motor patterns. Despite the interest in biting, functional morphologists lack a unifying operational definition of this behavior, presumably due to the diversity of biters. While biters exhibit interesting variation in key features related to prey capture, the vast majority of biters retain the ability to expand the buccal cavity for transport and respiration. Here, we provide an operational definition of biting that clearly distinguishes biting as a prey apprehension strategy from one that is employed for processing prey (i.e. manipulation). We also examine the relationship between maximal gape distance and prey capture time for biters that consume both non−elusive and elusive prey. Lastly, we examine the relationship between characters comprising the oral jaws and those comprising the hyoid apparatus in a subsample of biters spread across disparate teleost clades. We find that biting taxa that consume elusive prey exhibit a weaker relationship between the oral jaws and the hyoid apparatus compared to those consuming non−elusive prey. Thus in our preliminary analysis, apprehending elusive prey seems to have had cascading effects on other functional systems such as prey transport.

P3.205 MEIER, C*; GOLDINA, A; Elizabethtown College; *meierc@etown.edu*

Responsiveness to serotonin reflects social dynamics of crayfish Orconectes obscurus

Serotonin (5−HT) modulates agonistic behavior in crustaceans. However, the exact effect of 5−HT on social behavior has been difficult to determine because 5−HT modulates multiple neural circuits, its effects are concentration dependent and may reflect individual social history. Most studies examining the role of 5−HT in social behavior have used a simplified social paradigm of two individuals, a dominant and a subordinate; however, in nature, animals form social networks where they can be dominant to some individuals and subordinate to others. We examined how 5−HT modulates social behavior in a social network of the crayfish *Orconectes obscurus*. Fifteen crayfish were placed in an aquarium to establish social networks of dominant, intermediate, and subordinate individuals (n = 5 groups). Once social hierarchy stabilized, animals within a network were injected with 5−HT (0.002mM, 0.02mM, 0.2mM). Following injections, each animal was isolated to examine postural changes and activity. Then animals were returned to their network and monitored for changes in aggression and hierarchical shifts. Our preliminary results suggest that sensitivity to 5−HT reflects social dynamics. Subordinate animals produced a high, flexed posture in response to all three 5−HT concentrations, while the postures of dominant individuals were more variable and only the highest 5−HT concentration generated a high posture universally. In subordinates, 5−HT stimulated a high posture, but had no impact on aggression. In dominant individuals, the highest aggression was observed in response to the lowest dose. Intermediate individuals exhibited posture and aggression responses intermediate to the responses seen in dominants and subordinates. Our data suggest that sensitivity to 5−HT reflects social experience and complex social environment.

58.4 MEMBRENO, N.A.*; ELSEY, R.M.; OWERKOWICZ, T.; California State Univ., San Bernardino, Louisiana Department of Wildlife and Fisheries; *membrenn@coyote.csusb.edu*

Embryonic responses to carbonic anhydrase inhibition and exogenous calcium supplementation in eggs of the American alligator

During incubation, embryonic archosaurs mobilize calcium from the eggshell, and deposit it in the yolk and the skeleton. Previous experiments on eggs of the American alligator (*Alligator mississippiensis*) demonstrated that removal of the calcareous eggshell results in embryonic growth retardation. So far, no experiments have ascertained the role of carbonic anhydrase in eggshell calcium mobilization, nor the importance of calcium provenance to embryonic crocodilians. We conducted two experiments to test whether (i) carbonic anhydrase (CA) inhibition has similar effects on the embryo as eggshell removal, and (ii) exogenous calcium supplementation can rescue the original embryonic phenotype. To inhibit CA, we applied topical acetazolamide (150−600 µg/day AZA in DMSO vehicle). As exogenous sources of calcium, we used 0.1M $CaCO_3$ solution and calcite sand. We found AZA reduced embryonic wet mass after five weeks of treatment, with a significant dose−dependent response. Interestingly, the relative ash mineral content of the yolk was not affected by AZA treatment, which suggests compensatory mechanisms in calcium transport. Calcium supplementation of eggs with the eggshell removed yielded mixed results. Spraying with $CaCO_3$ solution partially rescued the phenotype, with alligator embryos being intermediate in wet mass between control and non−treated experimental siblings. Egg incubation in calcite sand, however, did not restore normal embryonic growth trajectory. This suggests alligator embryos can potentially obtain calcium from environmental sources, with presence of aqueous calcium especially important.

101.2 MENDELSON, L.R.*; TECHET, A.H.; MIT; *leahm@mit.edu*

Time−Resolved Volumetric Force Analysis of Unsteady Fish Propulsion

Unsteady aquatic maneuvers, including the rapid starts and jumps performed by fish, are highly three−dimensional events. The interactions between multiple fins and the body generate complex flow structures that need to be resolved simultaneously across varying time and length scales in order to gain a full picture of the resulting hydrodynamics. This work focuses on fully time−resolved, three−dimensional velocimetry during rapid maneuvers, prey capture, and jumping events. These events cannot be studied in a flume, as the organism must be allowed to move freely in a quiescent tank. Resultantly, the body kinematics and wake structures tend not to align with laboratory−centric reference frames and rectilinear measurement techniques such as planar Particle Image Velocimetry (PIV). Velocity fields must be analyzed with geometry−flexible frameworks and without the classical assumptions made in 2D PIV when quantifying swimming momentum and unsteady forces.

Light field imaging techniques and Synthetic Aperture PIV enable time−resolved volumetric measurements which, combined with advanced flow feature identification algorithms, are necessary to quantitatively analyze such behaviors and extract accurate 3D force measurements on the fish. We present results obtained from fully time−resolved volumetric PIV on maneuvering Giant Danio *(Devario aequippinatus)*, as well as canonical round vortex rings, which are the underlying propulsive mechanism in rapid maneuvers. We consider the influences of limited spatial resolution, flow feature identification for arbitrary geometries, and body reconstruction uncertainty on the measurement. Recommendations are made for a general procedure for propulsion analysis from 3D PIV data, regardless of which velocimetry technique was used to obtain the velocity fields.

67.1 MENEGAZ, RA*; BAIER, DB; METZGER, KA; HERRING, SW; BRAINERD, EL; Brown Univ, Providence Coll, Hofstra Univ, Univ of Washington; *rachel_a_menegaz@brown.edu*

XROMM analysis of tooth occlusion and temporomandibular joint kinematics during mastication in miniature pigs

Domestic pigs and their wild relatives are true omnivores, and are convergent in their craniodental morphology with other omnivores such as hominin primates. Prior attempts to characterize food−tooth interactions and jaw movements associated with mastication have been limited to those aspects of the oral apparatus that are externally visible (with videography) and/or to 2D movements of oral structures (with monoplanar videofluoroscopy). Here, we used XROMM, a 3D technique that combines CT−based morphology with biplanar videofluoroscopy, to measure tooth displacements during mastication and to examine the relative movement of opposing teeth during occlusion. We found that relative motions of the premolars contained a distinct, and somewhat unexpected, anteroposterior component within the transverse trajectory of the power stroke. Furthermore, the occlusal movements responsible for food reduction occur in the larger context of jaw movements at the posterior temporomandibular joints (TMJ). Despite a relatively mobile omnivore−type TMJ, we observed that the pig TMJ moved detectably in only 3 of 6 possible degrees of freedom during mastication: 2 rotations, pitch and yaw, and 1 translation, protraction−retraction. Jaw depression (pitch) was coupled to jaw protraction, and asymmetrical yaw produced the observed alternating left−right chewing cycles. The integration of tooth, joint, and rigid body jaw movements elucidated the kinematic underpinnings of the occlusal power stroke, a key aspect of mammalian mastication. XROMM also allowed us to determine how hypothetical kinematics inferred from tooth and TMJ structure compare with actual kinematics in the context of naturalistic feeding behaviors.

46.4 MERRILL, L*; COLLINS, P.M.; University of California, Santa Barbara; University of Illinois, University of California, Santa Barbara; *loren21@illinois.edu*

Environment− and sex−specific allocation strategies among gonadal, somatic and immune indices in a marine fish

Examining the role of temperature in shaping life−history strategies can aid our understanding of basic life−history theory, help us develop optimal rearing conditions for cultivated organisms, and improve our ability to predict how organisms will respond to changes in environmental temperatures. In this study we examined the relative investment in somatic, gonadal, and liver growth as well as a measure of immune function in a marine species of fish (cabezon, *Scorpaenichthys marmoratus*) reared under different ambient temperature regimes (mean temps. 14.8^{o}C and 12.7^{o}C). Previous work documented significant reductions in growth and immune function for fish in the colder rearing environment compared to fish reared in the warmer environment. We predicted that fish reared in colder water would exhibit more pronounced trade−offs among growth, development, and immune parameters than fish in warmer water, and that females would have more pronounced trade−offs than males due to increased energy requirements for ovary development. We found immune function and liver investment were positively related in the cold water fish, but not related in the warm water fish. Immune function positively covaried with gonadal investment, but was not associated with somatic investment. Gonadal investment was negatively related to somatic investment, but this was driven by females, as there was no relationship between gonad development and somatic growth in males. We also found a significant difference between the sexes in the relationship between gonadal investment and liver investment, in which females again exhibited a significant negative association, and males exhibited a positive association.

P3.117 MERSELIS, DG*; RODRIGUEZ−LANETTY, M; Florida International University; *danielmerselis@gmail.com*

Genotype Specific Response to Thermal Stress: Predicting for Efficient Coral Restoration in the Twenty−First Century

Reef building corals, engineers of Earth's most productive and diverse ecosystem, are at risk of extinction on a global scale. Among numerous threats, climate change is perhaps the most prominent; rising sea temperatures threaten to decouple the obligate symbiosis between corals and intracellular *Symbiodinium* algae, a process known as bleaching. Mass bleaching events lead to disease outbreaks and coral mortality. Management strategies can prevent over exploitation and nutrient loading while coral restoration strategies can repopulate degraded reefs, but climate change effects cannot be locally mitigated. Therefore, it is crucial for restoration groups to identify and facilitate adaptation and/or acclimatization within their nurseries. A model for coral restoration, the Caribbean Staghorn Coral, *Acropora cervicornis*, has declined precipitously from historic levels and is now listed as federally endangered. Coral restoration nurseries throughout the Caribbean now regularly grow and transplant this species back to the reef. However, it is not clear whether certain staghorn coral genotypes will be more or less capable of survival in thermal stress scenarios. In order to inform these nurseries, our group has conducted a preliminary investigation on the potential for inter−genotypic differences in thermal tolerance of nursery corals. Using *Symbiodinium* typing and quantification, photosynthetic efficiency, and polyp extension, we have identified significant and predictive differences between nursery genotypes which vindicate further investigation. By identifying genotypes with greatest potential for survival in future conditions, we hope to increase the resiliency of restored reefs in the Anthropocene.

P3.51 MERULLO, D.P.*; CORDES, M.A.; STEVENSON, S.A.; RITERS, L.V.; University of Wisconsin−Madison; *dmerullo@wisc.edu*

Neurotensin immunolabeling relates to sexually−motivated song and other social behaviors in male European starlings (Sturnus vulgaris)

The brain regions involved in vocal communication are well described for some species, including songbirds, but less is known about the neural mechanisms underlying motivational aspects of communication. Mesolimbic dopaminergic projections from the ventral tegmental area (VTA) are central to mediating motivated behaviors. In songbirds, VTA provides dopaminergic innervation to brain regions associated with motivation and social behavior that are also involved in sexually−motivated song production. Neurotensin (NT) is a neuropeptide that strongly modulates dopamine activity, co−localizes with dopamine in VTA, and is found in regions where dopaminergic cells project from VTA. Yet, little is known about how NT contributes to vocal communication or other motivated behaviors. We examined the relationships between sexually−motivated song produced by male European starlings *(Sturnus vulgaris)* and NT immunolabeling in brain regions involved in social behavior and motivation. Additionally, we observed relationships between NT labeling, non−vocal courtship behaviors, and agonistic behavior to begin to understand NT's role in socially−motivated behaviors. NT labeling in lateral septum and bed nucleus of the stria terminalis was related to sexually−motivated singing and non−vocal courtship behaviors. NT in VTA, lateral septum, medial preoptic nucleus, and periaqueductal gray was associated with agonistic behavior. This study is the first to suggest the involvement of NT in song, and one of the few to implicate NT in social behaviors more generally. Our results are consistent with the idea that distinct patterns of neuropeptide activity in brain areas involved in social behavior and motivation underlie differentially motivated behaviors.

57.2 MERZ, RA*; CRANE, RL; LEE, HR; CORCORAN, JP; SUI, J; Swarthmore College, Duke University; *rmerz1@swarthmore.edu*

Organismal perspectives on moving through and over sediment

Soft sediment dwellers gain protection and nutrition from the particulate world in which they live but are limited by their abilities to move within and upon this dense, gritty, shifting medium. False Bay, WA offers sedimentary landscapes from well−sorted sands to muds. By studying species that vary in body softness, stretchiness, and locomotor ability in addition to the material properties of the sediment in which they live, we achieve an organismal view of the physical challenges of this habitat. Sediment stiffness separates the distribution of two closely related polychaete species, *Abarenicola pacifica* and *Abarenicola claparedi*, within False Bay. Transplant experiments show that *A. claparedi* is a weak burrower and cannot successfully enter the stiffer habitat of *A. pacifica*. *A. pacifica* can burrow in all tested sediments, but may not be able to maintain a burrow in the more collapsible, less stiff regions of False Bay. The viscoelastic body of the burrowing sea cucumber *Leptosynapta clarki* allows it to slowly, inexorably extend its body through the dense medium as its tentacles make space by shifting sand grains. This is in contrast to the relatively rapid burial of *Metacarcinus magister* and *Cancer productus* that can bury in all regions of False Bay (although efficacy varies with species and sediment stiffness). Crabs use their posterior legs to disrupt the sediment and then anchor their bodies as their claws push this unconsolidated sediment away. To remain on the surface of the sediment, the bubble snail, *Haminoea vesicula*, must resist drag. By partial burial, it can quickly cover its body with a sheet of sediment−encrusted mucus increasing its effective density and lowering its profile. The morphologies and techniques of these different taxa provide organismal perspectives on a variety of physical challenges of sedimentary habitats even within this single bay.

P3.43 MEZALON, C*; MCBEAN, T; CARROLL, M.A.; CATAPANE, E.J.; Medgar Evers College; *catapane@mec.cuny.edu*

p−Aminosaylisylic Acid (PAS) Reverses Neurotoxic Effects of Manganese on the Physiological Response of a Dopaminergic System

Manganese (Mn) is a neurotoxin causing Manganism, a Parkinsons−like disease in humans. Mn neurotoxicity involves disruption of dopaminergic neurotransmission. The roxic mechanism is not fully resolved and is thought to be more related to downstream neuronal pathways than deficits in nigrostriatal function. Lack of effective treatment for Mn toxicity is a major obstacle. Recently, p−Aminosalicylic acid (PAS) was reported an effective treatment; however its mechanism of action is unclear. Gill lateral cell cilia of *Crassostrea virginica* are controlled by serotonergic−dopaminergic innervations from their ganglia. Dopamine (DA) causes cilio−inhibition, serotonin cilio−excitation. Our lab showed Mn blocks cilio−inhibitory effects of DA and this is prevented by co−treatments with PAS. We hypothesize PAS would reverse the neurotoxic actions of Mn when applied after Mn. We treated *C. virginia* for 3 days with Mn (500 mM) followed by 5 days with PAS (500 mM). Ciliary activity of gill lateral cells was measured by stroboscopic microscopy. We found, in congruence with our earlier studies, Mn treatments disrupts DA ($10^{-6} - 10^{-4}$ M) induced cilio−inhibitory of gill lateral cells. In addition we show PAS treatments after Mn exposure reversed this and cilia of lateral gill cells responded normally to DA with appropriate decreases in beating rates. The study shows PAS effectively reverses neurotoxic effects of Mn on the physiological response of a dopaminergic system innervating gill lateral ciliated cells. These finding are helpful to furthering understanding of the mechanism underlying Mn neurotoxicity and in the search for effective treatments for Manganism, and in particular concerning PAS as a therapeutic agent.

P2.37 MICHAELSON, C. S.*; DAGG, J. N.; ASSIS, V. R.; MENDONCA, M. T.; Auburn University, Universidade de São Paulo; *csm0022@auburn.edu*

Invasive Cane Toads in Florida advancing north and demonstrating latitudinal variation in an innate immune measure and baseline corticosterone levels

The *Cane Toad, Rhinella marina*, is native to South and Central America, but was introduced to Palm Beach County, Florida, for pest control circa 1935. Its range has been limited to the southern third of Florida for decades. Recently, we have documented established populations of this species at greater latitudes than the isothermal minimum predicted by Urban, Phillips, Kelly, and Shine (2007). As part of a study to determine what physiological adaptations have occurred to allow this northern range expansion, we examined baseline and constraint−challenged glucocorticoid levels and plasma bactericidal capability as indicators of physiological condition for populations along the invasion front. We hypothesized that *R. marina* populations at higher latitudes and exposed to a more temperate thermal regime would experience chronic thermal stress, yielding significantly elevated baseline glucocorticoid levels, and depressed stress and immune response. Plasma samples were collected from *R. marina* specimens from Miami, Lake Placid, Sebring, New Port Richey, and, Deland, Florida, representing populations along a South to North gradient. Preliminary findings indicate that both baseline corticosterone and bacterial killing ability were significantly elevated in more northern populations, indicating that although toads in more northern populations have elevated glucocorticoid levels, this does not seem to depress an aspect of their innate immune response.

67.2 MICHEL, K.B.*; AERTS, P.; GIBB, A.C.; VAN WASSENBERGH, S.; University of Antwerp, Northen Arizona University, University of Ghent; *krijn.michel@uantwerpen.be*

Kinematics and functional morphology of fishes capturing prey on land

One of the unresolved aspects of the evolution of terrestrial vertebrates is how the aquatic ancestors of tetrapods were able to access ground−based prey. Through study of several extant lineages of amphibious bony fishes capable of capturing prey on land, the functional and morphological requirements of the capture and intra−oral transport of prey at the transition from the aquatic to the terrestrial environment can be elucidated. Here we analyzed the functional morphology and kinematics of three morphologically diverse, terrestrial feeding fishes from different families: the reedfish (*Erpetoichthys calabaricus*), the Atlantic mudskipper (*Periophthalmus barbarus*) and the largescale foureyes (*Anableps anableps*). These species of fish each use different strategies to position the head and oral jaws to capture terrestrial prey. The reedfish uses its eel−like body to inclines its head downward, placing the oral jaws above the prey. The Atlantic mudskipper pivots over its strong pectoral fins, and uses its complex oral jaw apparatus in combination with generating buccal water displacement to pick up and transport prey on land. The largescale foureyes positions its head above the prey and uses extreme upper jaw protrusion and rotation of the jaws to pick prey from land. These finding show that diverse solutions exist to overcome the physical challenges for feeding posed by the shift from the aquatic environment to a terrestrial environment.

35.3 MILES, DB*; MENDEZ DE LA CRUZ, F; SINERVO, B; Ohio University, Universidad Nacional Autonoma Mexico, University of California, Santa Cruz; *urosaurus@gmail.com*

Effect of Temperature and hydration on locomotor performance in Marine Toads Rhinella marina from a Mexican Tropical Dry Forest

The marine toad *Rhinella marina*, or cane toad, has been introduced to over 40 countries. One major invasion in Australia has resulted in the rapid expansion of the range and numbers of toads leading to a potential major loss of biological diversity. Studies on the Cane Toad in Australia has demonstrated rapid evolution in limb length, locomotor performance, critical thermal minimum (CTmin), and behavior. Surprisingly, a limited amount of information is available on the same traits for Cane Toads in their native range. Here we present the results from a study designed to examine the consequences of temperature and hydration on locomotor performance in Cane Toads. We also present data on CTmin, rates of water loss and water uptake, and limb lengths. We captured 18 *R. marina* at Chamela Biological Station, which is situated at an elevation of ~500m. We measured locomotor performance (distance jumped for 10 minutes) at three temperatures (25, 30, 35°C) and four hydration levels (100, 90, 80, and 70%). Locomotor performance increased with temperature, but declined with hydration level. CTmin was 7.32°C and 8.3°C for females and males, respectively. We found that locomotor performance of Chamela toads exceeded that of Australian toads at each level of hydration. CTmin values for *R. marina* in Mexico overlapped the values for cane toads at low elevations in Australia (7·5°C). Water loss and water uptake rates were also similar between Mexico and Australian toads. Our results demonstrate a striking decline in locomotor performance in Australian toads. However, our results re−enforce the observation of rapid evolution of physiological traits in an invasive species.

P2.50 MILLER, G*; MARSON, K; EARLEY, R.L.; University of Alabama; *gcmiller@crimson.ua.edu*

Does predation threat cause wild mangrove rivulus fish to jettison from the water?

When faced with predation risk, many species evade the threat through escape behavior, which may include moving to new habitats. Avoiding predation, though beneficial, comes with costs, so prey must be able to recognize and distinguish between threat levels to respond appropriately. Mangrove rivulus fish (*Kryptolebias marmoratus*) have the ability to emerse exit the water, into air and locomote on land to find different environments. We hypothesized that rivulus would emerse to avoid predation by mangrove water snakes (*Nerodia clarkia compressicauda*). We further hypothesized that the geographical origin of the fish would influence the latency to emerse after exposure to predator cues. To test these hypotheses, fish from three different regions of Florida were collected and exposed to chemical cues from water snakes that had been fed rivulus or fasted; deionized water was the control. Latency to emerse following cue presentation was compared across populations and geographical regions to determine whether fish exposed to more informative cues of predation threat (snake fed rivulus) would show shorter latencies to emerse than fish exposed to cues indicating only predator presence (fasted snake) or control. Preliminary analyses indicate strong population−level differences in the tendency and latency to emerse and moderate regional differences in emersion behavior. Contrary to our prediction, we found little evidence that predator exposure regimes influenced emersion behavior. Future analysis will use Noldus Ethovision XT software to more precisely analyze behavioral data, including distance and speed traveled, latency and duration of emersions, and number of emersions that occurred during the trial period. These data suggest that selection pressures other than predation might drive local adaptation of emersion behavior in rivulus.

63.7 MILLER, L.P.*; ALLEN, B.J.; DENNY, M.W.; Stanford University, Hopkins Marine Station, California State University, Long Beach; *millerlp@stanford.edu*

Increased low tide temperature variation drives increased growth rates of intertidal consumers

High temperatures during low tide periods are typically viewed as a potential detriment to the energy budget and survival of intertidal organisms. Because most marine organisms stop feeding or curtail photosynthesis during aerial exposure, there is no immediate opportunity to offset increasing metabolic demands by increasing energy intake while warm, such that faster metabolic rates and the induction of heat shock responses could lower the scope for growth. Using a novel manipulation of substratum temperature conditions during low tide, we tracked densities of microalgal food resources and growth rates of herbivorous limpets over several months at our central California field site. In contrast to our expectations, when low tide temperature conditions were warm but not close to limpets' lethal limits, we found evidence of increased growth rates in warmer microhabitats provided that sufficient food was available for feeding during high tide. Limpets in warmer microhabitats may be able to exploit warm low tide conditions to increase rates of both catabolic and anabolic processes, and may increase subsequent grazing effort during high tide to accommodate their higher metabolic rates in warm microsites. In view of the increases in average global temperature projected for the coming decades, small increases in air temperature as the climate warms may initially increase energy transfer through this simple trophic chain and increase the top−down control on microalgal communities by grazing limpets.

85.4 MILLER, H; MLYNARSKA, I; MINICOZZI, M; MASS, S*; SUNY New Paltz, Northern Arizona University; *masss@newpaltz.edu*

Making heads and tails of xenoestrogens in planarian regeneration

Environmental endocrine disruptors such as BPA and BPS, used in the manufacture of polycarbonate plastics, thermal printing systems, epoxy resins and other industrial processes, have been shown to depress and delay regeneration in a variety of flatworms and are lethal at high doses. The estrogen receptor (ER) antagonist tamoxifen can rescue the worms from these effects. In this work we examine the effects of much lower concentrations of BPA which are more environmentally relevant and find a concentration dependent increase in blastema growth with decreasing dosage. In vertebrate systems, weak ER agonists like BPA are known to have non−monotonic dose−responses which are similar to the decrease and increase in growth we observe in regenerating planaria. Prior work in our lab has suggested that bisphenol compounds are interacting with an ER−like pathway in planaria, and our current finding is consistent with this mechanism.

S9.1 MILLER, Laura A*; BATTISTA, N; GRIFFITH, B; University of North Carolina at Chapel Hill; *lam9@unc.edu*

A quantitative biology lab to compare simulations of crossbridge attachments to force−velocity and length−tension curves in skeletal muscle

In this presentation, we will describe a quantitative biology lab that uses both computation and experiment to understand force−velocity and length−tension relationships for skeletal muscle mechanics. For the quantitative component of the lab, students were introduced to both micro− and macroscale models of skeletal muscle contraction. For the macroscale models, students were shown simple mathematical models of length−tension and force−velocity relationships. In the microscale model, a population density function was used to describe the configurations of each crossbridge and the total force generated. The relationship between the crossbridge dynamics and the macroscale model of the force−velocity curve was then derived. Students were asked to explore the parameter space and assumptions of the model using a MATLAB code. The experimental component of the lab was conducted at the university gymnasium. Students were asked to measure the time it takes to lift various weights using leg extensions and pull down machines. By calculating the velocity of contraction for a series of weights, each student was able to calculate their own force−velocity curves. In terms of mathematics, this exercise teaches students about probability density functions, stochastic simulations, and linear regressions.

P2.85 MILLER, LB*; SANTANA, SE; University of Washington; *leith1@uw.edu*

Do Diverse Sensory Structures Drive Ecological Diversity in Neotropical Leaf−Nosed Bats (Chiroptera: Phyllostomidae)?

The evolution of differences in the sensory system can create new dimensions to ecological niches and allow resource partitioning and potentially diversification in bats. Neotropical leaf−nosed bats (Phyllostomidae) are one of the most ecologically diverse groups of mammals. They have a wide range of diets, foraging styles and extreme morphological variation in their sensory structures (i.e. nose leaves and ears). To date, there have been few broad comparative analyses focusing on how morphological differences of the sensory system evolve, and how they functionally affect echolocation parameters in foraging bats. This is a significant knowledge gap because morphological differences can affect fitness via their effect on prey capture performance. We use phyllostomid bats to address one important question about the sensory evolution of bats: how does the morphological diversity of external sensory structures map onto ecological diversity? We assess the role of foraging ecology as a selective force on the morphology of nose leaves and ears, and use these data to illuminate the drivers of ecological diversity in this group. Our analyses contrast the results from two− and three−dimensional morphometric data, collected using traditional methods and micro−CT scanning for a varied sample of phyllostomid species. We find dimensions of the horseshoe, one section of the nose leaf, explains most of the variation among species, and there are significant differences in morphology among dietary groups. Post hoc analyses indicated that nectarivores, sanguivores and frugivores differ from one another in nose leaf morphology. This study provides insight into how the morphology of the sensory system could shape bat ecology in an extremely diverse lineage of bats.

P2.127 MILLER, H; MLYNARSKA, I*; MINICOZZI, M; MASS, S; SUNY New Paltz, Northern Arizona University; *masss@newpaltz.edu*

Modeling the effects of xenoestrogens on planarian regeneration

Environmental endocrine disruptors such as BPA and BPS, used in the manufacture of polycarbonate plastics, thermal printing systems, epoxy resins and other industrial processes, have been shown to depress and delay regeneration in a variety of flatworms and are lethal at high doses. The estrogen receptor (ER) antagonist tamoxifen can rescue the worms from these effects. In this work we examine the effects of much lower concentrations of BPA which are more environmentally relevant and find a concentration dependent increase in blastema growth with decreasing dosage. In vertebrate systems, weak ER agonists like BPA are known to have non−monotonic dose−responses which are similar to the decrease and increase in growth we observe in regenerating planaria. Prior work in our lab has suggested that bisphenol compounds are interacting with an ER−like pathway in planaria, and our current finding is consistent with this mechanism.

P3.174 MILLS, W.B.*; BUTLER, M.R.; DEAROLF, J.L.; AVERY, J.P.; Hendrix College, Conway, AR , Univ. of North Florida, Jacksonville, FL; *millswb@hendrix.edu*

Morphology of the neonatal guinea pig scalenus muscle

Glucocorticoids are a class of steroids that are normally administered to women whose infants are at risk of being born prematurely. This treatment has been shown to combat the risk of Respiratory Distress Syndrome, but in some cases has led to developmental consequences later in life. Therefore, it is important to understand the different physiological effects of exposure to prenatal steroids. Past studies in our laboratory have been conducted on the scalenus, an accessory breathing muscle, from guinea pig fetuses that were exposed to multiple courses of betamethasone. In these studies, the proportions and diameters of type IIX and IIA fast−twitch fibers, the citrate synthase (CS) activity, and the expression of myoglobin were determined in steroid−treated and untreated prenatal muscles. However, to know if the features of the prenatal steroid−treated fetal muscles reflect acceleration of their development, the scalenus of neonatal guinea pigs must be characterized. Thus, we examined the morphology of the neonatal guinea pig scalenus and compared it to the results from the studies of the fetal muscle. The proportions of IIX and IIA fast−twitch fibers were quantified through antibody staining and the diameters of these fibers were measured using ImageJ. CS activity was determined with enzyme kinetic assays and SDS−PAGE was used to measure the myoglobin concentration in the one−day−old neonatal muscles. The features of the neonatal scalenus will be compared to those of fetal muscles exposed to prenatal steroids using ANOVAs. If the neonatal muscle is found to not significantly differ in morphology from those of fetuses exposed to prenatal steroid, then this would indicate that the steroid−treated prenatal muscles experienced accelerated development.

P2.70 MINEO, PM*; WALDRUP, C; BERNER, NJ; SCHAEFFER, PJ; Berea College, Sewanee: The University of the South, Miami University ; *Patrick_Mineo@berea.edu*

Thermal plasticity has diverged between northern and southern populations of the eastern newt (Notophthalmus viridescens).

Many temperate ectotherms use thermal acclimation to remain functional over a wide range of body temperatures, but few studies have investigated if populations of a single species have evolved differences in thermal plasticity. Therefore, we asked if thermal plasticity has diverged between northern and southern populations of the eastern newt (*Notophthalmus viridescens*). Eastern newts from Florida and Maine were acclimated to cold (6°C) or warm (28°C) conditions for 12 weeks. Following acclimation, we compared the thermal plasticity of locomotor performance (burst swimming speed) and the activity of metabolic enzymes between populations. The thermal plasticity of locomotor performance differed between populations−the newts from Maine were better able to acclimate to low temperature compared to the Florida newts. The activities of metabolic enzymes in liver and skeletal muscle also responded to thermal acclimation differently between populations. We also compared the thermal plasticity of membrane composition between populations. Cold acclimation resulted in a lower saturated fatty acid (SFA) content in cold compared to warm−acclimated newts from Florida, but acclimation did not affect SFA content in liver membranes of the Maine population. In liver, cold acclimation resulted in a higher monounsaturated fatty acid (MUFA) content in the Florida population and a higher polyunsaturated fatty acid (PUFA) content in the Maine population. These results suggest that the plasticity of membrane composition differs between northern and southern populations. Together, these studies demonstrate that the thermal plasticity of ectotherms is labile and can diverge among different populations of a single species.

104.5 MINICOZZI, M*; FINDEN, A; HANSEN, S; GIBB, A C; Northern Arizona University; *mrm539@nau.edu*

Faster fish fly farther: the morphological and behavioral factors that determine tail−flip jumping ability in killifishes

Though many teleosts appear to be fully aquatic and show no obvious morphological adaptation to life on land, they are still able to produce a tail−flip jump to move effectively across terrestrial environments. This study examined killifishes in the order Cyprinodontiformes, which display a gamut of jumping behaviors, from those which can propel themselves up to eleven body lengths in a single jump to those that struggle to become airborne. We hypothesized that, as killifishes spend more time on land, selection pressures should drive the evolution of a morphology better suited for terrestrial locomotion and that species−level variation in fish size and shape is associated with different jumping abilities. Based on results from previous comparative studies, we predicted that species with shorter, deeper bodies would generate less effective jumps (i.e., producing less displacement), relative to fish with larger longer, shallower bodies. We filmed ten individuals (600fps) from three species of killifish that vary widely in their morphology: *Gambusia affinis* ("good" jumper), *Jordanella floridae* (intermediate jumper) and *Poecillia mexicana* ("poor" jumper). While that there was no clear effect of body shape, we found that smaller, lighter species jumped further (when distance is calculated in body lengths), relative to larger, heavier species. In addition, the time it took to complete the jumping behavior was negatively correlated with how far a fish could jump; that is, faster fish fly farther. We predict that amphibious fish species will evolve smaller body sizes and rapid behaviors to facilitate moving about on land.

35.2 MISLAN, KAS*; DUNNE, JP; SARMIENTO, JL; University of Washington, NOAA Geophysical Fluid Dynamics Laboratory, Princeton University; *kasm@uw.edu*

Regional variability in the vertical zonation of P_{50} depths in the global ocean

Large regions of the pelagic ocean are hypoxic between depths of 150 m and 1000 m. Recent observations indicate that deoxygenated waters are shoaling and compressing the thickness of the vertical habitat of overlying marine ecosystems. Marine organisms ranging in size from tiny zooplankton to large predatory fish utilize the vertical habitat to forage for food and avoid predators. One adaptation that determines the tolerance of organisms to hypoxic conditions is the oxygen affinity of oxygen−transport proteins, hemoglobin and hemocyanin. Oxygen affinity is quantified relative to the oxygen tension at which hemoglobin/hemocyanin is 50% oxygenated, which is referred to as P_{50}. Temperature is an additional environmental factor that needs to be considered because oxygen affinity is sensitive to temperature for many species and there are thermoclines in the ocean water column. P_{50} is adjusted for the effect of temperature by using the heat of oxygenation in the van't Hoff equation. P_{50} depth is the depth in the ocean water column at which the oxygen tension equals P_{50}. We use temperature data and bias−corrected oxygen data from the World Ocean Atlas 2009 to determine the global distribution of P_{50} depths for a range of oxygen affinities and heat of oxygenation values. The areas of ocean where there are P_{50} depths are the Pacific Ocean, Arabian Sea, and Bay of Bengal. Heat of oxygenation had an effect on the vertical position and areal extent of P_{50} depths. The vertical distance between P_{50} depths was regionally variable − in some areas P_{50} depths were similar while in other areas P_{50} depths were separated by >100 m. Based on these results, we predict that habitat compression will alter species interactions in regions where vertical distances between P_{50} depths are increasing or decreasing.

P3.152 MISTICK, E.A.*; MOUNTCASTLE, A.M.; COMBES, S.A.; Harvard University; *a.mountcastle@gmail.com*

Effects of wing flexibility on bumblebee flight in turbulent airflow

Insect wings bend and twist during flapping flight, and the aerodynamic consequences of these passive deformations have been the focus of intense research in recent years. Both computational and experimental studies have found that wing flexibility enhances aerodynamic force production in a range of insects, including locusts, moths, hoverflies, and bumblebees. However, all of these studies have focused on steady locomotion in smooth flow or still air, whereas in reality, insects flying in natural environments rarely encounter steady airflows. We have noted previously that the wings of bumblebees appear to undergo larger passive deformations during flight in turbulent air as compared to smooth flow, suggesting that wing flexibility may play a role in stability enhancement and/or gust mitigation. To test this hypothesis, we flew bumblebees (*Bombus impatiens*) in a wind tunnel modified to generate turbulent airflow, and examined the effects of wing flexibility on flight performance by artificially stiffening a single flexible vein−joint that contributes to chordwise wing flexibility, using an *in vivo* micro−splinting technique. We tracked three−dimensional flight trajectories and compared lateral and rotational body motions in bees with unstiffened and stiffened wings. Our results reinforce the challenge that turbulent airflow poses to insect flight stability, and suggest that wing flexibility may play an important role in enhancing flight performance beyond its effects on force production.

P1.159 MITCHELL, G.W.; GUGLIELMO, C.G.*; HOBSON, K.A.; Univ. of Western Ontario, Environment Canada; *cguglie2@uwo.ca*

Measurement of whole body CO_2 production in birds using isotope concentrations in breath water

The doubly labeled water (DLW) method is an important tool for measuring energy expenditure in free−living animals, including humans. Here we present the results of a validation study where we measured isotope ratios in real−time from the water vapor of exhaled breath with a cavity ring−down (laser) spectrometer (CRDS). We administered DLW via intramuscular injection to five zebra finches (*Taeniopygia guttata*, mean mass = 16 g), five brown−headed cowbirds (*Molothrus ater*, mean mass = 52 g), and five European starlings (*Sturnus vulgaris*, mean mass = 79 g). Blood and breath samples were taken prior to enrichment (background), at equilibration, and 24 h following administration of the isotopes. Both breath and blood samples were measured with the CRDS. Isotope values from the blood were validated by comparing estimates of dilution space (g) with total body water (g) measured with quantitative magnetic resonance. We found a very strong linear relationship between dilution space and total body water for both isotopes ($R^2 = 0.99$), indicating the accuracy of isotope ratios measured from the blood. When comparing isotope concentrations from the breath and blood, we also found very strong linear relationships for both ^{18}H ($p < 0.001$, $R^2 = 0.98$) and ^{18}O ($p < 0.001$, $R^2 = 0.99$). Comparing estimates of whole body CO_2 production (mol/h) between the breath and blood, we again found a strong positive linear relationship ($p < 0.001$, $R^2 = 0.90$). Together our results suggest isotope ratios measured real−time from the water vapor in breath with a CRDS represents a promising new, less invasive, efficient, and simple method for quantifying energy expenditure in free−living animals.

20.3 MITCHELL, TS*; JANZEN, FJ; Iowa State University; *timmitch@iastate.edu*

Experimental analysis of the influence of nest substrate on offspring reptile phenotypes in the field

Embryos are highly sensitive to environmental conditions experienced during development. For oviparous reptiles, the hydric conditions and temperature of a nest are the key environmental factors shaping phenotypic variation. Weather is the primary determinant of nest temperature and hydric conditions, yet the effects of weather are mediated through the nest microhabitat selected by the mother. For example, there is a well−documented relationship between canopy cover above a nest and the nest thermal regime. Some aspects of the microhabitat have received considerably less attention, yet are plausibly also important in influencing nest conditions. Soil characteristics of nests vary substantially within and among populations, and these characteristics may influence temperature and/or water potential of the nest. Surprisingly, then, the influence of nest substrate type on phenotypes has not been experimentally assessed in the field. In this experiment, we incubate painted turtle (Chrysemys picta) eggs in three substrate types that are commonly selected by turtles within our study population. In a common area, we constructed six pits, which were refilled with loamy soil, sand, or gravel. Artificial nests were created in each substrate, and eggs were randomly assigned to a substrate type in a randomized block design. Eggs remained in these nests for ~90% of incubation, and were returned to the lab for hatching. Nest temperatures were measured, and preliminary analyses reveal that substrate type influenced nest temperatures. Thus, we expect that offspring phenotypes, including developmental rate, body size, and sex will also be influenced by substrate type. These findings suggest that soil characteristics are important aspects of the microhabitat for oviparous reptiles, and should be more carefully considered in future research.

115.3 MONAENKOVA, D.*; KUTNER, R.; GOODISMAN, M.A.D.; GOLDMAN, D.I.; Georgia Institute of Technology, School of Physics, Georgia Institute of Technology, School of Biology; *dmonaen@physics.gatech.edu*

Unequal division of labor among fire ant workers

S. invicta red imported fire ants (RIFA) construct complex subterranean nests. Nest construction is a collective effort emerging from interactions of individual workers with each other and the environment. We studied the distribution of the work load in small groups of RIFA during nest construction. In laboratory experiments, groups of thirty labeled RIFA were challenged to excavate nests in transparent containers filled with simulated soil of d=0.24 mm grain size and wetness W (W =0.01 or W=0.1 by mass). The excavation process was recorded continuously over 48 hours. The video data were analyzed to determine which ants participated in the excavation process and the proportion of the workload corresponding to each individual. We found that group members did not contribute to excavation equally. Aggressive diggers performed up to 50% of the total number of group excavations, while the contribution of less active individuals was sometimes less than 1%. We used Gini coefficient, G, derived from Lorenz curve to describe the inequality of work load distribution in groups of digging RIFA. We found that the average value of G was 0.74 (maximum value of G = 1) and was not affected by soil wetness W (p=0.21). Although the contribution of individuals to excavation varied with time, G did not vary with time G (p=0.31). The high values of G suggest that aggressive diggers were present in all experiments. We posit that an asymmetry of workload distribution is an important component of the organization of nest excavation and could function to reduce tunnel crowding.

28.5 MONROY, J.A.*; NISHIKAWA, K.C.; Denison University, Northern Arizona University; *monroyj@denison.edu*
Titin function during in vitro cyclic movements
The goal of predicting how muscle force changes during natural cyclic movements remains elusive. The sarcomeric protein, titin, has been suggested to play a role in a number of muscle properties that influence muscle work during cyclic movements. However, the role of titin remains to be elucidated. We used the muscular dystrophy with myositis (*mdm*) mouse, with a deletion in the N2A region of titin to investigate titin's role during *in vitro* work loop experiments. Previous research suggests that upon activation, the N2A region binds to actin, which increases titin stiffness. We hypothesized that the absence of N2A−actin binding in (*mdm*) muscles reduces force enhancement and doublet potentiation during cyclic movements. Using a servomotor force lever, we measured *in vitro* force and work of soleus and EDL muscles from wildtype and (*mdm*) mice. Muscles were subjected to sinusoidal length changes at a strain amplitude of ±5%L_0 while phasically stimulated at submaximal frequencies. Muscle force and work were compared with and without a doublet added to the train of stimuli. In wildtype soleus and EDL muscles, the addition of a single stimulus increased force throughout the entire stretch−shortening cycle. Work increased by 50% in wildtype soleus and 30% in wildtype EDL. In contrast, (*mdm*) soleus and EDL muscles showed little increase in force upon activation during stretch, and the work was the same with and without a doublet. These results are consistent with the hypothesis that upon activation, titin stiffness increases as a result of N2A−actin binding and contributes to active force and work of muscles during cyclic movements. In addition, these results demonstrate the importance of the (*mdm*) mouse as a model system for understanding how activation and applied forces interact to determine muscle force and work.

67.5 MONTUELLE, SJ; CRANE, EA; DAVIS, JS; WILLIAMS, SH*; Ohio University, Athens, University of Michigan, Ann Arbor, High Point University, North Carolina; *willias7@ohio.edu*
Gape cycle dynamics and omnivory: Is morphological generalization a one−size−fits−all' approach to food breakdown?
Mastication serves to change the physical properties (e.g., size, texture) of the food prior to swallowing. Recent investigations into gape cycle dynamics during mastication have identified food to be a major factor influencing variability in jaw kinematics. This work has also shown interspecific differences in patterns of variability that may be related to morphology and diet. Indeed, the close link between diet and morphology in mammals, particularly in the dentition, suggests that dietary generalists and specialists may differ in their ability to respond to differences in food mechanical properties. Here we investigated the impact of food mechanical properties on the temporal dynamics of the gape cycle in a quintessential mammalian omnivore, the pig, using X−ray Reconstruction of Moving Morphology. Results show that the power stroke and fast−open phases were shortest among all foods examined, but had the highest variability. Slow−opening was longest and exhibited low variability across the foods. Gape cycle phases during the mastication of brittle foods exhibited low variability compared to tough or soft foods, the latter which resulted in the highest variability in all phases of the cycle. Within a given food type, gape cycle phases are more variable than total gape cycle duration, which is relatively maintained across the different foods. This suggests that pigs temporally modulate gape cycle dynamics while maintaining overall chewing rhythmicity. Comparisons with other species, especially dietary specialists, will further highlight the different strategies utilized by mammals to effect food breakdown.

55.6 MOODY, KN*; CHILDRESS, MJ; WREN, JLK; KOBAYASHI, DR; BLUM, MJ; BLOB, RW; PTACEK, MB; Clemson University, University of Hawai'i at Manoa, University of Hawai'i at Manoa, Tulane University; *knmoody@clemson.edu*
Going with the flow: patterns of divergence, adaptation, and connectivity in a Hawaiian stream goby.
The interaction of larval transport and post−settlement selection on marine population connectivity influences how local adaptations arise in the face of gene flow. In the waterfall−climbing Hawaiian fish, *Sicyopterus stimpsoni*, larvae hatch upstream, are swept to the ocean and develop for months before returning to streams. Migration upstream requires climbing of waterfalls before reaching predator−free habitats. The environments to which juveniles return differ between the youngest (waterfalls close to shore, placing a premium on climbing ability) and the oldest (waterfalls far inland, placing a premium on predator evasion) islands. However, larvae from different islands may mix in the ocean, resulting in high gene flow and little differentiation between subpopulations. We developed spatially−explicit individual−based models for the islands of Hawai'i, O'ahu and Kaua'i coupled with a Lagrangian transport model for the Hawaiian Islands. We examined how topography, stream flow, predation, and immigration influenced optimal phenotype evolution and the rate of evolution. Immigration and emigration is largely unidirectional from Hawai'i to Kaua'i. All levels of immigration resulted in diminished rates of evolution of optimal phenotypes across all streams and islands. However, phenotypes conferring improved climbing performance on Hawai'i and O'ahu evolved even with high immigration rates. However, phenotypes conferring improved predator evasion on Kaua'i did not evolve. Our results suggest that a combination of local retention and environmental selection contribute to the potential for locally adapted phenotypes to evolve despite the high degree of gene flow between islands.

S1.9 MOORE, Talia Y*; VASUDEVAN, Ramanarayan; BIEWENER, Andrew A; Harvard University, MIT; *talia@oeb.harvard.edu*
Outrun or Outmaneuver: Ecological context informs more broadly applicable biomechanical studies
Many studies of terrestrial locomotion have expertly characterized maximum speed and metabolic cost of transport (relative to speed) for a variety of animals. Although these metrics can inform evolutionary hypotheses for a subset of animals that sustain high speeds for survival, biomechanical inquiry could be more broadly applicable by considering how the natural diversity of locomotion has evolved. For example, a predator with only one striking opportunity and limited feedback during the strike exerts a specific selective pressure on their prey. Measuring this prey's cost of transport may misleadingly report low fitness. In this case, locomotor unpredictability is more informative to evolutionary, ecological, and neuroethological hypotheses. To characterize the movement patterns of prey of single−strike predators, we developed methods to quantify the unpredictability of locomotion, and then determine the components of locomotion that generate unpredictability. We applied this method to sympatric desert rodent species and identified distinct predator evasion strategies. The bipedal ricochetal rodent varies speed and 3D direction of locomotion in short bursts to increase unpredictability. The quadrupedal rodent returns to safety using predictable 2D locomotion over a short distance when in danger. These results, when coupled with known differences in foraging behavior, suggest that this divergence in locomotor strategy may decrease interspecific competition for limited food resources. We demonstrate the broad benefits of developing new methods to analyze a variety of locomotor strategies: from engineering applications of pursuit and evasion tactics, to informing hypotheses regarding behavior, evolution, and ecology.

P3.197 MOORE, T Y*; FIELD, D J; BIEWENER, A A; COOPER, K L; Harvard University, Yale University, Univ. of California, San Diego; *talia@oeb.harvard.edu*

Quadrupedal to bipedal skeletal transformations inferred from a morphological and phylogenetic analysis of Dipodidae

Three desert−dwelling groups of rodents have independently acquired bipedal locomotion. The most diverse clade, Dipodidae, exhibits 8 distinct morphotypes across its extant taxa. This morphological diversity, interpreted within a novel phylogenetic framework, provides an unprecedented opportunity to study the transition from quadrupedal to bipedal locomotion in rodents. To identify traits associated with bipedality, we generated the first behaviorally relevant skeletal reconstructions of a bipedal jerboa (*Jaculus jaculus*) and a quadrupedal birch mouse (*Sicista betulina*). We then traced morphological transitions from quadrupedality to bipedality mapping characters from the 8 hindlimb morphotypes onto a molecular phylogeny of Dipodidae and estimating ancestral traits for each character within a Bayeseian framework. To compare jerboa limb proportions to those of other rodent ecomorphs, we performed a phylogenetic Principal Components Analysis using 38 species across Myomorpha. Our morphological data best fit a dual−optimum OU model, suggesting that although dipodid rodents experience different selective pressures from their quadrupedal relatives, they experience similar degrees of selection and drift as other members of Myomorpha. Combining functional morphological and phylogenetic comparative methods establishes testable hypotheses for the biomechanical advantages of bipedal locomotion and developmental mechanisms of skeletal transformation in response to changing selective pressures. Together, these data reveal fundamental insights into the repeated acquisition of bipedality across Myomorpha, one of the most conspicuous macroevolutionary patterns observed within rodents.

P1.36 MOORE, J. M.*; PAULAY, G.; Florida Museum of Natural History, Univ. of Florida; *jmoore@ufl.edu*

Abbreviated larval development in Majoidea is a driver of geographic differentiation

Crabs in the superfamily Majoidea have an abbreviated larval development, with fewer zoeal molts than most other brachyuran groups. A possible consequence of a shortened planktonic stage is reduced dispersal ability. This, in turn, may restrict gene flow between populations and lead to genetic structuring of taxa across geography. Populations of several widespread species in the superfamilies Majoidea, Xanthoidea, and Grapsoidea were sampled from western and eastern Australia, the Line Islands, French Polynesia, Hawaii, and the southwest Indian Ocean. Mitochondrial CO1 DNA sequences were obtained from multiple individuals at each location, and phylogenetic trees were constructed to evaluate geographic differentiation. Results show that most widespread majoid crabs are species complexes of highly differentiated, reciprocally monophyletic Evolutionarily Significant Units, often limited to single archipelagoes. In contrast, most xanthoid and grapsoid crabs appear to be truly wide−ranging, sharing haplotypes across distant localities. These results lend support to the hypothesis that planktonic larval duration is an important determinant of geographic differentiation.

105.2 MOORE, A.L.*; BARNES, C.J.; LEE, D.V.; University of Nevada, Las Vegas; *moorea3@unlv.nevada.edu*

Under Pressure: A tubular 3D force analysis of kangaroo rat burrowing

The study of burrowing biomechanics has been largely restricted to kinematics and one−dimensional force analyses in unnatural, soil free environments. We introduce the Tunnel−tube 2.0, a reworking of our previous force−sensitive tunnel−tube. This tube is composed of two custom designed and 3D−printed ABS plastic tube halves. The first half serves as an entry−tube leading to a soil−filled tunnel−tube. This second half consists of a thin−walled rubber tube covered with an array of x−ray markers and sealed inside of an oversized ABS plastic tube. The x−ray markers change position as the animal presses against the soil inside of the rubber tube, allowing us to track the direction in which outward force is applied to the soil during burrowing. A pressure transducer monitors the air in the inter−tube space between the thin−walled rubber tube and rigid ABS tube to determine the magnitude of outward force applied to the soil during burrowing. Each half of the tube is mounted on a separate six−axis force−torque transducer (ATI nano−17) six−axis load cell that measures the net reaction force exerted on the animal. During burrowing, the entry tube measures reaction forces on the hind limbs, while the soil−filled tunnel tube measures reaction forces on the forelimbs. With the exception of body weight support, reaction force must be equal and opposite in the entry−tube and tunnel−tube. In contrast, reaction moments about the transducers of the entry−tube and tunnel−tube provide information about the point of application of force for the hind− and forelimbs during burrowing. We use Tunnel−tube 2.0 to measure the burrowing of Merriam's kangaroo rats (*Dipodomys merriami*), which are known to dig extensive burrows, and we elucidate some mechanisms of burrowing in this species.

97.2 MORAN, C/J*; GIBB, A/C; Northern Arizona University; *cmoran.mlml@gmail.com*

Intraspecies variation of predator escape response kinematics in a Southwestern cyprinid

Most fishes perform a C−start (or fast−start escape response) in response to a negative stimulus. The C−start accelerates the center of mass away from the stimulus and is the primary mechanism for predator avoidance. We sought to determine the effect of temperature on development of the vertebrae and to ascertain if variation in vertebral number affects the C−start. To accomplish this we spawned roundtail chub (*Gila robusta*) and held individuals at 15°C, 20°C and 25°C through eight months of development. After this period, some individuals were cleared and stained to determine vertebrae number and the abdominal: posterior vertebrae ratio. With the remaining individuals we triggered a C−start behavior and recorded the response with high−speed videography. Performance variables were measured from these videos using ImageJ and Kinovea. Vertebral numbers did not differ between the three temperature treatments; however, the vertebral ratios did change with temperature. The 15°C−reared fish had a higher ratio of posterior to abdominal vertebrae, but 20°C− and 25°C−reared fish did not differ. During the C−starts, 15°C−reared fish had the highest body curvature, followed by the 20°C− and 25°C−reared fish. Variation in curvature did not translate to an increase in speed. The 20°C−reared fish reached the end of stage one (preparatory phase) in 0.041 seconds which was significantly faster than the 15°C− and 25°C− reared fish (0.049s and 0.045s respectively). Thus the 15°C−reared fish were the slowest during the C−start and displayed the highest curvature coefficient. 15°C−reared fish may be disproportionally long in the caudal region because they have more posterior vertebrae relative to the other fish. The extra vertebrae in the posterior region could allow them to be more flexible but decrease their speed entering and exiting the C−start.

97.4 MORINAGA, G.*; BERGMANN, P. J.; Clark University; *gmorinaga@clarku.edu*

The vertebral kinematics of convergent elongate, limb reduced squamates

The convergent evolution of body elongation and limb reduction is an extreme, yet widespread phenotype among vertebrates, especially among squamate reptiles. In addition to snakes and amphisbaenians, lizards have independently evolved snake like bodies at least 25 times. Snake like form in lizards evolves either through the addition of trunk vertebrae or via addition of caudal vertebrae. Snakes evolved from lizards via the addition of trunk vertebrae, having about 200−300 vertebrae, far exceeding those of snake−like lizards, which have up to 110 vertebrae. These differences in vertebral number may lead to functional and kinematic differences between these convergent body shapes. Furthermore, because these taxa rely solely on the vertebral column for locomotion, understanding the flexibility of the column is vital to understanding limbless locomotion. Here, we compared the vertebral kinematics and function between three taxa, a robustly limbed lizard, representing the ancestral state (*Lepidothyrus fernandi*), a long tailed surface−dwelling legless lizard (*Pseudopus apodus*), and a burrowing snake (*Eryx colubrinus*). We simultaneously took high−speed video from the dorsal aspect to measure the number of bends per body length and high−speed X−ray video to measure vertebral joint angles. We hypothesized that the legless lizard would exhibit vertebral joint angles and bends per body length intermediate to the robustly limbed lizard and burrowing snake, owing to an increased number of vertebrae relative to limbed lizards, but still having fewer vertebrae than snakes. Our findings suggest that legless lizards do indeed exhibit intermediate levels of bends per body length and vertebral joint angles, as snakes exhibited the greatest degree of flexibility and were capable of much sharper bends.

S5.1 MOROZ, Leonid L.; Univ. of Florida; *moroz@whitney.ufl.edu*

Convergent evolution of neurons and synapses from distinct cell lineages. NeuroSystematics: from Ctenophores to Vertebrates

Advances in Omics and their implementations to basal metazoan clades (Ctenophora, Porifera, Placozoa, Cnidaria, Bilateria) resulted to revisions of the animal phylogeny and hypotheses of neural evolution. Our analysis suggests that both neurons and synapses evolved independently from different cell lineages recruiting the ancestral machinery for secretion and reception developed in early eukaryotes. Temporal differentiation of cellular phenotypes found in unicellular eukaryotes (as result of their complex life cycles) was substituted and extended by spatial differentiation in metazoans leading to a greater diversity of cell types. Some components of synaptic and neuronal machinery might represent examples of convergent evolution. The most remarkable case is the parallel origins of cell lineages supporting intercellular signaling using various transmitters. Combining data from 20+ phyla, we will discuss how recruitment of various molecular modules together with environmental constrains might lead to independent origins of neurons and synapses across distinct animal clades. The cladistic reconstructions also suggest that neuronal centralization and mosaic formation of complex brains evolved at least 12 times across the animal kingdom. We define neurons as a functional rather than a genetic category. Neurons are polarized secretory cells specialized for directional propagation of electrical signals leading to release of intracellular messengers − features that enable them to transmit signals, primarily chemical in nature, beyond their immediate neighbors without affecting all intervening cells en route. However, using an array of molecular markers within some animal lineages one can recognize homologous neuronal lineages. These examples and criteria for homologization of distinct cell lineages will be discussed toward reconstruction of natural classification of neurons or NeuroSystematics.

111.5 MULLER, T.*; TAYLOR, G.K.; Animal Flight Group, University of Oxford, UK; *tonya.muller@zoo.ox.ac.uk*

Vision−based flight control of lateral perturbations in hawkmoths

The aim of this study is to link the optomotor response of tobacco hawkmoths *Manduca sexta* to their lateral flight dynamics. Using a virtual−reality flight simulator, we exposed the moths to oscillating wide−field, sinusoidal gratings and simultaneously measured the flight response with a six−component force−moment balance. The moths were exposed to single−sine stimuli with temporal frequencies ranging from 1 to 12Hz. Apparent self−motion was provided about four axes: pure roll about the horizontal body axis x, pure yaw about the vertical body axis z, and coupled roll/yaw rotations about either the longitudinal body axis x' or the dorsoventral body axis z'. We characterized the control mechanisms by estimating their time delays and comparing the magnitude and phase responses to those of common controllers. The responses to the four lateral perturbations consist of a coupled moment response, and to a first approximation depend upon feedback of both the angular position and angular rate of the stimulus. Additionally, we combined the measured responses to oscillations about the x and z axes to predict the measured responses to oscillations about the x' and z' axes. For most temporal frequencies, the linear superpositions closely match the measured responses to perturbations about the longitudinal and dorsoventral body axes. Although the measured optomotor responses are nonlinear inasmuch as they depend upon stimulus amplitude, it appears that these nonlinear responses to motion about different axes are effectively linearly superposed.

108.3 MUNOZ−GOMEZ, SA; PAIGHT, C; SAFF0, MB*; LANE, CE; SLAMOVITS, CH; Dalhousie Univ., Univ. of Rhode Island; *mbsaffo@post.harvard.edu*

A mutualistic apicomplexan symbiont in molgulid tunicates

With its unusual morphology and unexpected habitat (the renal sac of molgulid ascidians), *Nephromyces* has posed a stubborn phylogenetic puzzle since its first description 140 years ago. Recent data show indisputably that *Nephromyces* is an apicomplexan. As the only beneficial symbiont thus far found among the otherwise parasitic apicomplexa, *Nephromyces* presents an exceptional tool to probe the evolution of mutualistic outcomes in symbiotic interactions. In the first stage of a long−term study of *Nephromyces*−molgulid coevolution, we have begun a comprehensive genomic analysis of *Nephromyces*. Phylogenetic analysis of apicoplast genomes indicates that *Nephromyces* is a divergent apicomplexan clade, clearly distinct from, and possibly sister to, "core" apicomplexan clades. 18s rDNA sampling suggests that *Cardiosporidium*, an apicomplexan parasite of non−molgulid ascidians, is the sister group of *Nephromyces*. The association of both taxa with ascidians, the presence of symbiotic bacteria (rare among apicomplexa) in both taxa, and the highly derived features of both *Nephromyces* and molgulids raise the possibility that the *Nephromyces*−molgulid mutualism evolved from an ancestral apicomplexan−ascidian parasitism. There is surprising genomic diversity in *Nephromyces*, even among *Nephromyces* isolated from a single host individual; these data are reinforced by infection mechanisms that indicate the plausibility of multiple *Nephromyces* infections in individual hosts and by cross−inoculation experiments suggesting that some *Nephromyces* strains may infect more than one *Molgula* species. The observed genomic complexity also raises the possibility of functional diversity among different *Nephromyces* variants, and complex evolutionary and metabolic dynamics of both symbiont−symbiont and symbiont−host interactions in this system.

37.3 MURELI, S; FOX, JL*; Case Western Reserve University; *sxm822@case.edu*

Visual and mechanosensory integration for figure−ground discrimination

Multisensory integration is crucial for many animal behaviors. In flies, information from the mechanosensory halteres is combined with information from the visual system. Without this mechanosensory information, flies are unable to fly freely. We ablated the halteres of fruit flies (Drosophila melanogaster) and found that they are able to fly normally if glued to a rigid pin. This tethering prevents them from rotating their bodies, but permits them to steer their wings as they would in free flight. In doing so, we are able to observe the behavioral effects of the relationship between halteres and the visual system independently of the haltere's sensing of body rotations. We manipulated the haltere by removing the end−bulb to decrease the mass, and by removing the entire haltere including the campaniform sensilla. We find that manipulating the mass of the haltere has no effect on the fly's wing−steering efforts, but removing the campaniform sensilla prevents flies from responding to wide−field open−loop visual stimulation. Despite their defects in responding to wide−field stimuli, haltereless flies presented with a moving figure or a moving figure on a moving background showed similar responses to intact flies. Similarly, when flies are allowed to use their wing steering to control their own visual stimulus in closed−loop simulations, haltereless flies are able to fixate a figure in the frontal field, but cannot stabilize a wide−field stimulus. Our manipulations of the haltere feedback loop show that the haltere campaniform sensilla are necessary for wing−steering responses to wide−field visual stimulus, but the added mass of the haltere bulb is not.

S7.6 MURPHY, D.W.; WEBSTER, D.R.; KANAGAWA, M.; KAWAGUCHI, S.; KING, R.; OSBORN, J.; YEN, J. *; Johns Hopkins, Georgia Tech, Australian Antarctic Division [AAD], AAD, Univ. Tasmania; *jeannette.yen@biology.gatech.edu*

Aggregative behavior of Antarctic Krill: group interactions, multi−oar biomechanics, and hydrodynamic wake signature.

Many members of the plankton rely on multi−oared propulsion. One species that travels 200,000 body lengths/day and form schools generally characterized by synchronized and polarized swimming is the Antarctic krill, *Euphausia superba*. We have investigated the coordination of krill 3D swimming behavior, biomechanics of locomotory appendages, and structure of hydrodynamic wake. Krill swim by multi−oared propulsion, beating five pairs of swimming legs metachronally. Metachronal swimming, in which adjacent appendages stroke in sequence, is widespread among crustaceans inhabiting the transitional flow realm in which both viscosity and inertia effects are important. The ratio of the distance between adjacent appendage bases and appendage length is identified as a key design parameter. Our drag coefficient model comparing metachronal, synchronous, and intermediate motions revealed metachronal kinematics give the highest average body speed for both linear and quadratic drag laws. Experimentally, we found that krill increase swimming speed first by increasing beat amplitude and secondarily by beat frequency. Our time−resolved tomographic PIV measurements of a hovering Antarctic krill reveal flow being drawn backwards with each pleopod stroke with vortices forming around each pleopod pair during the power stroke. Measurements in the wake of the krill reveal a pulsed jet flow with mean and oscillatory components. This wake signature may form a communication channel with nearby conspecifics. To determine the presence of structure within schools of krill, parameters such as density, polarity, nearest neighbor distance, and nearest neighbor position suggest an anisotropic school structure in which nearest neighbor positions are nonrandomly distributed.

P1.158 MURRAY, J.D.*; OBERNDORF, M.E.; KIRCHER, B.K.; STERCULA, J.M.; JOHNSON, M.A.; Trinity University; *jmurray@trinity.edu*

Higher blood glucose levels linked to increased activity in wild lizards

Circulating glucose provides animals with an important energy substrate, as the metabolism of glucose is a primary mechanism by which ATP is produced. In healthy individuals, increased blood glucose levels are thought to indicate the mobilization of energy stores needed for sustained activity. However, this relationship is rarely tested in wild animals. In this study, we examined the relationship between activity levels and blood glucose in a Puerto Rican lizard, *Anolis stratulus*. This small−bodied species primarily occurs on large tree trunks or rocks, and is classified in the "trunk−crown" anole ecomorph category. We captured 32 adult male, *A. stratulus* from their natural habitat, and for each lizard, we conducted a 10 min open field test. These tests were conducted within 30 min of each capture, in a mesh cage located in the same forest patch where the lizards were captured. After each trial, we measured the lizard's blood glucose, mass, and snout−vent length. Our results indicated that individuals with higher glucose levels moved earlier, and longer distances, within a trial. In addition, we found no relationship between body size and blood glucose, or body size and movement patterns in the trials. In sum, this study provides evidence from a wild population of lizards for the link between blood glucose and activity levels, supporting the generality of this relationship.

P1.86 MYDLOWSKI, E.A.*; LEONARD, J.B.K.; Northern Michigan University; *emydlows@nmu.edu*

Dwarf hermit crab (Pagurus longicarpus) habitat selection in artificial tide pools

Most recent studies investigating tide pool phenomena have been field based and used constructed barriers or plots within natural intertidal zones; however, this environment can be challenging to control and manipulate. In this study, artificial tide pools were developed to mimic natural conditions in the laboratory. Replicate tide pools were constructed using plastic barrels with standpipes, submersible pumps, and head tanks to control the tidal stage and were equipped with video cameras for data collection. Using these replicated systems, we were able to control the tidal cycle, including the duration of exposure to flooding and ebbing as well as the length of the slack high and low tides. Oxygen profiles showed high oxygenation during flooding and high tides, while dissolved oxygen depleted as expected during the isolation of low tide. The dwarf hermit crab (*Pagurus longicarpus*) was then used to observe habitat selection of four substrate options (gravel, cobbles, sea grass, or no substrate) during different tidal stages within the artificial systems. Crabs survived well during six hour experiments and behaved as expected, including display of aggressive behaviors toward each other (including cannibalism). Analysis of 132 hours of video footage revealed that *P. longicarpus* moved freely among the habitat types during high and low tide periods, typically occupying the same area for a two hour period. This data suggests that the artificial tide pools function as a reasonable mesocosm and will allow researchers to test specific variables of interest, control for variation, and study tidal organisms under replicated, closed−circulation systems.

32.2 MYKLES, D.L.*; PITTS, N.L.; DAS, S.; DURICA, D.S.; Colorado State University, University of Oklahoma; *donald.mykles@colostate.edu*

Transcriptome analyses of intermolt and premolt molting glands from the blackback land crab, Gecarcinus lateralis

Growth via molting in crustaceans is regulated by arthropod steroid hormones, ecdysteroids. These hormones are synthesized and released from a pair of molting glands or Y−organs (YO). Molt−inhibiting hormone (MIH), released from X−organ/sinus gland complex in the eyestalk, negatively regulates ecdysteroid biosynthesis and thereby inhibits molting. mTOR and TGF^{2} signaling pathways control YO activity during molt stage−specific transitions. To further identify the genes involved in the regulation of molting, transcriptome libraries were generated from YO from intermolt and from early, mid, and late premolt animals. RNA−Seq, using the Illumina HiSeq platform, of three intermolt YO biological replicates generated 227,811,829 raw reads. These 100 bp paired end reads were mapped *de novo* using Trinity assembly software. The assembly generated 288,673 contigs with average length of 872 bp and contig N50 = 1842 bp. Using Bowtie 2.0, 91% of the raw reads were mapped back to the reference transcriptome. Preliminary targeted BLAST analysis of the reference intermolt YO transcriptome identified previously reported genes, as well as new sequences that encode ecdysteroid biosynthetic enzymes and a suite of phosphodiesterases. The reference transcriptome was evaluated by comparing full−length sequences obtained by Illumina sequencing with *G. lateralis* genes in the GenBank database (e.g., mTOR, Akt, ^{2}−actin, EcR, RXR, NO synthase, Elongation Factor−2, E75, myostatin−like, Ras, and NO−insensitive guanylyl cyclase). There were 98% to 100% nucleotide identities and protein similarities. Following annotation of reference transcriptome library, the goal is to identify gene networks that regulate YO activity and sensitivity to MIH through the molt cycle. Supported by NSF (IOS1257732).

13.2 NAIR, A.M.*; CHANGSING, K.H.; STEWART, W.J.; MCHENRY, M.J.; Univ. of California, Irvine, Univ. of Florida; *arjunnair0513@yahoo.com*

Larval zebrafish use visual information to direct their escape

Larval fish must detect and evade attacking fish predators to survive the ambush. The visual system is key to predator sensing in fish, but it is unclear how fish interpret visual stimuli to plan a successful escape. Essentially, what is the fish escape strategy and how does visual information feed into this strategy? To decipher this escape strategy, we used a robotic−fish predator to approach larval zebrafish (*Danio rerio*), while high−speed cameras recorded their escape responses in 3D. Larval zebrafish were able to detect and escape away from the fish predator. We modeled the visual stimulus presented by the predator from the larva's perspective using a visual model. By relating observed escape direction with respect to the direction of the predator's appearance, we determined that the larval zebrafish escape strategy is not sensitive to the predator's approach angle. Instead, the results imply that larvae use a "binary" escape strategy, where they escape roughly 90° to either their left or right side. This suggests that the visual escape strategy is a basic scheme to avoid fish predators. This conclusion brings to question if this is the best strategy larval zebrafish could implement or are there constrictions prevent larvae escaping in a move advantageous manner.

S5.5 NAKANISHI, N*; DEGNAN, S.M; DEGNAN, B.M; Univ. of Queensland; *n.nakanishi@uq.edu.au*

Sensory biology of sponge settlement and metamorphosis: towards defining the baseline for nervous system evolution

Neurons often are thought to have evolved from cells capable of sensing and communicating environmental signals to other cells. However, mechanistic understanding of sensory biology in early−branching metazoans is limited, and thus the basal conditions from which nervous systems may have originated remain poorly defined. Sponges are one of the earliest−branching extant animal groups and do not possess recognizable nervous systems. Currently it is debated whether the last common ancestor to all living animals was aneural, as in modern sponges, or possessed a nervous system, which was subsequently lost in the sponge lineage. Here we present recent analyses of the sensory system controlling larval settlement and metamorphosis in the demosponge *Amphimedon queenslandica*. We show evidence that an epithelial cell type enriched in the anterior third of the larva, referred to as the flask cells, constitutes the chemosensory organ for sensing metamorphic cues associated with the settlement substrate. At metamorphosis, these cells undergo metamorphic signal−dependent cellular transformation into a stem cell type the archeocytes. Given that the regulation of the initiation of metamorphosis by larval chemosensory neurons is a conserved feature of Eumetazoa, we propose that a larval sensory system to detect and respond to inductive environmental signals was present in the last common ancestor of Eumetazoa and sponges. However, the eumetazoan and sponge chemosensory organs strikingly differ in their developmental potential; eumetazoan larval chemosensory organs and nervous systems are thought to be terminally differentiated, while the sponges' are not. The terminal differentiation mechanisms may thus be critical for the emergence, or the maintenance, of stably interconnected networks of neurons in evolution.

81.4 NAKATA, T.*; LIU, H.; BOMPHREY, R.J.; The Royal Veterinary College, Chiba University; *tnakata@rvc.ac.uk*

Optimization−based study on the aerodynamic performance of flapping wings using a CFD−informed quasi−steady model

Insects take to the air and manoeuvre in three−dimensional space by generating aerodynamic force with their flapping wings. The tuning of wing kinematics with wing morphology is crucial for their fitness because it directly affects aerodynamic performance and agility. It is also an important consideration for the design of bio−inspired unmanned air systems. In this study, we investigate the aerodynamic performance of a flapping wing using the optimization of wing kinematics with a novel CFD (computational fluid dynamics)−informed quasi−steady model. The quasi−steady model is parameterized by a Navier−Stokes−based CFD model that is capable of integrating realistic wing−body morphology, wing kinematics and aerodynamics. Our model depends on the assumption that the aerodynamic forces simulated by CFD can be decomposed into the quasi−steady forces. Using least−square fitting, we calculated the wing shape−dependent coefficients for the quasi−steady model, or, in other words, the proportional constants for the relationship between the wing kinematics and instantaneous aerodynamic force and power. The quasi−steady model is validated by comparing the aerodynamic performance of a hovering hawkmoth between a CFD model and the new quasi−steady model. It demonstrates that our quasi−steady model outperforms a conventional blade−element model while remaining computationally cheap once the model has been parameterized. We use the model to explore a large range of kinematic patterns and identify the optimal wing kinematics. We can then see whether the wing kinematics of hovering hawkmoth is the global optima, and, if not, determine the kinematic constraints that limit aerodynamic performance.

69.4 NALINI, M.; Karpagam University, Coimbatore, India; *dr.nalini27@gmail.com*

Lectin− (=agglutinin) mediated Cellular Immune Responses in a freshwater crab, Parathelphusa hydrodromus

Non−self materials are melanized in arthropod hemocoel and thus the enzyme responsible for this melanization, phenoloxidase, has been believed to be involved in host defense. PO activity was found in the serum of *Parathelphusa hydrodromus* and this enzyme activity was enhanced by trypsin and microbial polysaccharides (zymosan). The serum also consisted of lysozyme−like activity detectable against Gram−positive bacteria *Micrococcus lysodeikticus*. Hemocytes are the main immunocompetent cells in crustacean cellular immune reactions. A quantitative study on the *in vitro* phagocytosis of rabbit RBC by the hemocytes showed that an enhanced phagocytic uptake was dependent on the presence of opsonic molecules, possibly a sucrose−specific agglutinin in the serum of *Parathelphusa hydrodromus*. Further the recognition and engulfment of rabbit RBC by hemocytes was also observed by the pretreatment of RBC by heteroagglutinins. Hemocytes showed phagocytic generation of superoxide anion but nitric oxide generation was not apparent. In addition hemocytes showed in vitro encapsulation response by selectively encapsulation DEAE Sepharose CL−6B beads. The results suggest the importance of these immune responses in host protection against invading pathogens.

112.4 NAPIER, KR; MCWHORTER, TJ*; MARTINEZ DEL RIO, C; FLEMING, PA; Murdoch University, Univ. of Adelaide, Univ. of Wyoming; *todd.mcwhorter@adelaide.edu.au*

Mistletoebirds vary their dietary intake of arthropods depending on time of year

Mistletoebirds (*Dicaeum hirundinaceum*, family Dicaeidae) are the primary dispersers of mistletoe seeds in Australia and are mistletoe fruit specialists, but are also known to ingest other fruits, nectar, and invertebrates. We used stable isotopes of carbon (δ13C) in breath, blood and feathers and nitrogen (δ15N) in blood and feathers from mistletoebirds to detect potential changes in diet through time and to investigate the proportional contribution of arthropods vs. fruit to their diet. Mistletoebirds were mist−netted and sampled and diet sources (i.e. arthropods and mistletoe fruit) sampled at three sites in south−west Western Australia when ripe mistletoe fruit was available at each site. Sampling occurred during the austral autumn, winter and summer months. We found that mistletoebirds appear to change their diet over time, as indicated by the significant differences in δ13C values of breath and feathers (tissues that have significantly different turnover rates) from birds at two of the three sites. We also found that the contribution of arthropods to the diet of mistletoebirds varies depending on the time of year, or between sites, ranging from 45% to 67%. This could be associated with increased protein requirements during breeding and moulting or differences in availability of food sources between the sites occupied at these times.

P3.89 NARANJO, SM*; PASTOR, MJ; YOUNG, CM; SALAZAR, TR; ABRAMSON, CI; HRANITZ, JM; University of Central Florida, San Francisco State University, Muhlenberg College, University of Chicago, Uluda University, Bloomsburg University of Pennsylvania; *Smorales20@knights.ucf.edu*

A pilot study investigating the effects of sublethal doses of imidacloprid on honeybee larvae: survival and cleaning behavior in nurse bees

Honeybees are important pollinators that appear to be threatened by the widespread use of neonicotinoid pesticides such as imidacloprid. The sublethal effects of imidacloprid on adult bee foraging effort and navigational abilities are well known. Recent studies of imidacloprid−induced winterkill revealed that bioaccumulation in hive reserves affects colony survival. We hypothesized that larvae fed pollen and nectar contaminated with sublethal doses of imidacloprid may not develop normally or, if successfully metamorphosed to adults, may perform poorly in the hive. Larvae by matched queens were divided into control and imidacloprid treatments. Larvae in the imidacloprid treatment were fed 1/100 of the LD50 (0.18 ng/larvae) in 1.5 M sucrose whereas control larvae were fed only 1.5 M sucrose. Larvae were fed 5 uL daily for 5−6 days before pupation and were maintained in hive frames. We subsampled 20 larvae for HSP70 assays and the remaining larvae pupated and emerged in an incubator. Larval mortality was difficult to assess in frames but did not differ between treatments. Pupal mortality was higher in imidacloprid treatments than control treatments but emergence rates of healthy pupae were not different between them. When new nurse bees were tasked with cleaning 20−30 cells contaminated with hive dust, nurses fed imidacloprid as larvae cleaned fewer cells than nurses in the control treatment. Our preliminary results suggest that larvae exposed to sublethal doses of imidacloprid exhibit latent effects on adult performance traits important to hive maintenance and survival. If confirmed in future studies, this may inform predictive models of colony collapse disorder.

73.6 NAVON, D*; ALBERTSON, RC; University of Massachusetts, Amherst; *dnavon@cns.umass.edu*

Characterizing the genetic basis of variation in African cichlid fin morphology

Neoteleosts exhibit tremendous diversity in morphology and behavior that often closely matches their adaptation to a particular feeding niche. For instance, benthic fish that pluck or scrape food items off the substrate tend to differ in consistent and predictable ways from pelagic fish that hunt food items suspended in the water column. Many fish radiations vary along this benthopelagic axis of diet, behavior, and morphology. While conspicuous differences occur in the head and trophic structures, significant changes in body shape and fin structure can also be found, which likely evolve in response to distinct locomotive demands associated with different foraging tactics. The highly speciose radiation of African cichlids have rapidly and repeatedly diverged along this major ecomorphological axis. Here we characterize natural variation of fin morphology found within two ecologically similar species of African cichlid, *Labeotropheus fuelleborni* (LF) and *Tropheops* sp. 'red cheek' (TRC). Notably we find that even between these close ecological competitors, variation in fin morphology is similar to that among major lineages. We also describe variation within a population of LF x TRC hybrids, and use that population to perform a quantitative trait loci analysis seeking the genetic factors that influence fin shape and its underlying musculature. Our work seeks to better understand the fundamental interplay between genetics, diet, and morphology, as well as its role in this adaptive radiation.

P2.117 NAYLOR, M. F.*; GRINDSTAFF, J. L.; Oklahoma State University; *madeleine.naylor@okstate.edu*

17± Ethinylestradiol Influences Courtship and Reproductive Success in Male Zebra Finches

Estrogen has a number of organizational and activational effects in birds. Female birds require estrogen for reproductive anatomy development. During adulthood, male and female courtship and reproductive behaviors are associated with the presence of estrogen as well. Even at low concentrations, hormones can have organizational and activational effects; therefore, exposure to exogenous estrogens can cause significant changes in physiology and behavior. 17± Ethinylestradiol (EE2), the synthetic estrogen in birth control pills, is found ubiquitously in wastewater effluents. Previous research has primarily addressed the organizational effects of EE2 exposure during embryonic development in birds, not the activational effects during adulthood. We tested the potential for EE2 to disrupt the courtship behavior of adult zebra finches (*Taeniopygia guttata*). Adults were divided among treatment groups (control, 0.03, 4 or 100 ng EE2) and orally dosed every other day for 3 weeks prior to courtship trials. Interactions between newly paired males and females were then recorded for 20 minutes. One day after courtship trials, nest boxes and nesting material were provided to the pair. Boxes were checked every day to monitor nest building, egg laying, incubation behavior, and hatching. To quantify growth rates, offspring were measured on days 5, 10, 17, 28, 36 and 50 post hatch. Adults were dosed up until nestlings hatched. Overall, EE2 treated males made fewer mounting attempts than control males. However, males treated with 4 ng of EE2 produced more offspring than control males. Control females produced more offspring than treated females, however this difference was not significant. These findings strongly suggest that EE2 exposure in adulthood influences courtship behavior and reproductive success.

78.5 NEEMAN, N; SOBEL, MJ; O'CONNOR, MP*; Drexel University, Temple University; *mike.oconnor@drexel.edu*

A particle learning approach to tracking moving animals

A common application of ecological times series analysis is reconstruction of animal locations with classification of animal behaviors (e.g., foraging, migrating, aestivating) at those locations. Among the most common analytic tools for such data are dynamic state space models and change point analyses. We sought to analyze movements of sharks with a data set characterized by: 1) large numbers of observations (up to 16000 locations per individual, 2) frequent (> 100) putative behavior shifts, and 3) uneven time intervals between successive locations. These characteristics limited the utility of standard methods and we sought to extend state space models via a particle filtering/particle learning approach that we believe may be useful in other ecological applications. Our approach serially examines each successive measured location (assumed to be contaminated with measurement error), proposes a series of latent true' locations, ranks each path (particle) and preferentially selects those paths best corresponding to the measured locations as in the particle learning method of Carvahlo et al. The method is computationally intensive but allows both flexible description of the putative behavioral states (here foraging vs transiting) and confidence estimation for states at each location. Synthetic data sets suggest that state classifications can be improved by analyzing each data set repeatedly to eliminate estimates with low confidence, and finding consensus' estimates among high confidence estimates.

P3.105 NEKOLNY, SR*; DENNY, M; BIEDENBACH, G; HOWELLS, EM; MAZZOIL, MM; DURDEN, WN; MORELAND, L; LAMBERT, JD; GIBSON, QA; University of North Florida, Georgia Aquarium Conservation Field Station, Harbor Branch Oceanographic Institute, Hubbs−SeaWorld Research Institute; *s.nekolny@unf.edu*

The Effects of Study Area Size on Home Range Estimates of Bottlenose Dolphins (Tursiops truncatus)

Knowledge of an animal's home range is a crucial component of informed management decisions. Yet, many home range studies are limited by study area size, and thus may underestimate the size of the home range. Here, data collected by multiple research groups studying dolphins on the east coast of Florida were combined to determine how home range estimates change with increasing study area size. Analyses used photo−identification data collected in the St. Johns River (SJR; Jacksonville, FL) and adjacent waterways, extending a total of 253 km south to Mosquito Lagoon in the Indian River Lagoon estuarine system. Univariate kernel density estimates (KDE) were computed for individuals with 10 or more sightings (n=20) by projecting coordinates onto a midline through all study areas with distances from the origin measured for each point. Sightings were weighted by survey effort in each area. Kernels were calculated for the primary study area (SJR) first, then additional kernels were calculated by combining the SJR and the next adjacent waterway; this continued in additive fashion until all study areas were included. The 95% and 50% KDEs calculated for the SJR study area alone ranged from 21−35 km and 4−19 km, respectively. The 95% and 50% KDEs calculated for all combined study areas ranged from 116−217 km and 9−70 km, respectively. This study illustrates the degree to which home range may be underestimated by the use of limited study areas and demonstrates the benefits of conducting collaborative science.

BERN.1 NELSON, Randy J; Ohio State University; *rnelson@osu.edu*

The Dark Side of Light at Night

Life on earth has evolved during the past 3−4 billion years under relatively bright days and dark night conditions. The wide−spread adoption of electric lights during the past century exposed animals to significant light at night for the first time in their evolutionary history. Endogenous circadian clocks depend on light to entrain to the external daily environment, and seasonal rhythms depend on clear nightly melatonin signals to assess time of year. Thus, light at night can derange temporal adaptations. Indeed, disruption of naturally evolved light−dark cycles results in several physiological and behavioral changes with potentially serious implications for reproduction and survival. In this talk, I will discuss several mechanisms through which light at night may exert its effects on circadian and seasonal rhythms, as well as describe the downstream effects of disrupted biological clock mechanisms on reproduction, immune function, and the timing of food intake.

102.4 NEMETH, Z*; GRAVES, E; RAMENOFSKY, M; University of Debrecen, Hungary , University of California, Davis; *mramenofs@ucdavis.edu*

Is testosterone required for a timely departure from the wintering grounds for a long−distance migrant?

Testosterone is thought to play a major role in the physiology and behavior of spring migration but questions remain. American Redstarts (*S. ruticilla*) treated with testosterone advance departure from their wintering grounds in the Neotropics. Yet various species castrated after winter solstice will fatten and express migratory restlessness in captivity. It is not known whether testosterone is essential for initiation of vernal migration in free−living White−crowned Sparrows (*Z.l. gambelii*). Thus, we tested the hypothesis that testosterone is necessary for a timely departure at the outset of vernal migration by chemically castrating male White−crowned Sparrows. We captured 12 adults (A) and 11 first years (F) birds near Davis, CA early April 2014 as they were finishing prealternate molt prior to premigratory fattening and migratory departure. Individuals were randomly assigned to either treatment or control group. Treatment birds (6 A and 6 F) received two flutamide (antiandrogen) and two 1,4,6−androstatriene−3,17−dione (ATD, aromatase inhibitor) implants after capture while controls (6 A and 5 F) received blank implants. Birds were then held for 48 hours in outdoor aviaries for observation then received a 0.7 g radio−transmitter before release. Each bird was located at least once every day after release until they disappeared from the area. We found that treatment did not delay departure ($P>0.05$); however, age influenced timing − adults departed significantly earlier than first year birds regardless of treatment ($P<0.05$). Contrary to the hypothesis, testosterone is not influencing initiation of migratory departure while suggesting age and possibly other factors are involved, the nature of which remain to be investigated.

18.6 NEUMAN−LEE, LA*; BRODIE, JR., ED; FRENCH, SS; Utah State University, Utah State Univ.; *lorin215@gmail.com*

Physiological consequences of evolution: Quantifying the costs of adaptive resistance to tetrodotoxin in gartersnakes

Measuring the physiological consequences of discrete evolutionary adaptations is a critical component to predicting ecological responses. While adaptations may be overall beneficial to an animal, there may be unknown costs. To adequately understand potential trade−offs associated with discrete physiological adaptations, we must measure the true costs of these adaptations. To accomplish this, we utilized a well−known model of co−evolution: the resistance of the natural toxin tetrodotoxin (TTX) by gartersnakes that are sympatric with TTX−secreting newts, a prey item. Gartersnakes that have evolved outside the range of these newts have not evolved this resistance, making a contrast between individuals with high and low resistance possible. We measured individual resistance to TTX in snakes from a resistant population from Benton County, OR and a non−resistant population from Cache County, UT by determining the dose that reduced racing speed by 50%. To assess the potential trade−offs involved with evolving this resistance, we determined the efficacy of the stress and immune responses in these individuals by quantifying corticosterone (CORT) and bactericidal ability. By correlating these important life−history functions to a measurable adaptation such as resistance to a natural toxin, we can better understand the role of physiological processes in evolution.

14.2 NEUTENS, C; DE DOBBELAER, B; CLAES, P; ADRIAENS, D*; Ghent University, Catholic University Leuven; *dominique.adriaens@ugent.be*

3D surface−based morphometrics used to determine the intraspecific differences within the tail of syngnathid fishes

Seahorses and pipehorses both possess a prehensile tail, a unique characteristic among teleost fishes, allowing them to grasp and hold onto substrates, like sea grasses. Pipefishes, representing the ancestral condition, have a rather rigid tail. The tail of all these syngnathid fishes is characterized by a vertebral column that is surrounded with dermal plates − four per vertebra. The goal of this study is to determine the relation between the differences in plate and vertebral morphology and the flexibility of the tail. To do so, a 3D morphometrical analysis based on surface meshes generated based on µCT−scans was performed, followed by a PC analysis and a scree plot with broken stick analysis. Four different analyses were applied on the tail of nine different species (four pipehorses, two seahorses, one pipefish and one seadragon): (1) a comparison between the proximal and distal vertebrae, (2+3) a comparison between the proximal and distal ventral resp. dorsal plates and (4) a comparison between both the dorsal and ventral dermal plates. For the analysis on the vertebrae, the main differences could be found in the length and orientation of the parapophyses and the neural and hemal spines in all species, as well as the inclination angle of the vertebral body in species with a prehensile tail. The main difference between the proximal and distal dermal plates in prehensile tails is the overall shape of the plates, which changes from rectangular to square. The analysis comparing the ventral and dorsal dermal plates showed significant differences between both in all studied species. Overall, a higher intraspecific variation is observed in species with a prehensile tail.

107.6 NEVELN, I.D*; CHEN, C.; MACIVER, M.A.; Northwestern Univ., Evanston, IL; *ineveln2@gmail.com*

Increased movement compensates for noisy sensory acquisition

Many animal behaviors involve motion of the body or appendages for sensing the environment to gain information, which we term active sensing. As an example, weakly electric fish will sweep back and forth near a novel object to gain information. Using information theoretic approaches should help explain such movements in active sensing tasks that seem counterproductive. For instance, bats aim their sonar pulses off axis from a target, which decreases signal intensity but maximizes a common measure of information. However, in simulations of a mobile sensor tasked with tracking a target moving along a line, sensor motions that visit portions of the line proportional to the amount of expected information vastly outperform motions that constantly maximize information. The resulting simulated trajectories feature oscillations around the target in order to maintain a low variance estimate of object location. Moreover, as the signal to noise ratio (SNR) increases, these oscillations diminish and the sensor trajectories more closely match target motion. Electric fish (*E. virescens*) will follow the movements of a swaying shelter to remain hidden but also exhibit extraneous fore−aft and bending motions similar to when they are sensing a new object. This extra movement is more prevalent when visual cues are unavailable and SNR is low. Moreover, by further decreasing the SNR through conductivity increase or by applying a jamming signal (both shown to degrade electrosense), the fish increases the amplitude of the extra movements. These trends are consistent with the simulations of the target tracking task in various levels of noise. Using this information−theoretic approach might elucidate reasoning behind other non−intuitive animal behaviors and guide robotic algorithms for information gathering tasks to be more effective.

P2.91 NEWTON, K.C.; Florida Atlantic University; *knewton5@fau.edu*

Magnetic Field Perception, Learning and Memory in the Yellow Stingray, Urobatis jamaicensis.

Sharks and rays are hypothesized to use geomagnetic cues to orient and navigate across the ocean, but magnetoreception is not well documented in elasmobranchs. Yellow stingrays (N=10) were held in a flow through seawater tank under a 12:12 hr light dark cycle and were fed daily. Rays were trained to associate a magnetic stimulus with food by giving each ray a morsel of food when it swam over a magnet buried in the sand. Neodymium magnets and non−magnetic controls were coated in epoxy to prevent galvanic currents between the metal and seawater that would stimulate the electroreceptors. The learning criterion was the minimum latency for each ray to correctly orient and stop over a buried magnet (e75%) in four tests per day for three consecutive days. Once criterion was met the training stopped and memory retention tests began without additional reinforcement. Each test was a simple choice between a magnet and a demagnetized control buried under the sand at a random location within the arena. Memory retention was tested at 30, 60, and 90 days after training ceased. All rays were demonstrated a magnetoreception because they reached criterion within two weeks and retained the memory for over 60 days. Future experiments will determine the nature and range of magnetic stimuli that elasmobranchs can detect, and whether these stimuli are potential cues for orientation and navigation.

P2.57 NGUYEN, T.T.*; BURNAFORD, J.L.; California State University, Fullerton; *vynguyen313@csu.fullerton.edu*

Effects of low tide conditions on the photosynthetic health of the kelp Egregia menziesii

Conditions in the intertidal zone differ at high and low tide. Exposure to stressful low tide conditions (high light and temperature, wind and low humidity) may have immediate and persistent negative effects on the photosynthetic ability of seaweeds. We utilized laboratory manipulations to investigate the effects of stressful low tide conditions on the photosynthetic health of the low intertidal canopy−forming seaweed *Egregia menziesii*. We compared responses of individuals in five treatments: one no−emersion treatment (low light, low temperature, no desiccation) and 4 realistic emersion treatments: low stress (low light, moderate temperature, low desiccation), low light + desiccation (low light, moderate temperature, constant wind), high stress (high light, high temperature, ambient desiccation), and high light + hydration (high light, high temperature, seawater spray every 5 minutes). We assessed the seaweed's photosynthetic potential by measuring dark−adapted Maximum Quantum Yield (MQY) via pulse amplitude−modulated fluorometry, evaluated tissue damage by quantifying tissue colour (as % of total area with visible discolouration), and measured biomass loss. After a 2 hour simulated low tide, we assessed performance each day for 3 consecutive days. We found that both high light and desiccation reduced photosynthetic performance and resulted in tissue damage and biomass loss although the individual effects of these factors were not equal in magnitude. Our study suggests that even a single stressful low tide can have permanent consequences for the seaweed. Understanding how individual seaweeds respond to combinations of environmental factors will aid in predicting how seaweed populations will be affected by the changing climate.

P3.29 NICASTRO, LK*; MISTRY, HL; COUGHLIN, DJ; Widener Univ., Chester, PA; *lknicastro@mail.widener.edu*

The effects of thermal acclimation on gene expression in rainbow smelt, Osmerus mordax , muscle

Rainbow smelt, *Osmerus mordax*, show a strong thermal acclimation response to cold water, including significantly faster muscle properties in winter fish. Our goal is to understand the effects of thermal acclimation on gene expression in muscle using RNA−Seq. We examined differential gene expression in smelt fast−twitch or white myotomal muscle of cold− vs. warm− acclimated fish. Our analysis initially targets genes that code for important muscle proteins such as myosin heavy chain and light chains (MyHC, MyLCs), tropomyosin, and troponin C. We predict that expression of these genes will be affected by thermal acclimation. &beta−Actin did not differ with thermal acclimation and served as an appropriate control. Each of the four muscle proteins that we targeted originally showed a significant difference in expression in the cold− versus warm−acclimated fish. For instance, cardiac MyHC, a slow isoform of myosin, was expressed at a significantly higher level in warm− vs. cold−acclimated fish. As reported previously for liver tissues, glyceraldehyde−3−phosphate−dehydrogenase and glycerol−3−phosphate−dehydrogenase expression varied significant with thermal acclimations. When controlling for actin expression, troponin C, tropomyosin, and alkali MyLC showed significant but conflicting as to the effects of thermal acclimation. Results will be presented for RNA−Seq analysis of thermal acclimation and gene expression in smelt fast−twitch myotomal muscle.

P3.20 NICHOLAS, J*; AWAN, A; MCCUE, MD; WILLIAMS, CM; HAHN, DA; HATLE, JD; Univ. of North Florida, St. Mary's Univ., Univ. of Florida; *jhatle@unf.edu*

Life−extending ovariectomy and dietary restriction each alter leucine metabolism in grasshoppers, but in different ways

Reduced reproduction and dietary restriction each increase lifespan in many animals. Reducing reproduction decreases dietary intake, and dietary restriction similarly reduces reproductive output. This has led to the widespread view that both treatments extend lifespan by overlapping physiological mechanisms. Work in *C. elegans* and mice suggests that long−lived animals have greater turnover of lipids. Hence, we measured nutrient oxidation in lubber grasshoppers. Four treatment groups were used: sham−operated & full diet (Sham−FD), ovariectomized & full diet (OVX−FD), sham−operated & dietary restricted (Sham−DR), and ovariectomized & dietary restricted (OVX−DR). Ovariectomy reduces feeding rate about 30%, and the Sham−DR group was fed the same daily amount as that consumed by the OVX−FD group. Exogenous nutrient oxidation was tested by feeding each individual one ^{13}C−labeled metabolic tracer (glucose, leucine, or oleic acid). Breath samples were collected hourly and tested for ^{13}13C content, which reflected nutrient oxidization during sampling. Glucose metabolism was highest in Sham−FD and lowest in OVX−FD. Dietary restriction increased leucine metabolism, whereas ovariectomy delayed leucine metabolism, with peak longer after ingestion. OVX−FD and Sham−DR animals with matched feeding had distinct profiles of leucine metabolism. Oleic acid metabolism was not affected treatment. In contrast to prior studies, our results suggest that highly reproductive animals metabolize more sugar, while minimally reproductive animals metabolize more amino acid. Oxidation of amino acids may be more important in life−extension than previously thought, especially for phytophagous animals.

P2.110 NIEBERGALL, A.K.*; DOUGHERTY, L.F.; CALDWELL, R.L.; University of California, Berkeley; *alex.niebergall@berkeley.edu*

Behavioral function of flashing in Ctenoides ales: "disco clams"

Ctenoides ales is an Indo−Pacific bivalve that has a vivid flashing display caused by the rapid movement of the mantle lip. One side of the mantle tissue has a dense collection of silica nanospheres, which are highly reflective, and the other side of the mantle tissue is absorbent. Experiments were conducted to determine the behavioral function of the flashing. Hypothesized fitness values included phototaxic prey luring, aposematic signaling, and/or conspecific recruitment. To test prey luring and aposematism, the clams were presented with stimuli of food (phytoplankton) and a looming predator, respectively. Their reactions were filmed and the flash rate was analyzed 5 seconds before and after the stimuli. Results showed a significant increase in flash rate with both stimuli. To test conspecific recruitment, nine tanks were divided in half using either transparent or opaque barriers. The experimental side of the tanks housed a *C. ales*, and the stimulus side of the tanks housed either another *C. ales*, a video of *C. ales*, the non−flashing congener *C. scaber*, a rock, or nothing (control). This setup allowed both visual cues (the ability to see another *C. ales* flashing, see only an object, or see nothing) and chemosensory cues (barriers either allowed water flow or prevented it) to parse out cues used in settlement position. Distance and orientation toward the stimulus was recorded every hour for 5 hours. Preliminary results indicate that both chemosensory and visual cues caused the experimental *C. ales* to move closer to the *C. ales* stimuli than the control. To investigate ecological variations in flash rate, light trials were conducted in different intensities of blue light to mimic various depths. Results showed no significant difference in flash rate between light intensities. Behavioral analysis is ongoing.

111.4 NIEDERSCHUH, S. J.*; SCHMIDT, M.; HELBIG, T.; WITTE, H.; Friedrich−Schiller−University Jena, Germany, University of Technology Ilmenau, Germany; *sandra.niederschuh@uni−jena.de*

Sinus hair sensing in forelimb positional control during the locomotion of rats (Rattus norvegicus, Rodentia)

Facial (mystacial) vibrissae, a kind of sinus hairs within the group of tactile hairs, have been intensively studied for muscle activities, neurological patterns, anatomy details and their biological role in different species. The skill to move in a more or less regular pattern (whisking) is known from various species, like rats. In addition to these whiskers rats have other sinus hairs, e.g. the non−moving carpal ones on the forelimbs. It has been assumed that carpal sinus hairs have a sensory function during locomotion on different substrates by detecting discontinuities while whiskers detect vertical obstacles. The possibility of a coupled sensorimotor control between the limbs and the sinus hairs might lead to a stabilized locomotion over uneven substrate. To test this hypothesis several spatiotemporal speed dependent parameters as well as kinematic data for the limbs were quantified and linked to the motion of carpal and facial sensors. Parameters were measured from x−ray and high−speed videos. A treadmill with continuous and discontinuous substrate was used. Rats had to walk under the presence and absence of the carpal and/or mystacial tactile hairs. Data were collected for a speed range of 0.2 to 0.5 m/s. Collecting tactile information by whiskers and carpal sinus hairs during touchdown and swing phase of the limbs is an important factor to get information about the substrate where the limb is going to be placed next. Loss of the sinus hairs affected the degree of parameter variation but not average parameters or the failure rate of the limbs during walking on the perforated treadmill. The motion of whiskers is affected by the presence/absence of the carpal sinus hairs and might compensate the loss of this substrate sensor.

P3.108 NIGHOHOSSIAN, C.B.; University of New Orleans; *cbnighoh@uno.edu*

Arthropod Abundance and Diversity in Restored Longleaf Pine Savannas at Abita Creek Flatwoods Preserve

The primary objective of this study was to determine whether changes in arthropod community structure in restored longleaf pine savannas corresponds to differences in vegetation structure often associated with burn frequency. Longleaf pine savannas are fire−maintained ecosystems characteristic of the southeastern United States and have experienced severe declines (around 97%) since European settlement. Changes in fire regime have been instrumental in the declines. Restoration of these ecosystems has involved reinstitution of periodic burnings to promote and maintain vegetative characteristics of the savannas. This study investigates trends in arthropod communities from areas heavily invaded by hardwood shrubs against those dominated by longleaf pines and associated vegetation. These data suggest that herb−dominated sites have higher overall diversity. While overall abundance differences were not found, significant differences have been detected at the order and family level, indicating that vegetation structure and periodic burning are important factors in maintaining arthropod communities characteristic of these savannas.

28.8 NISHIKAWA, K*; FUQUA, RD; HANSON, S; MONROY, JA; PACE, CM; Northern Arizona University, The Jackson Laboratories, Denison University; *kiisa.nishikawa@nau.edu*

Simulating titin's role in force enhancement using the "winding filament hypothesis"

We developed a "winding filament" hypothesis for muscle contraction that includes a role for titin in active muscle. The hypothesis proposes that N2A titin binds to actin upon Ca2+ influx in skeletal muscle, and PEVK winds on thin filaments during force development because cross−bridges not only translate but also rotate thin filaments. We used a kinematic model based on the winding filament hypothesis to simulate residual force enhancement in mouse soleus and extensor digitorum longus (EDL). In the simulations, N2A binds to thin filaments on Ca2+ activation, cross−bridges produce axial and radial forces according to the F−L relationship, and radial forces wind titin on thin filaments. Model variables are N2A distance (nm) from the Z−line and PEVK contour length. Residual force enhancement increases as N2A moves closer to the Z−line and as PEVK contour length decreases. We optimized N2A distance and PEVK contour length to fit passive tension and residual force enhancement data (R2 = 0.99) from soleus. Residual force enhancement in soleus is consistent with N2A binding, titin winding geometry, and PEVK contour length predicted by the kinematic model. We asked what changes in N2A or PEVK can explain observed differences in residual force enhancement between soleus and EDL. The simulations predict that N2A is 21 nm closer to the Z−line in EDL than in soleus. This corresponds to a deletion of ~4−5 proximal tandem Ig domains. The predicted difference in N2A location between mouse soleus and EDL is consistent with observed exon skipping events in the rat. Results show that the kinematic model of titin winding makes testable predictions about titin structure and function. Supported by NSF IOS−1025806.

53.7 NOEL, A*; WAGNER, C; MCKINLEY, G; MENDELSON, J; HU, D; Georgia Institute of Technology, Massachusetts Institute of Technology; *alexis.noel@gatech.edu*

To catch a fly: The role of saliva adhesivity during prey capture in frog tongue projection

Frogs and other amphibians attack flying insects through high−speed tongue projection, some achieving tongue accelerations of over fifty times gravity. In this experimental study, we investigate how a frogs sticky saliva enables high−speed prey capture. At the Atlanta zoo, we use high−speed video to film the trajectory of frog tongues during projection. We have also designed and built a portable extensional rheometer which allows us to analyze biological fluid properties. Using a frog saliva sample, we can mimic separation rates present during prey capture and so infer the adhesive force between tongue and prey.

P1.22 NOLEN, ZJ*; MILLER, CW; University of Florida; *zjnolen@ufl.edu*

The relationship between territory quality and male competition intensity in the cactus bug, Narnia femorata.

Sexual selection is primarily studied under artificial conditions or in only one ecological context. However, the dynamic nature of natural environments can alter sexual selection. We investigated changes in male−male competition, one agent of sexual selection, in multiple semi−natural contexts.. Males of the leaf footed cactus bug *Narnia femorata* compete using enlarged hind femurs for cactus territories. The nutritional quality of cactus territories varies seasonally through the availability and quality of fruit. We experimentally assigned males cactus territories without fruit, with unripe fruit, or with ripe fruit and observed male−male competition and mating success. We did not find a significant effect of territory quality on the intensity of male−male competition. However, we did see trends of both increasing number of male interactions with increasing territory quality, as well as heightened relative fitness for dominant males in higher quality territories. These trends, though not statistically significant, suggest a possible ecological interaction on male−male competition intensity as well as a possible underlying cause for this interaction.

14.6 NOTO, C.R.; University of Wisconsin−Parkside; *noto@uwp.edu*

What Big Claws You Have: The Ecomorphology of Felid Unguals

Felids differ widely in their predatory behavior, prey preferences, habitat preferences, and locomotion and have evolved unique anatomical adaptations to this end. While there has been much focus on the limbs and head, relatively little attention has been paid to the unguals. Ungual morphology and range of motion is interrelated with limb anatomy due to their role in both locomotion and predatory activities. This study applied a geometric morphometric analysis to over 180 individual claws representing 18 extant felid species. Results of principal components analysis (PCA) show that the majority of variation between species is explained by differences in the relative robustness (height vs. length) of the proximal ungual and degree of curvature in the keratinous sheath. Further analysis suggests that large and small prey specialists significantly differ from each other, while generalists are more variable. Results confirm the extreme specialization of cheetahs, whose claws are unlike those of all other living felids. Claw morphology is also strongly influenced by whether the species lives primarily in an open or closed habitat. These results have important implications for how we understand the anatomy and function of claws in felids, while creating a basis for determining ecological traits of extinct felids and other fossil carnivores. Studies like this provide the opportunity to examine the evolution of tetrapod unguals and identify ecomorphological traits common to particular niches.

46.5 NUNEZ, J.C.B.*; BARIS, T.Z.; CRAWFORD, D.L.; OLEKSIAK, M.F.; Rosenstiel School of Marine and Atmospheric Science , Rosenstiel School of Marine and Atmospheric Science; *j.nunez8@umiami.edu*

Genetic Variation in Mitochondrial Genomes from Populations of Fundulus heteroclitus Distributed Along a Thermal Cline

The marine teleost *Fundulus heteroclitus* is distributed along a steep thermal gradient (1°C/degree latitude) in the eastern coast of the United States. The mitochondrial DNA (mtDNA) of this teleost displays two characteristic haplotypes along this gradient. This haplotypes correspond to north, south and a phylogenetic break found at the Hudson River where there is an introgression of northern haplotype into the southern one. We examined mitochondrial activity and mtDNA variation in populations of *F. heteroclitus* with the aim of gaining insight into evolutionary adaptations to thermal stress. Activity assays were performed in 3 populations 1 from the north (ME), one from the south (GA) and one from the introgression zone (NJ); all populations were acclimated to 12 and 24 degrees. Activity was measured for state 3, complexes 1 and 2, and LEAK at maximum state. No differences where found between populations for any of the assays. However, significant high activity was found across all populations at different acclimated to 12°C temperatures for the assays of state 3 ($p=0.0176$) and LEAK ($p=0.0108$). mtDNA sequencing will be performed for the aforementioned populations plus 2 more southern populations (NC and VA) and the sister taxa *Fundulus grandis* (used as out−group). Data from sequencing will be analyzed to gain information on divergence due to the thermal gradient and possible signatures of natural selection.

P1.122 NUTTER, S.B.*; POWERS, D.R.; WETHINGTON, S.M.; CORMIER, T.A.; GRAHAM, C.H.; GOETZ, S.; George Fox Univ., Newberg, OR, HMN, Patagonia, AZ, Woods Hole Research Ctr, Falmouth, MA, Stony Brook Univ., Stony Brook, NY; *snutter11@georgefox.edu*

Climate−Change Response: The Impact of Solar Radiation on Hummingbirds at Mid and High Elevations

Faced with increasing temperatures due to climate change, researchers are looking to small, temperature−sensitive organisms such as hummingbirds to help understand how these changes will alter ecosystems and impact biodiversity. In response to increasing temperatures, these organisms may travel to higher elevations to escape thermal stress. At high elevations, however, lower air density can decrease convective−conductive heat transfer, and increase exposure to solar radiation. In this study we assess whether increased intensity of solar radiation at high elevations results in higher thermal loads for hummingbirds in spite of lower environmental temperatures. To test this we used infrared thermography to measure surface temperature (T_s) in free−living hummingbirds at mid−elevation (1500−1900m) and high−elevation (~3000m) sites in SE Arizona to measure the impact on radiant load. We found a strong linear relationship between hummingbird T_s and environmental temperature at both our mid and high elevation sites. At mid elevation, T_s changed 0.5−0.8 °C/°C T_a depending on species and, in some cases, gender. At high elevation, T_s changed <0.3 °C/°C T_a. Lower environmental temperatures at high elevations may affect thermal gradients in such a way that convective−conductive heat loss from a hummingbird's surface far surpasses any increase in radiant heat gain. Additionally, both high mid elevation sites offered dense vegetation that likely enabled hummingbirds to avoid exposure to direct solar radiation. These data suggest that vegetative structure will play an important role in the ability of hummingbirds to tolerate increased environmental temperature due to climate change.

5.7 O'BRIEN, HD*; BOURKE, J; Ohio University; *haley.d.obrien@gmail.com*

Physical and Computational Hemodynamics Models for the Artiodactyl Carotid Rete

In the mammalian order Artiodactyla, the majority of arterial blood entering the cranial cavity is supplied by a large arterial meshwork, the carotid rete, which functionally replaces the internal carotid artery. Extensive experimentation demonstrates that the artiodactyl carotid rete drives one of the most effective selective brain−cooling mechanisms recorded for vertebrates. Additionally, the unique morphology of the rete may have a beneficial impact on the hemodynamics of blood flow to the cerebrum. It has been hypothesized that the numerous interdigitating segments protect the brain from extreme changes in blood pressure by increasing resistance to blood flow. We test this hypothesis by applying simple and complex physical models to a 3D surface rendering of the carotid rete of the domestic goat, *Capra hircus*. First, we modeled the potential for increased resistance across the carotid rete using an electrical circuit analogy, wherein extensive branching of the rete equates to a parallel circuit linked proximally and distally to single arteries in series. This method calculates a near−zero increase in resistance across the rete. These basic equations do not incorporate drag, shear−stress, or turbulence, so computational fluid dynamics simulation was used to model the impact of more complex factors on resistance. Multiple−grid simulations of blood flow through the rete during both the high and low pressure portions of the cardiac cycle revealed negligible changes in pressure within the rete (a decrease of ~0.94 mmHg). Because both simple and complex models demonstrated minute changes in resistance and blood pressure across the arterial meshwork, we find blood pressure mitigation to be an unlikely function for the artiodactyl carotid rete.

51.3 O'CONNELL, K.J.*; MCGRAIL, K.A.; LAVERGNE, J.N.; RILEY, L.A.; WALKER, R.A.; DEAROLF, J.L.; AVERY, J.P.; Hendrix College, Conway, AR, Univ. of North Florida, Jacksonville, FL; *oconnellkj@hendrix.edu*

Fatigue properties of the neonatal guinea pig diaphragm

Glucocorticoids are commonly delivered to women who are at risk of premature birth in order to stimulate lung development in their infants. Although studies have shown an increase in lung development in steroid−treated babies, effects of glucocorticoids on ventilatory muscle development are not widely known. Previous studies in our laboratory found no change in the activity of an oxidative enzyme, citrate synthase (CS), in prenatal steroid−treated fetal guinea pig diaphragms. However, we found a decrease in the myoglobin concentration and fatigue resistance of these muscles in comparison to control fetal diaphragms. In order to determine if these changes in the morphology of the fetal diaphragm (DIA) represent acceleration of muscle development due to prenatal steroid exposure, a morphological profile of the neonatal muscle must be developed for comparison. The activity of CS was determined with enzyme kinetic assays on DIA samples of one−day−old guinea pigs. In addition, the fatigue resistance of neonatal diaphragms was measured using a standard two−minute fatigue test. Finally, SDS−PAGE was performed on neonatal DIA samples to determine the myoglobin concentration. The neonatal CS activity, fatigue resistance, and myoglobin concentration will be compared to prenatal steroid−treated fetal DIA characteristics using ANOVAs. If the steroid−treated fetal DIAs are found to not differ significantly from the neonatal DIAs in these characteristics, then the hypothesis that prenatal steroids accelerate breathing muscle development will be supported. And, if it is supported, treated babies would be better able to withstand ventilatory challenges when compared to their untreated counterparts due to an increase in oxidative capacity.

106.7 O'SHAUGHNESSY, K.L.*; DAHN, R.D.; COHN, M.J.; Genetics and Genomics, University of Florida, 7322 Countrywood Lane, Madison, WI, 53719, Howard Hughes Medical Institute, Department of Molecular Genetics and Microbiology, University of Florida; *koshaugh@ufl.edu*

Development of chondrichthyan claspers and the evolution of copulatory organs

The earliest known vertebrate copulatory organs are claspers, penis−like modifications of the pelvic fins that first appear in the fossil record of Devonian placoderms and are associated with evolution of internal fertilization and viviparity. Today, claspers are found in male chondrichthyans, where they retain their function as intromittent organs. However little is known about clasper evolution, or why only males undergo this fin modification. Using the Little Skate (*Leucoraja erinacea*) as a model organism, this study aims to identify the molecular mechanisms involved in formation of this evolutionary novelty. We find that the genetic circuit that drives vertebrate fin and limb development has prolonged activity in the fin buds of male skates, where it promotes localized outgrowth and differentiation of the clasper skeleton. Sexually dimorphic activity of the *Sonic hedgehog* (*Shh*) pathway, including its upstream regulator *Hand2*, maintains the feedback loop between Shh and fibroblast growth factors (Fgfs) in the posterior male pelvic fin. We demonstrate that Shh signaling is necessary for male clasper development, as well as sufficient to induce a clasper−like skeleton in female embryos. The sexually dimorphic activity of this circuit led us to ask whether androgen receptor (AR) is required for the male−specific pattern of *Shh*. We find that AR is necessary for *Shh* activity in male pelvic fins, and treatment of female embryos with the androgen 11−ketotestosterone is sufficient to maintain the *Shh−Fgf* circuit in female embryos. Taken together, these results suggest that hormonal control of *Shh* signaling was essential for the evolution of early copulatory organs.

69.1 OAKLEY, T.H.; Univ. of California, Santa Barbara; *oakley@lifesci.ucsb.edu*

On homology of Pancrustacean Compound Eyes

Compound eyes are quintessential complex traits, comprised of numerous parts that work together to perform exquisite functions. How and how often does such complexity evolve? One approach to this question is to trace the evolutionary histories of separate parts. The compound eyes of Pancrustacea (insects plus crustaceans) are variously comprised of corneas, crystalline cones, corneagenous cells, pigment cells, and receptor cells. These parts are themselves comprised of genetic components. For example, receptor cells express opsin genes, crystalline cones express crystallin proteins, and pigment cells express pigment synthesis genes. While many previous studies of compound eye origins and evolution considered compound eyes as a whole, an increasing database, including better phylogenetic trees, is becoming available to allow evolutionary investigation into parts of compound eyes. I will focus on the question of whether all Pancrustacean compound eyes are homologous. In particular, ostracod compound eyes may be non−homologous because many of their close relatives lack compound eyes. I will illustrate how genetic data from transcriptomes, such as opsin, crystallin, and pigment synthesis genes, can inform the question of compound eye homology.

P2.111 OBERNDORF, M.E.*; KIRCHER, B.K.; JOHNSON, M.A.; Trinity University , University of Florida ; *moberndo@trinity.edu*

Static and Dynamic Visual Displays in Anole Lizards

Many animals use visual displays as a method of signaling to conspecifics. Lizards in the genus *Anolis* are an excellent model for studying visual communication; most species possess a brightly colored throat fan called a dewlap, the structure and behavioral use of which is well−studied. Anoles generally extend the dewlap in response to potential mates or competitors, and retract the structure so that it is not visible when not in use. In addition to the dewlap, several anole species also have tail crests. These crests are composed of extended spines of scales on the lizard's tail that cannot be retracted. In this study, we tested whether dewlap size, a dynamic signal, and crest size, a static signal, were correlated with measures of individual quality in two species: *A. cristatellus* and *A. gundlachi*. We focused on two measures of quality: body condition and head shape, which is associated with bite force (and thus fighting ability). In male *A. gundlachi*, we found that crest area was correlated with head size, while dewlap area was correlated with both head size and body condition. In male *A. cristatellus*, we found that crest area was correlated with body condition, and that there was no relationship between dewlap area and any other traits. In females of both species (which do not possess tail crests, but do have dewlaps), we found that the dewlap area was not correlated with either head size or body condition. Together, these results suggest that in male anoles, both static and dynamic visual displays can communicate important information about an individual's physical condition. In contrast, in female anoles, use of the dewlap may primarily communicate information about an animal's immediate motivation.

34.5 OGUCHI, Y.*; SMITH, R.J.; OWEN, J.C.; Michigan State Univ., Univ. of Scranton; *oguchiyu@msu.edu*

Health consequences of differential stopover habitat use in fall migrating landbirds

Physiological markers related to health are important tools in evaluating stopover habitat quality for migrating birds. Stopover habitat is being altered by land−use change such as introductions of exotic shrubs. These shrubs bear fruits that differ in nutrient composition from their native counterparts, but knowledge is lacking on how that difference impacts the health status of birds. We hypothesized that fall migrating landbirds using exotic−dominated habitat in central Michigan, USA experience poorer health, with lower fat gain, constitutive immunity, and antioxidant capacity relative to those in the native−dominated habitat. We assayed blood from two migrating species (gray catbird *Dumetella carolinensis* and Swainson's thrush *Catharus ustulatus*) captured in native or exotic shrubland in the fall of 2012 and 2013 for triglycerides (fat gain index), total and differential leukocyte counts, activities of natural antibodies and complement, and antioxidant capacity. We found no differences by habitat in any of the measures in Swainson's thrushes. In gray catbirds, triglycerides, total leukocyte counts, and granulocyte: lymphocyte ratio did not differ by habitat, but individuals in the exotic shrubs showed lower natural antibody activities compared to conspecifics in the native shrubs in 2013. Furthermore, antioxidant capacity of gray catbirds in the exotic shrubs was lower relative to those in the native shrubs in both 2012 and 2013. Our results indicate that while use of exotic shrubs does not impact fat gain, reduced health relative to using native shrubs could occur in some species. Studies evaluating habitat quality using physiology should measure markers of immunity and oxidative status in addition to indices of fat gain.

104.1 OLBERDING, J.P.*; HERREL, A.; HIGHAM, T.E.; GARLAND, T. JR.; University of South Florida, CNRS/MNHN, University of California, Riverside, University of California, Riverside; *jpolberding@mail.usf.edu*

Segment contributions to hind limb evolution in phrynosomatid lizards

In lizards, longer hind limbs are often associated with faster maximum sprint speeds measured in the laboratory and sometimes with increased Darwinian fitness in studies of natural populations. Limb length may be altered by changing the length of one or all segments, with different functional consequences. For example, longer thighs may lead to increased speed by limb elongation, but could also decrease maneuverability by increasing the lateral extent of the limbs in a sprawling posture. Segment length evolution can be influenced by lineage−specific effects (multiple solutions), natural, and sexual selection. We examined segment evolution among 46 species of phrynosomatids. Because the sexes may be behaviorally dimorphic, we examined them separately to reveal any dimorphism in limb evolution. Limb segments do not scale isometrically with the combined length of the other segments; the thighs and toes of phrynosomatids are relatively shorter in species with longer hind limbs. *Cophosaurus*, *Holbrookia*, and *Uma* species have significantly longer hind limbs for their body size than other phrynosomatids. *Phrynosoma* have significantly longer crura and shorter toes for their body size than other species. Variation in hind limb length and segment lengths is not explainable by habitat use. Males in the genus *Sceloporus* have significantly longer hind limbs for their body size compared to other phrynosomatids, but this difference is not apparent in females. These results suggest that clade−level differences are more important than habitat use for explaining differences in limb length/proportions, and sexual dimorphism may be an important consideration in morphology−performance−behavior−fitness relationships.

95.3 OLSEN, AM*; WESTNEAT, MW; University of Chicago, IL; *aolsen@uchicago.edu*

When linkages deviate from planarity: A new 3D computational linkage model applied to the cranial linkages of birds and fishes

Skeletal linkages, or closed loops of inter−jointed, rigid elements, have evolved multiple times independently in the feeding apparatus of several groups of vertebrates, including fishes, snakes and birds. Previous research has shown that the geometry of a linkage is often sufficient to accurately predict its dynamic properties *in vivo*. Thus, linkage geometry can be used to better understand musculoskeletal function in single organisms, the functional diversity of species in an ecosystem or the evolution of musculoskeletal systems in a comparative context. Predictions of linkage properties have largely been made using 2D linkage models. However, 2D models are less suitable for modeling linkages that deviate substantially from planarity, such as the cranial linkages of birds and some fishes. More generally, we lack models for analyzing and comparing linkage geometries (2D and 3D) within the same theoretical framework. We present a new computational model, written in the R language, that predicts force and torque distribution, range of motion and kinematic transmission from four− and five−bar linkages of two and three dimensions. We use this model to develop a set of minimum parameters sufficient to represent all possible 3D four−bar linkage configurations, a subset of which includes all possible 2D configurations. Lastly, we apply this model to a dataset of 3D landmarks collected from a diversity of bird and fish skulls to ask whether and how deviations from planarity affect linkage properties. This new model unifies 2D and 3D linkages into a single theoretical framework, providing more realistic representations and accurate predictions of biological linkages. This work was funded by NSF grants DGE−0903637 and IOS−142549.

99.2 OLSON, RA*; WOMBLE, MD; THOMAS, DR; GLENN, ZD; BUTCHER, MT; Ohio University, Youngstown State University; *ro603313@ohio.edu*

Functional morphology of the forelimb of the nine−banded armadillo (Dasypus novemcinctus): comparative perspectives on the myology of Dasypodidae

The nine−banded armadillo (*Dasypus novemcinctus*) is a member of the family Dasypodidae, which contains all species of armadillos and represents the most diverse group of xenarthran mammals by their speciation, form, and range of digging ability. This study aims to identify muscle traits that reflect specialization for fossorial habit by directly observing forelimb structure in *D. novemcinctus* and comparing it among armadillos using available myological data as characters for future phylogenetic analysis. A number of informative traits were observed among Dasypodids, including the absence of m. rhomboideus cervicis and profundus, a scapular insertion of m. pectoralis profundus, the variable presence of m. articularis humeri and m. coracobrachialis, a lack of muscle mass for antebrachial supination, and two heads of m. triceps brachii with a scapular origin. Muscle mass and myosin heavy chain (MHC) isoform content were additionally quantified from our forelimb dissections. Notably, nearly 50% of the forelimb muscle mass is devoted to forelimb retraction and 25% to elbow extension, with fast MHC−2X as the predominant isoform expressed across all muscles studied. The digital and carpal flexors contain the greatest amount of the MHC−2A isoform, corresponding with an overall fast−to−slow shift in MHC expression along the length of the forelimb. Collectively, the findings emphasize muscle mass and power output for limb retraction and specialization of the distal limb for sustained purchase of soil by strong pronation and carpal/digital flexion. Moreover, the data assessed here provides a valuable resource for interpretation of myology and internal muscle architecture among digging mammals.

P1.129 OLSON, MN*; BOWMAN, J; BURNESS, G; Trent University, Peterborough, Ontario, Ontario Ministry of Natural Resources, Peterborough, Ontario; *meganolson@trentu.ca*

Torpor patterns and interspecific nesting in North American flying squirrels within a hybrid zone

The interbreeding of North American flying squirrel species is among the first contemporary examples of climate change−induced hybridization. Recent climate warming has caused the southern flying squirrel (*Glaucomys volans*) to expand its range northward, increasing sympatry with the northern flying squirrel (*Glaucomys sabrinus*). Flying squirrels are active in winter and share nest cavities to ensure survival in cold climates. We tested the hypothesis that cold temperatures lead to interspecific social nesting in the flying squirrel hybrid zone, a process that could facilitate hybridization since mating in flying squirrels occurs in late winter. We also tested whether differences in torpor use between flying squirrel species would make torpor a costly strategy in heterospecific nest groups compared to conspecific groups. Contrary to our prediction, the frequency of interspecific nesting did not increase with decreasing ambient temperature. Instead, *G. volans* chose to nest with conspecifics regardless of temperature, and *G. sabrinus* usually preferred to nest alone. While flying squirrels used torpor in winter, neither species used torpor when exposed to cold conditions during the summer months. Flying squirrels may only be physiologically capable of torpor in cold seasons; our continued research is evaluating these seasonal differences in torpor use. Identifying the causal mechanisms and the consequences of hybridization may facilitate the prediction of the future extent of hybridization in *Glaucomys* species, as well as the larger impact on biodiversity resulting from rapid rates of global change.

P1.31 ORFINGER, A.B.; University of Central Florida; *aorfinger@knights.ucf.edu*

Assessing the condition of the invasive catfish Hoplosternum littorale (Hancock, 1828) in peninsular Florida

Introduced species pose a major threat to biodiversity globally. One species of callichthyid catfish, *Hoplosternum littorale* (Hancock, 1828), was introduced to Florida waters from Neotropical South America and has enjoyed rapid dispersal since first being reported in 1995. Assessing the condition of invasive stocks is an important step in understanding the dynamics and success of introduced populations. In order to quantitatively evaluate the condition of the *H. littorale* in its nonnative range, this study reports for the first time the length−weight relationship (LWR) and Fulton's condition factor of the invasive *H. littorale* in Florida. Sampling was conducted from November 2013 to April 2014 in Tosohatchee Wildlife Management Area in Christmas, Florida. A total of 477 specimens were caught (6.40−13.50 cm TL). The allometric coefficient b of the LWR was greater than the isometric value (b=3.11), suggesting positive allometric growth. The average value for Fulton's condition factor (K) was 1.396, with no significant differences between size classes. The results differ from data recorded from the fish's native range, suggesting that this freshwater invasive is flourishing in Florida. Thus, these data could pave the way for additional studies addressing the ultimate causes of the success of *H. littorale* in Florida (e.g. parasite release). In addition, a new maximum total length of the species is reported.

P3.4 ORSBON, C.P.*; FAYANJU, O.A.; NEWCOMB, J.A.; GREENWALD, M.L.; ROSS, C.F.; University of Chicago; *orsbon@uchicago.edu*

Novel Program Identifies Individual and Class−wide Strengths and Weaknesses in Human Anatomy

Because the clinical importance of anatomical knowledge differs depending on a clinician's specialty, an anatomy curriculum must ensure that undergraduate medical students demonstrate competency in the full breadth of anatomical knowledge. Conventional testing methods are often unable to determine the specific strengths or weaknesses of both the students and the curriculum. For example, one would not know whether students pass exams by satisfactorily understanding all of the material, as opposed to ignoring some portion of it but studying another sufficiently to achieve a desired score (e.g. 65% in a pass/fail course). To address this uncertainty, we developed a program to quantitatively analyze student performance on electronic anatomy exams using resources readily available to many medical educators. Our program automatically identifies those individual questions which are potentially too easy or too hard as well as the overall concepts that the class both succeed and struggled in demonstrating competence. For example, analysis of two years of thorax exams revealed class−wide weaknesses in medical imaging and histology. We analyze each exam separately, and we then aggregate the exams to identify the concepts on which students consistently performed well or poorly, as well as which concepts on which students improved or declined. Though developed for anatomy in medical education, educators in a variety of disciplines can apply our program to their own courses to discover and correct potential weak points in the both individual students' knowledge base and the curriculum. Future directions include generating personalized student reports to facilitate targeted remediation for borderline and failing students.

102.7 OUYANG, JQ*; VAN OERS, K; HAU, M; Netherlands Institute of Ecology, Max Planck Institute for Ornithology; *j.ouyang@nioo.knaw.nl*

Becoming more like your mate: hormonal similarity reduces divorce rates in a wild songbird

In animals with bi−parental care, maintaining a pair−bond is of adaptive value because it increases reproductive success and reduces costs, such as energy and time, for finding a new mate. Hormones are important mediators of social behaviors as well as parental care, and endocrine mechanisms therefore are likely to be involved in the decision whether to stay with the same mate or separate after a breeding season. Because behavioral compatibility has been shown to increase fitness and hormones regulate behavioral traits, the implications from documenting the degree of endocrine similarity have broad applications for reproductive success and pair−bond longevity. We used a three−year study on free−living great tits (Parus major) to test if mates had similar hormone levels during the parental phase. We tested specifically if the metabolic hormone corticosterone was related to pair−bond longevity and reproductive success. Baseline, but not stress−induced, corticosterone concentrations were highly correlated between members of a pair and became more similar between members of a stable pair over multiple years. Pairs that increased their hormonal similarity within a season (from the pre−breeding to the breeding) had the highest reproductive success. Pairs with more similar baseline corticosterone levels and higher reproductive success were more likely to remain together after the breeding season. The results of this study suggest that pair−bond longevity is related to endocrine similarity and reproductive success, and raises the possibility that hormonal mechanisms may be under sexual selection.

S3.7 OWERKOWICZ, Tomasz; California State University, San Bernardino; *towerkow@csusb.edu*

Phenotypic plasticity of the crocodilian skeleton

Skeletal plasticity has been extensively documented in mammals, and some evidence of plasticity exists in modern birds. In contrast, little is known about skeletal responses to physiologic and environmental perturbation in "reptiles". Our understanding of skeletal biology of modern crocodilians is critical for confident functional interpretation of fossil specimens of extinct archosaurs. Here I review the available experimental evidence of how various factors affect bone growth and remodelling (or lack thereof) in modern crocodilians, focusing on laboratory−based studies of the American alligator (*Alligator mississipiensis*) and the estuarine crocodile (*Crocodylus porosus*). I consider potential influences of cardiovascular design (in−series *versus* in−parallel), locomotor activity (walking and swimming), muscle disuse (*via* tenotomy), atmospheric oxygen composition (12−36%), thyroid hormone level, and calcium supply. Most of these factors exert at best a limited effect on bone tissue in crocodilian hatchlings and juveniles, although chronic exposure to severe hypoxia and extreme hyperthyroidism can significantly alter post−hatching bone growth trajectory and microstructure. Developmental constraint on calcium supply, however, has a pronounced effect on macro− and microstructural properties of the embryonic skeleton. This suggests that skeletal plasticity in crocodilians may be temporally restricted to the pre−hatching period. Reduced post−hatching plasticity may be of selective advantage, as it allows these successful sit−and−wait predators to maintain a robust skeleton during long periods of musculoskeletal disuse. Whether it is an ancestral or derived character of crocodilians hinges on documentation of skeletal plasticity in other "reptiles", data for which are currently lacking.

P2.65 OYEN, K.J.*; SHELDON, K.S.; DILLON, M.E.; University of Wyoming; *koyen@uwyo.edu*

Effects of body size and acclimation on thermal tolerance limits of native bees

Thermal tolerance is a critical physiological trait with potentially broad ecological implications. Studies have linked critical thermal minima and maxima (CTmin and CTmax, respectively) to geographic distributions of diverse organisms, and these thermal limits will likely play a critical role in predicting shifts in geographic ranges and timing of phenological events in response to climate change. Recently, native bees have shown shifts in geographic ranges and phenology, however, despite their ecological importance, very little data exist on the thermal physiology of native bees and the mechanisms underlying thermal limits. We developed and implemented a high throughput analysis for determining CTmin and CTmax of bumblebees (*Bombus impatiens*). Comparison of CTmin and CTmax from high− and low−elevation populations of bumblebees reveals variation in these traits with respect to body size and in response to acclimation. Characterizing thermal limits for native pollinators may be particularly important for predicting responses to ongoing climate change.

S11.4 O'DONNELL, Michael J*; WEIHRAUCH, Dirk; McMaster University, Hamilton, University of Manitoba, Winnipeg; *odonnell@mcmaster.ca*

Links between detoxification, excretion and osmoregulation in insects and crustaceans.

The functional kidney in insects is comprised of the Malpighian tubules and hindgut. Together, these tissues play preeminent roles in osmoregulation and excretion. In crustaceans, the gills contribute to multiple processes, including osmotic and ionic regulation, nitrogenous waste excretion, pH homeostasis and gas exchange. Antennal and maxillary glands constitute the principal crustacean excretory organs. Uric acid is the primary nitrogenous waste in insects, but ammonia may also make an important contribution. By contrast, crustaceans have retained ammonotely, even in terrestrial groups. Both the V−type H^+−ATPase and the Na^+/K^+ ATPase are implicated as the energizers of transepithelial ion transport in the crustacean gill. In insect Malpighian tubules, however, the V−ATPase plays the pivotal role, perhaps as a consequence of coevolution of insects and flowering plants, resulting in a high K, low Na diet for most insects. The presence of high levels of allelochemicals in plants has also lead to the development of extraordinary capacities for detoxification and excretion by the gut and Malpighian tubules of insects. Ingestion of experimental diets containing high levels of potential toxins is correlated with increases in gene expression for both detoxification enzymes and toxin transporters in the Malpighian tubules of fruit flies. Recent studies of tubule toxin transport have made use of RNAi knockdown or P−element insertion mutation of organic anion transporter genes as a means of identifying the transporters involved. The urinary bladder of the crustacean antennal gland and the insect Malpighian tubule can provide useful models for understanding mechanisms of toxin transport by their functional analogue, the vertebrate proximal kidney tubule.

28.3 PACE, CM*; MONROY, JA; NISHIKAWA, KC; Northern Arizona University, Denison University; *Cinnamon.Pace@nau.edu*

Passive force along the length−tension curve: A role for titin?

When a muscle has been stretched during activation, the passive tension of the relaxed muscle is greater than after an isometric contraction at the stretched length. This muscle property is not well understood, but the protein titin has been suggested to play a role. To study titin's contribution to passive tension along the length−tension curve, we used *mdm* mutant mice, which carry a deletion in the N2A region of their titin gene. This deletion makes *mdm* muscles passively stiffer, but actively more compliant, than wild type muscle. Using the *mdm* mouse genotypes, we asked how passive tension changes with activation and stretch along the length tension curve, and whether it varies among genotypes? We used soleus muscles from *mdm* genotypes to perform three tests using a servomotor force lever: a reference isometric contraction, a 5% passive stretch, and an activation+5% stretch. These muscle tests were performed from Lo−5% to Lo+20% in 5% increments. We then compared the effect of stretch versus activation+stretch on muscle passive tension. In both wild type and mutant muscle, activation alone caused a slight depression in passive tension. In contrast, both passive stretch and activation+stretch increased passive tension. In wild type muscles, activation+stretch increased passive tension more than stretch alone at lengths greater than Lo+5%. In mutant muscle, passive stretch alone generally increased passive tension more than stretch+activation. The results suggest that a structural element (i.e. titin) becomes stiffer when activated and/or stretched, and that wild type titin is affected more by activation than *mdm* mutant titin.
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85.2 PAITZ, RT*; BOWDEN, RM; Illinois State University; *rpaitz@ilstu.edu*

Do vertebrate eggs contain maternally derived steroidogenic enzymes that are susceptible to inhibition by endocrine disruptors?

Developing ovarian follicles are a primary site for steroid production in vertebrates and result in eggs that contain numerous maternally derived steroids. Embryonic exposure to these maternal steroids can have long−lasting consequences for the developing embryo, but recent work demonstrates that embryonic exposure to these steroids is modulated by steroid metabolism. Research to date suggests that little to no maternal steroids reach the embryo without first being metabolized. Currently we know very little about when and where this in ovo metabolism takes place. Additionally, the metabolism of maternal estradiol is inhibited by the endocrine disruptor bisphenol−A (BPA), altering embryonic exposure to this maternal steroid. In this study, we examined the potential for BPA to affect the in ovo metabolism of progesterone, testosterone, estrone, and corticosterone during the first 72 hours of development in the red−eared slider turtle (*Trachemys scripta*). We report that all four steroids are extensively metabolized within 24 hours of topical administration, but that BPA only inhibited the metabolism of estrone, while the metabolism of progesterone, testosterone, and corticosterone were not affected. The rapid metabolism of these steroids at such an early stage of embryonic development suggests that maternally derived enzymes are present in the egg at oviposition. The apparently unique susceptibility of estrogen metabolism to disruption by BPA may help explain the estrogenic effects of BPA and other so−called estrogenic endocrine disruptors. Deciphering the processes that underlie how embryos are exposed to maternal steroids will advance our understanding of how both maternal steroids and endocrine disruptors produce long−term phenotypic effects.

P1.147 PALES ESPINOSA, E*; ALLAM, B; Stony Brook University; *bassem.allam@stonybrook.edu*

Food quality and endogenous factors affect the expression of a mucosal lectin and food sorting abilities in the blue mussel Mytilus edulis

Molecular recognition of food particle epitopes has been suspected to play an important role in particle selection in suspension feeding bivalves such as the blue mussel, *Mytilus edulis*. Among molecules involved in this mechanism, lectins are a group of sugar−binding proteins that are widely implicated in biological recognition. Recently, we identified a mucosal lectin (MeML) in pallial organs of *M. edulis* and suggested its involvement in the capture and sorting of food particles. In the current study, we used a combination of physiological experiments (food selection) and molecular biology tools to link mussel sorting efficiencies to transcriptional changes in MeML as related to the quantity and quality of mussel diet and season (mussel reproductive cycle). Results showed that sorting efficiencies and MeML expression in *M. edulis* significantly increase when mussels were either fed poor quality food or starved. In addition, results suggested that particle capture and degree of selection increased during the spawning period, although the quality of food delivered to mussels during acclimation before the experiments seemed to have a stronger impact on particle sorting efficiency. Overall, the impact of both intrinsic (physiological status) and extrinsic (food quality) factors were shown to affect the expression of MeML in mussel feeding organs, and the food sorting abilities.

50.1 PALMER, G; JOHNSEN, S*; Duke Univ.; *sjohnsen@duke.edu*
By the light of the silvery moon: The effect of lunar phase on the color of twilight and its implications for animal behavior
Although the dramatic changes in illumination level, and to a lesser extent the associated changes in color, that accompany the rising and setting of the sun are well known, the effects of the presence of the moon and its phase on general illumination during twilight have received less attention. This is unfortunate, given the importance of crepuscular periods to animal activity, the importance of lunar phase during crepuscular periods to animal reproduction, and the ability of certain species to see color under dim light. We measured downwelling spectral irradiance (from 350 to 800 nm) during evening civil and nautical twilight (solar elevation down to −12 deg) at a remote site chosen to minimize light pollution. Nine sets of measurements were taken to cover the first half of the lunar cycle (from new to full moon) and were used to calculate human−based chromaticity and to generate images of the average color of the sky and the appearance of objects. Lunar phase had no consistent effect on downwelling irradiance until solar elevation was less than −8 deg. For solar elevations lower than −8 deg, the effect of the moon increased with the fraction of the lunar disk illuminated until the fraction was approximately 50%. For fractions greater than 50%, the brightness and chromaticity of the downwelling irradiance were approximately independent of the fraction illuminated, likely because the greater brightness of a fuller moon was offset by its lower elevation during twilight. In summary, the phase of the moon can profoundly affect both the brightness of the illumination and the appearance of objects during late twilight, affecting vision and providing ample cues for lunar timing, even for animals that lack spatial vision.

P1.161 PALMER, SE*; SALISBURY, J; TORRENCE, H; YEE, H; HO, D; University of Chicago; *sepalmer@uchicago.edu*
A new database for natural motion
While the characteristics of static images have been explored in large image repositories, much less is known or measured in the temporal domain. We describe a new database for natural motion, which is comprised of a large collection of fixed−camera, high resolution grayscale and color video from field recordings of moving objects. Videos include motion of both animate and inanimate objects from a variety of camera−to−subject distances. This database effort carefully selects natural subjects to maximize the quantity, quality and continuity of motion in each clip. These data are well−suited for use as stimuli in visual neuroscience experiments because of their variety of motion and the fine temporal and spatial information available in each recording. We also report on preliminary analysis of the motion content of these scenes. Static images strikingly exhibit a power−law distribution of spatial frequencies. Power−law behavior in the frequency distribution of temporal fluctuations in total scene luminance has also been observed in natural contexts, and we find that our scenes similarly display power−law behavior with a scaling exponent that depends on the particular motion content. To quantify the dynamics of motion in our scenes, we fit translation fields to pairs of stimuli and analyze the statistics of the resulting flow. These flow fields are then used to guide the trajectories of "tracer" particles released at various points in the frame and subjected to the inferred flow from the natural movie. One important aspect understanding of predictive computation in the brain of the observer of natural motion (a predator, for example) is characterizing the structure of predictable events in the world itself. These tracer particles allow us to define the predictive information content of naturalistic trajectories.

8.1 PANKAEW, K. A.*; MILTON, S. L.; Florida Atlantic University; *kpankaew2012@fau.edu*
Physiological Effects of Disorientation in Loggerhead (Caretta caretta) and Green (Chelonia mydas) Sea Turtle Hatchlings
The first 24 hours after hatching are incredibly dangerous and important for sea turtle survival. In Florida, between the months of June and October, loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtle hatchlings emerge at night from their nests on ocean beaches. From the nest they locate the sea by orienting away from the dark, dune vegetation and crawling toward the brighter, lower oceanic horizon. However, hatchlings can be misoriented landward by strong, localized artificial sources of light or disoriented by diffuse skyglow from urban areas causing them to wander the beach without direction. Even in cases where mis−/disoriented animals reach the ocean, the increased distances hatchlings crawl to reach the ocean consumes valuable energy and the exhausted animals are less likely to survive. This study presents laboratory simulations of extended crawl distances to investigate the energy cost to sea turtle hatchlings incurred during these misorientation and disorientation events. Oxygen consumption, blood glucose levels, and lactic acid concentrations are measured as well as crawl behavior and swim performance following crawl trials. Results will determine if the energy consumed by misorientation and disorientation events affects hatchling ability to swim offshore. This research will provide quantitative physiological data to managers to determine the best practices for sea turtle conservation and add to the current biological knowledge of these animals.

2.2 PARDO, JD*; SZOSTAKIWSKYJ, M; ANDERSON, JS; Univ. of Calgary; *jdpardo@ucalgary.ca*
Stereotypical adaptation for headfirst burrowing in early reptiles
Recumbirostra is a group of small tetrapods from the Late Carboniferous and Early Permian generally interpreted as stem−lissamphibians, stem−caecilians, or stem−amniotes. We present an expanded phylogenetic dataset to investigate the phylogenetic relationships of recumbirostrans among early tetrapods, incorporating substantial new braincase data gleaned from broad application of micro−CT to numerous recumbirostran fossils. Phylogenetic analysis of both braincase and postcranial characters supports a placement of this group within crown amniotes, along the reptile stem. These phylogenetic results simplify interpretations of the evolution of the ankle, middle ear, and otoccipital region. Unique recumbirostran characteristics do not strongly support alternate phylogenetic hypotheses, contra previous studies, and are uniformly consistent with stereotypical headfirst burrowing morphology among modern squamates. This suggests that early reptiles rapidly filled specialized niches characteristic of modern squamates in ways that other Paleozoic tetrapods did not.

P1.120 PARKER, C.E.*; FRANCO, L.A.; ROMERO, L.M.; Tufts Univ., Medford, Borough of Manhatten Com. Col., New York; *clare.parker@tufts.edu*

Are novel objects stressful? The relationship between heart rate and neophobia in the European starling (Sturnus vulgaris)

Neophobia is an ecologically relevant behavior characterized by an aversion to novelty, often measured by exposing animals to novel objects on or near a food source. To an animal in the wild, a novel object could represent either a threat or a potential untapped resource. Novel objects may be perceived as stressful. Exposure to stress can cause increased neophobia. However, in wild birds, glucocorticoid stress responses to novelty have been found to be very small or non−existent. The fight−or−flight response has never been measured in association with neophobia. We hypothesized that neophobia would be associated with an increase in heart rate (HR) in captive European starlings (*Sturnus vulgaris*), indicating that novel objects are perceived as stressors. Heart rate transmitters were surgically implanted in European starlings. After overnight food deprivation, food was returned to the birds in either their normal dishes, or in dishes modified with a novel object. Dishes were presented remotely by using a cover that can be lifted from outside the room to eliminate the HR response to the experimenter. Each bird was exposed to 5−6 novel objects and a no object control in random order. Time to approach the food dish and HR were recorded. We found that the time to approach was greater in response to modified food dishes − the birds displayed neophobic behavior. There was a sharp increase in HR (a startle response) coincident with exposure to the modified and unmodified food dishes. However, HR did not remain elevated, even when birds were exposed to novelty. Remote presentation of the food dish caused an increase in HR and may delay approach to unmodified dishes, but a fight−or−flight response was not associated with novel objects.

P3.50 PARKER, M.R.*; AVERY, M.L.; Washington and Lee Univ., U.S. Dept. of Agriculture, National Wildlife Research Center; *mrockwellparker@gmail.com*

Initial analyses of putative sex pheromones in Burmese pythons

Burmese pythons (*Python bivittatus*) are an invasive species of concern in the Florida Everglades and pose a significant threat to native vertebrates, especially birds and mammals. Their reproductive ecology is poorly understood in their invasive range, and successful management strategies may be derived from establishing fundamental knowledge of their sexual signaling. Thus, this project is designed to determine the role of chemical signals in Burmese python reproduction. We have been collecting and processing shed skins from wild caught male and female pythons and are extracting skin lipids from these sheds. Sex pheromones in other species of snakes are abundant in both the exposed surface of intact snake skin and in shed skins, with the latter accurately reflecting the native composition of skin lipids while being much easier to collect. Extracts from the sheds will be fractionated using column chromatography and analyzed using GC−MS. We then plan on using multidimensional analysis to quantify expression differences between sexes, seasons and individuals. We predict that Burmese pythons, like garter snakes and brown tree snakes, express a series of long−chain methyl ketones that are sexually dimorphic and may be capable of eliciting trailing behavior from wild males in the field during the breeding season.

27.4 PARKER, M.R.*; FENG, D.; CHAMURIS, B.; MARGOLSKEE, R.F.; Washington and Lee Univ., Monell Chemical Senses Center, Univ. of Pittsburgh, Lehigh Univ., Monell Chemical Senses Center; *mrockwellparker@gmail.com*

Stress and the sweet taste cell: glucorticoid receptor activation in taste receptor cells

The stress response in vertebrates is intimately associated with appetitive behavior. Not only are there changes in food preference and consumption rates following acute or chronic application of stressors, but modulation of the peripheral sensory environment is also a direct outcome of HPA axis activation. Glucocorticoids (GCs) are the principal stress hormones that affect sensory tissues by interaction with glucocorticoid receptors (GRs). We have found that GRs are expressed in the mouse taste bud, specifically in sweet− and umami−sensitive cells that express a subunit of the sweet receptor, T1r3. Further, when mice are restrained (2h), GR translocates to the nucleus. Concomitant with these changes, we have observed increased expression of chaperone molecules (Hsp70 and Hsp90) in stressed taste buds from mice, and these proteins are known to be directly involved in GC−based signaling in target tissues. Lastly, we have recently found that GR colocalizes with lamin−B in the nuclear envelope which may temper taste receptor cell responsiveness to free GCs. While the link between sweet taste and stress have been thoroughly studied in human and rodent models, our work is the first to examine how GCs can directly activate the network of stress−responsive genes in the taste epithelium.

P2.10 PARKS, R/A; ANDERSON, M/G; MOORE, W/J; COLE, J; GORDON, S/G; GRIM, J/M*; Presbyterian College, Presbyterian College/University of Tampa; *jgrim@ut.edu*

Metagenomics indicates that microbial communities of fish guts vary by both trophic level and habitat

The microbial ecosystem associated with fish guts is complex and dynamic, and the characteristics of this community are likely varied to support the occupation of a range of ecological niches by the host. For example, the composition of the microbial community in fish guts can differ in their ability to produce enzymes that aid in the digestion of host−specific diets. Additionally, environmental factors (*e.g.*, temperature and salinity) are also likely to influence the composition of the microbial community in fishes. To further test these observations, we are examining the intestinal microbiota from two pairs of species from near−shore, temperate and near−shore, polar marine habitats. Spotted sea trout (*Cynoscion nebulosus*) and flathead mullet (*Mugil cephalus*), two species which utilize different trophic niches (carnivore and herbivore, respectively), were sampled from Charleston Harbor, Charleston, SC. Additionally, two Antarctic notothenioid fishes (blackfin icefish − *Chaenocephalus aceratus* and black rockcod − *Notothenia coriiceps*) were sampled that represent unique trophic levels in near−shore habitats of the thermally stable Southern Ocean. The metagenome of intestinal samples were determined by sequencing 16s rDNA. Sequences were compared between species within a habitat and between habitats using Principal Component Analysis. Our data reveal that microbial communities can be distinguished by fish species and also by habitat, indicating that both abiotic and biotic factors influence the composition of the gut microbiota. Future work will be required to determine the functional consequences of these varying microbial communities for the fishes. Work supported by NSF Office of Polar Programs ANT−1019305 (JMG), Presbyterian College Faculty Development Committee (JMG), and PGRP NSF 11−500 (SGG).

P2.53 PARLIN, A.F.*; SCHAEFFER, P.J.; DO AMARAL, J.P.; DOUGHERTY, J.K.; NARDONE, J.A; Miami University, Oxford, OH, University of Cincinnati Clermont College, Batavia, OH, The College of New Jersey, Ewing, NJ; *parlinaf@miamioh.edu*
Linking physiology to habitat use: a turtle's perspective
Monitoring organisms in the field offers novel insight into the interaction between a free−living organism and their environment under natural conditions. Recent advances in biologging technology have allowed for fine−scale, detailed data collection of behavior, movement, and physiology on individual organisms. Additionally, biologging can provide indirect information regarding the relationship between an organism and their available versus used habitat. We monitored movement, body temperature, and heart rate of eastern Box turtles (*Terrapene carolina carolina*) during the spring, summer, and fall of 2014 in southwest Ohio. Operant models were placed in the field at randomly generated coordinates in different habitat types. Home−range was calculated for each turtle using a minimal convex polygon (MCP) and varied from 0.14 ha to 6.5 ha for two−weeks of monitoring. Turtles remained primarily in closed, forested habitats during the duration of the study while exploiting various thermal niches similar to temperatures recorded in open, grassy habitats. Average body temperature of the turtles was 20.5°C with an interquartile heart rate range of 11 to 20 beats per minute.

113.4 PARRIN, AP*; GOULET, TL; YAEGER, MA; BARNES, L; BROSS, LS; MCFADDEN, CS; BLACKSTONE, NW; Northern Illinois University, University of Mississippi, Harvey Mudd College; *apparrin@gmail.com*
Symbiont movement and survival during bleaching in octocorals
The effect of elevated temperature and illumination is examined in three species of alcyonacean octocorals, *Phenganax parrini*, *Sarcothelia* sp., and *Sympodium* sp. A microscopic analysis of symbiont (*Symbiodinium* spp.) location and counts demonstrated that the three host species generally responded similarly to perturbation, with decreased numbers of symbionts in the tissue and increased numbers in the gastrovascular system. Only a small proportion of symbionts were expelled, and variable mortality and retention was found (H84.6, 0, and 52.7% of the initial number of Symbiodinium died and H15.4, 100, and 45.4% were retained by *P. parrini*, *Sarcothelia* sp., and *Sympodium* sp., respectively). The variation in the response to perturbation between the three species could be due to host and symbiont genetic differences, or host architectural differences, or both. Mitochondrial (mtMutS and COI) and nuclear (28S rDNA) gene sequences showed that *Sympodium* sp. and *Sarcothelia* sp. are closely related xeniids but are only distantly related to *P. parrini*. *Sympodium* sp. and *Sarcothelia* sp. host *Symbiodinium* type D1a, while *P. parrini* have type B1. Following considerable symbiont movement within the colonies, the three octocoral species retained high densities of symbionts (>2.07 x 105 per mm2) in the coenenchyme. This investigation is currently being extended to other species selected for their phylogenetic relevance, e.g. *Briareum* sp. and *Stylophora* sp.

58.5 PARROTT, BB*; GUILLETTE, LJ; Department of Obstetrics and Gynecology, Medical University of South Carolina and Hollings Marine Laboratory; *benbparrott@gmail.com*
SEXUALLY DIMORPHIC DNA METHYLATION PATTERNING IN THE AMERICAN ALLIGATOR: POTENTIAL TARGETS OF ENDOCRINE DISRUPTING CONTAMINANTS
Unlike traditional lab models, the American alligator is a long−lived apex predator that displays high site fidelity, and thus represents an ideal model in which to examine the effects of long−term, chronic exposures to complex mixtures of environmental contaminants. When compared to alligators living in relatively pristine environments, alligators living in environments contaminated with endocrine−disrupting contaminants display a suite of reproductive disorders. Among these, the expression of *CYP19A1* (*Aromatase*), a key gene within the estrogen synthesis pathway, is misregulated in animals originating from contaminated environments. We have previously shown that the promoter of *CYP19A1* undergoes sexually dimorphic DNA methylation patterning, with males displaying hyper−methylation when compared to females. Here, we employ targeted bisulfite−sequencing on the Illumina platform to examine methylation patterning at the *CYP19A1* promoter and other loci within male and female embryos across sites with varying contamination levels. We find that sexually dimorphic *CYP19A1* promoter methylation is significantly abated in embryos originating from a contaminated site (Lake Apopka) when compared to females from a relatively pristine site (Lake Woodruff). This reduction in sexual dimorphism is due to elevated gonadal methylation within females from Lake Apopka. We next examined the effect of embryonic estrogen exposures on *CYP19A1* and report these findings. These results suggest that sexually dimorphic DNA methylation patterning may be a target of endocrine disrupting contaminants in an established sentinel species.

40.6 PARSLEW, B*; SIVALINGAM, G; The University of Manchester; *ben.parslew@manchester.ac.uk*
A Virtual Bird that Simulates Jumping Take−Off and Flight
In jumping take−off birds are known to generate forces up to eight times their own weight. While the wings do help out, the bulk of this effort comes from the legs. Given the opportunity birds will often choose to avoid this exertion by diving from the edge of a perch, exploiting gravity for acceleration. But in many instances this is not an option, and birds must take−off from the ground and climb. To explore these ground−based take−offs a theoretical model has been developed that captures the dynamics of the legs and the wings. This model extends previous flight performance models by accounting for the energetic cost of becoming airborne from rest. A sensitivity analysis is applied to the model to examine which kinematic, aerodynamic and inertial parameters dominate the overall take−off performance. The findings help to identify the most relevant variables that should be recorded in future experiments on avian jumping. The model is also used to examine the trade−off between jumping capability and cruise performance, showing how strong, powerful legs make for an easier departure, but carrying this extra baggage can be costly when up in the air.

P2.139 PASCO, S.T.*; ROARK, A.M.; Furman University;
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Effects of 17^2−estradiol, coumestrol, 9−cis−retinoic acid, and citral on asexual reproduction in the sea anemone Aiptasia pallida

The role of nuclear receptor−mediated signaling in cnidarians is unknown. The purpose of this study was to examine the responses of sea anemones to chemicals that have known effects on vertebrate nuclear receptor−mediated processes. The species we used was *Aiptasia pallida*, a sea anemone that reproduces asexually through pedal laceration. In our 40−day exposure trial, we treated adult anemones from ten distinct clone lines with low and high concentrations of 17^2−estradiol, coumestrol, 9−cis−retinoic acid, and citral. We examined the effects of these chemicals on the total number of lacerates produced, the proportion of lacerates that matured, and lacerate development rate. These data were analyzed using a generalized linear mixed effects model that tested the potential effects of clone line, treatment, and anemone size on each response variable. Our project provides important insights into the potential role of nuclear receptors in the physiology of cnidarians.

P2.13 PASSEMENT, C/A*; KOHL, K/D; MEYERHOLZ, D/K; MCCUE, M/D; St. Mary's University, Univ Utah, Univ Iowa;
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Fasting−induced morphological reorganization of the colon may not drive concomitant changes in the microbiome

We previously documented varied changes in the colonic microbiomes of animals representing five classes of vertebrates (i.e., tilapia, toads, leopard geckos, quail, and mice) over the course of fasting. In the current study we tested the hypotheses that the extent of tissue reorganization in the fasted colon was correlated with the observed changes in the microbiome. Colon segments adjacent to those used for the genomic study were fixed in Carnoy's solution, mounted on slides, and stained with hematoxylin and eosin. We used ImageJ software to quantify cross−sectional and mucosal surface areas as well as thicknesses of mucosa, submucosa, and tunica muscularis. We found no fasting−induced differences in the morphology of colons of the mice (3days), quail (7days), or geckos (28 days). The toads that exhibited a general increase in phylogenetic diversity of their microbiome also exhibited reduced mucosal circumference at 14 and 21 days. The tilapia that increased their phylogenic diversity also exhibited a thickened tunica muscularis in 21 days, but this change is unlikely to explain the dramatic changes in their microbiome that we documented. Given that the mice and quail exhibited fasting−induced increases and reductions, respectively, in their microbial diversity but did not exhibit detectable changes in colon morphology, we conclude that structural reorganization is not the primary factor shaping changes in microbial diversity within the fasted colon.

73.1 PASSOW, C.N*; KELLEY, J.L; TOBLER, M; Kansas State University, Manhattan, Washington State University, Pullman;
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Comparative transcriptomic analysis across four divergent ecotypes of an extremophile fish (Poecilia mexicana)

Adaptation and speciation are key processes in the evolution of biodiversity. Elucidating the genomic basis of traits involved in these processes remains a major task for the field, especially in non−model organisms. High−throughput sequencing allows for a comparative genomic approach to identify molecular changes in organisms currently undergoing ecological speciation. Here, we studied genetic changes underlying adaptation using genetically distinct and locally adapted populations of extremophile fishes (*Poecilia mexicans*) living in toxic, hydrogen sulfide−rich springs and caves. The recent divergence of ecotypes inhabiting different habitats and the contrasting environmental conditions makes this system ideal for studying the genetic basis of adaptation and speciation. We used RNA−sequencing to assemble and annotate transcriptomes of Poecilia mexicana based on transcripts from 16 wild−caught individuals with four individuals and four tissue types per ecotype (non−sulfidic surface, sulfidic surface, non−sulfidic cave, and sulfidic cave). Transcripts from each organ type were mapped against the de novo assembled reference transcriptome to call single nucleotide polymorphisms (SNPs) and estimate gene expression variation. We quantified coding changes in transcribed genes among ecotypes by identifying FST outliers to test for SNPs under selection. We identified variation in gene expression patterns between ecotypes and tissues by using the EdgeR package to identify genes that are differentially expressed. We find variation, both in gene expression and coding changes, across the ecotypes examined, thus making the P. mexicana transcriptome a valuable genomic resource for studying the underlying genetics of adaption and speciation.

P3.87 PASTOR, MJ*; YOUNG, CM; SALAZAR, TR; NARANJO, SM; PLASCENCIA, M; GUNES, N; CAKMAK, I; HRANITZ, JM; San Francisco State University, Muhlenberg College, University of Chicago , University of Central Florida, University of Santa Cruz, Uluda University, Bloomsburg University of Pennsylvania;
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The sublethal effects of Thiacloprid on Apis mellifera

Currently, serious population declines have been associated with, among other causes (beekeeping practices, parasites, and viruses), Colony Collapse Disorder (CCD). We studied the sublethal effects of the neonicotinoid pesticide Thiacloprid, which is mainly used on green apples, cherries, and pears. Thiacloprid acts as an agonist for nicotine on insects, constituently binding to sodium channels. To understand the sublethal effects of Thiacloprid in *A. mellifera*, we examined sucrose sensitivity to assess effects on central nervous system processing, and motor function to evaluate peripheral nervous system function. We studied sublethal doses that were dilutions (1/5, 1/10, 1/50, 1/100, 1/500, 1/1000) of the LD50 in 1.5 M sucrose. Bees were fed 10uL of a Thiacloprid treatment in 1.5 M sucrose. Motor response was assessed 4h after feeding by testing the proboscis extension reflex (PER), along with leg, abdomen, and wing movement. Sucrose sensitivity was measured 4h after feeding by a positive PER to six (1%, 3%, 10%, 20%, 35%, 50%) sucrose solutions. At 1/5 of the LD50, Thiacloprid reduced motor coordination compared to the controls. Similarly, bees in the 1/5 LD50 treatment displayed reduced sucrose sensitivity. Our results indicate that the performance of crucial components in foraging controlled by the CNS and PNS, are reduced by sublethal doses of Thiacloprid. This provides further evidence that concentrations used in agriculture may produce harmful effects in honey bees that could contribute to CCD.

P2.7 PATRICK, T.*; VARLEY, L.; MONZON, R.; Saint Xavier University; *patrick.t01@mymail.sxu.edu*

Characterization and Expression of the Cyr61/CCN1 Gene in Medaka (Oryzias latipes)

Cyr61 is a member of the CCN family of matricellular proteins, modulating a diverse set of functions in vertebrates with putative roles in development and human disease states. Recent studies have begun to examine CCN function in fish model systems such as the zebrafish (Danio rerio), which provides powerful genetic analysis and accessible visualization of embryonic structures. In this study we examine Cyr61 expression in medaka (Oryzias latipes), a similar fish model system with comparable genetic analysis and embryonic development. Cyr61 expressed sequence tag (EST) sequences obtained from the UCSC Genome Browser website were used to construct targeting primer sequences for Reverse transcription polymerase chain reaction (RT−PCR). An RT−PCR product representing the medaka Cyr61 coding region was derived from total RNA and subcloned into a pDP19 expression plasmid, which was sequenced and analyzed for homology to other vertebrate species. Using RT−PCR and in vitro transcribed mRNA probes from the pDP19 vector, we then looked for differential expression patterns of the medaka Cyr61 gene in embryonic development and adult tissues. Together these studies reveal the utility of the medaka as a useful model system for examining Cyr61 function, while providing insights into the development of CCN proteins between different vertebrate species.

P3.206 PAUL, RJ*; BRADSHAW−WILSON, C; WHITENACK, LB; Allegheny College; *paulr@allegheny.edu*

Fin morphology and locomotion in Etheostoma darter fish

Pelvic and pectoral fins play major roles in both controlling how a fish moves itself, and its ability to station−hold. However, the effect that the morphology of these fins has is something that isn't as well understood. This study examined the relationship between fin shape and locomotion in six species of sympatric *Etheostoma* darter fish, which will provide a clearer picture of the ecological niches of the six species examined. We measured slip speed and fin angle during four different types of movement: hovering, ascending, descending, and braking. These tests were performed in a 5'x1'x1' unidirectional flume, with a gravel substrate, and recorded with a high speed digital camera at 250 frames per second. The shape of the fins was described using geometric morphometrics, in order to more accurately quantify any differences in shape. The fish were dissected in order to remove the adductor and abductor superficialis muscles to identify the effect of muscle mass. Regression analysis was used to determine whether there is a significant relationship between fin shape and locomotion. Based on the results of previous studies, we believe that larger pelvic and pectoral fins, such as those seen in *Etheostoma variatum*, will result in generally higher slip speeds, and also believe that larger pectoral fins will show smaller fin angles in the fin angle tests. Having a greater understanding of these species' ecology could improve preservation efforts, as other sympatric darters in this stream are threatened or endangered.

S5.10 PAULAY, Gustav; University of Florida; *paulay@ufl.edu*

Nervous diversity: variation in reproductive signaling influences the dynamics of speciation across animals

Nervous systems are a hallmark of animals, present in all but the most basal phyla and a few highly degenerate groups. Nervous and sensory systems greatly enhance modalities of communication and are important in mate choice, reproduction, species recognition, and in turn influence speciation. The type and nature of neurosensory communication in mate (and thus species) recognition varies substantially across the diversity of animals. In the simplest and likely most plesiomorphic condition, gametes are liberated into the water column, and mate choice is largely at the cellular level, mediated chemically, without nervous input, as in many anthozoans. Conversely, diverse sensory signaling modes can be associated with mating behaviors in highly−cephalized taxa with internal fertilization, as in many arthropods. This variation in reproductive communication leads to variation in the type of selective forces, and in turn influences the dynamics speciation. I review the diversity of reproductive strategies from this perspective, provide examples of potential correlates in speciation, and discuss the resulting variation in the dynamics of diversification.

P3.128 PAULSON, T J*; MERCADER, R J; University of Tennessee; *tpaulson@vols.utk.edu*

Size dependent herbivory of stems within patches of an understory clonal tree, Asimina triloba, by an outbreaking specialist herbivore, Omphalocera munroei.

1. The effect of herbivorous insect population outbreaks on understory plant dynamics are relatively understudied. In particular, the influence of herbivore behavior during outbreaks on plant patch dynamics is poorly understood. 2. During the summer of 2012 an outbreak of a specialist herbivore asimina webworm moth, *Omphalocera munroei* was observed. The asimina webworm feeds exclusively on the common paw−paw, *Asimina triloba*, a patch forming clonal understory tree.3. Within patches 63.4% of the observed individual paw paws experienced over 75% defoliation.4. Results indicate that individual size within a patch, neighbor size, and neighbor damage were significant predictors of infestation level. Results indicate a strong potential for moth ovipositional behavior and population size to influence patch dynamics.

48.2 PECK, H.E. *; COSTA, D.P.; CROCKER, D.E.; Sonoma State University, Univ. of California, Santa Cruz;
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Immune response varies with life−history stage in female northern elephant seals

Pinnipeds forage in the marine environment but aggregate terrestrially for breeding. Little is known about how breeding and associated extended fasts impact immune function. Elephant seals give birth in high−density environments and undergo wide fluctuations in plasma cortisol, a hormone known for immunosuppressive effects, while fasting. Our goal was to characterize immune response across life history stages in adult female elephant seals and explore potential impacts of natural variation in cortisol on immune function. We measured a suite of cytokines, acute phase proteins, and immunoglobulins early and late in breeding and molt haul−outs in 198 samples from 131 female elephant seals taken over 4 years (2011−2014). All immune markers varied significantly with life history stage. In general, immune responses were greater and more varied during the breeding haul−out, particularly in samples closest to parturition. Immune markers were not associated with plasma cortisol levels with one exception. The exception to this pattern was immunoglobulin E, a marker of immune response to parasitic infection. IgE was highest after the post−breeding foraging trip and exhibited a significant negative association with cortisol across all life history stages. This association was strongest directly after foraging trips. IgE also declined significantly over the four study years, despite similar foraging success, suggesting declining parasite exposure or response across the study period. These data suggest that breeding carries an immune cost in female northern elephant seals, but elevation of cortisol in association with breeding fasts does not suppress immune function. In contrast, immune responses to parasites may be influenced by variation in plasma cortisol during foraging.

22.1 PENA, J; NICHOLS, SA*; University of Denver;
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Characterizing gene expression in the sponge choanoderm

A fundamental challenge in the field of evo−devo is to understand the evolution of animal body plan diversity. The body plan of sponges (phylum Porifera) is an outlier among modern animals and is thought to have special evolutionary significance. Sponges lack muscles, nerves and a gut. Instead, they are composed of few cell types and simple tissues that function to pump water through an internal canal network where bacterial prey are filtered by a specialized tissue called the choanoderm. Not only is the choanoderm the defining feature of the sponge body plan, it is composed of cells with striking similarity to choanoflagellates, the unicellular relatives of animals. Thus, the traditional view is that the sponge choanoderm is a useful model of the first animal epithelial tissues. Using the freshwater sponge model, Ephydatia muelleri, we have performed comprehensive gene expression analysis of the choanoderm tissue and have begun to experimentally validate and characterize the function of candidate choanoderm genes. An early insight from these data is that the sponge choanoderm may be the only metazoan tissue not reliant upon the classical cadherin/catenin complex for cell−cell adhesion. In contrast, we find evidence for conserved developmental mechanisms and other structural features, such as a possible role for tolloid−like 1 and hensin in choanoderm morphogenesis, and a possibly role for usherin, VLGR1, and cadherin 23 in regulating microvillar organization. Moreover, both planar and apical polarity markers are differentially expressed in the choanoderm, suggesting homology with other animal epithelia, despite the absence of a conserved cadherin/catenin complex. Finally, we will explore the possibility that genes unique to choanoflagellates and sponges, have conserved functions in the choanoderm tissue. This prediction derives from the hypothesized homology of these putatively ancient cell types.

P1.92 PENROD, L.M.*; TURINGAN, R.G.; Florida Institute of Technology; *lpenrod2011@my.fit.edu*

Thermal Sensitivity of Invasive−Predator and Native−Prey Interactions in Fishes

Invasive species have negative ecological and economic consequences for their invaded ecosystems and societies. The ability of invasive species to adapt to environmental conditions, especially temperature, has motivated research investigating the effects of environmental temperature on organismal performance. The effects of temperature on feeding performance in invasive fishes have been determined by focusing exclusively on predator−response to temperature. However, temperature−induced changes in physical properties of water (e.g., viscosity) and physiological systems (e.g., contractile properties of muscles) affect both predator and prey. This study is the first to investigate the effects of environmental temperature on the relationship between invasive and native prey. At a given temperature, distance traveled by predator toward prey (i.e., Ram−feeding) was greater than distance traveled by prey toward the predator's mouth (i.e., Suction−feeding) during prey−capture. However, the magnitude of ram−feeding relative to suction−feeding (i.e., Ram−Suction Index (RSI) values) increased as water temperature became warmer. Temperature sensitivity (Q_{10}−values) of both predator and prey declined with increasing temperature. These results indicate that the responses of both invasive−predator and native−prey have to be addressed by ecologists and conservation biologists in investigating the consequences of environmental temperature for the community dynamics and management of invaded ecosystems. Furthermore, the ability of invasive fishes to modulate their feeding performance in response to temperature (i.e., temperature sensitive RSI) enables them to successfully expand their invasive−range of distribution as higher latitude ecosystems experience higher temperatures as a consequence of global warming and climate change.

S9.9 PEPPER, Rachel E.*; CHASTEEN, Stephanie V.; POLLOCK, Steven J.; PERKINS, Katherine K.; University of Puget Sound, University of Colorado Boulder; *rpepper77@gmail.com*

Applying the results of education research to help students learn more

Over the past several years, the physics faculty at the University of Colorado have worked to transform four upper−division courses: Classical Mechanics/Math Methods, Electricity and Magnetism (E&M) I and II, and Quantum Mechanics. I discuss our transformations as a model for other upper−division courses, such as quantitative biology courses. The goals of our course transformation were to improve student learning and to develop materials and approaches that other faculty could easily adopt or adapt. We applied the principles of active engagement and learning theory to transform many elements of the course. Reforms included peer instruction ("clicker" questions), tutorials, modified homework, and more. In this talk, I will outline the process, the reforms, and present evidence of the effectiveness of these reforms relative to traditional courses. I will also focus on peer instruction as an effective way to add active learning to a traditional lecture course. Tips for effective use of peer instruction, banks of clicker questions available for biology courses, and other−research based materials for biology courses will also be discussed.

102.2 PEREZ, JH*; WINGFIELD, JC; RAMENOFSKY, M; Univ. of California, Davis; *jhperez@ucdavis.edu*

The effects of thyroid replacement on pre−alternate molt, migration and reproduction in the White−crowned Sparrow (Z. Leucophrys gambelli)

The photoinduction of breeding and migratory behavior in songbirds has been a subject of intense research focus since Rowan's discovery in (1926). The transition from a wintering life history stage through pre−alternate molt into migration and then breeding requires coordination of numerous changes in physiology, morphology and behavior. Previously we found that chemical thyroidectomy with the anti−thyroid agent, Methimazole, led to suppression of circulating thyroxine levels, pre−migratory fattening, flight muscle hypertrophy, and onset of nocturnal restlessness (Perez in prep). Additionally, Methimazole treatment was found to arrest pre−alternate molt and gonadal growth. In order to confirm that the observed effects of Methimazole induced thyroid knockdown are indeed due to suppression of circulating thyroid hormone levels and not direct drug effects we conducted a thyroid rescue experiment. White−crowned sparrows were held on natural photoperiod and divided into a control and three treatment groups. All treatment groups received Methimazole both orally and via silastic implant. One of the three groups was maintained as a Methimazole only control while the other two received triiodothyronine and thyroxine respectively via silastic implant. As expected Methimazole treatment suppressed events associated with pre−alternate molt, migration and initiation of gonadal recrudescence. Thyroxine replacement rescued fattening, mass gain, vernal molt, and testicular growth to control or near control levels. Curiously, the theoretically more potent triiodothyronine treatment, displayed only partial rescue. These findings confirm that observed changes in behavior and physiology are due to thyroid suppression and not direct drug effects.

P2.45 PEREZ, RG*; VOYLES, J; RICHARDS−ZAWACKI, C; New Mexico Tech, Tulane University; *perezrachel617@gmail.com*

A closer look: Microhabitat Conditions in amphibian populations that have persisted after chytridiomycosis outbreaks

Amphibians are declining at an alarming rate. A recent IUCN assessment shows that one−third or more of known amphibians are threatened with extinction. Many of these declines are due to the disease chytridiomycosis, which is caused by the fungal pathogen, *Batrachochytrium dendrobatidis* ("Bd"), and has been linked with declines and extirpations of over 200 species worldwide. Temperature strongly affects growth rates, replication and survival of Bd *in vitro* and *in vivo*. In the tropics, previous studies have suggested prevalence and intensity of Bd infection is greater at high elevation sites where temperatures are consistently low. However, these studies generally only look at prevalence in community assemblages, not a single species, and typically only at one time point, not across seasons. Also, little is known about the microhabitat conditions and how they vary across spatial and temporal scales at high and low elevation sites. We recently discovered that a highly susceptible species, the common rocket frog (*Colostethus panamensis*), is persisting with Bd infection in low−mid elevation sites but has not recovered in high elevation sites. We conducted field surveys, recorded microhabitat temperatures and collected diagnostic samples to determine infection intensity in this species at three sites along an altitudinal gradient and across seasons (wet and dry seasons). We used temperature loggers to characterized the seasonal patterns in microhabitat conditions and link patterns with infection data from our diagnostic samples. We suggest that microhabitat conditions may be a key factor driving infection dynamics and limiting recovery in this species at high elevation sites. These findings will provide a better understanding of broad patterns seen on a global scale and provide insights for local management of amphibian health and conservation.

P2.94 PEREZ−CLAUDIO, E*; RODRIGUEZ−CRUZ, Y; ABRAMSON, C.I.; GIRAY, T; WELLS, H; University of Puerto Rico, Inter American University, Oklahoma State University, University of Tulsa; *alconi30@gmail.com*

Reversal learning differences between subspecies of Apis mellifera in Turkey

We used Proboscis Extension Response (PER) and Spatial Avoidance Conditioning (SAC) assays to examine differences in appetitive and aversive (respectively) reversal learning across two honey bee subspecies: *Apis mellifera caucasica* (Pollman), and *Apis mellifera syriaca* (Skorikov) in a "common garden" apiary. These subspecies are indigenous to very different environments: *Apis mellifera caucasica* inhabits temperate deciduous forests in the northeast of Anatolia and the eastern Black Sea coast regions of Turkey, whose weather limits foraging to a small seasonal period. Contrastingly, *A. mellifera syriaca* inhabits rocky mountains and plains in the Hatay region of Turkey, a generally dry habitat with longer seasonal foraging periods constrained by periodic blooms of one or few flowers. In the initial phase of the tests, bees were trained to respond to rewarded conditioned stimuli (CS+) and not to an unrewarded conditioned stimuli (CS−). During the second phase, the rewarded and unrewarded conditioned stimuli were reversed. The ability to reverse a learned paradigm or sequence becomes important for foraging plasticity in changing environments. We found no significant differences among the species in the first phase of the trials in either aversive or appetitive learning situations. During the second phase *A. mellifera syriaca* showed a reduced ability to learn the reversed association, in both aversive and appetitive learning tasks. This observation is consistent with the hypothesis that differences in behavioral responses are due to adaptation to the ancestral environments of these bees.

21.1 PERLMAN, B.M.*; ASHLEY−ROSS, M.A.; Wake Forest University; *perlbm0@wfu.edu*

An odd little fish that spends time...on land!

The evolution of jointed limbs, flexible axial skeletons, and a reduction in body armor allowed early vertebrates to transition from water to land in the Devonian period, about 370 million years ago. The mangrove rivulus, *Kryptolebias marmoratus*, is a quasi−amphibious modern teleost with no obvious morphological characteristics that would suggest these fish would be able to efficiently move onto land. We recorded several aspects of their aquatic versus terrestrial behaviors: (1) kinematics of the water−to−land transition and terrestrial excursions, (2) forces generated during terrestrial leaping, and (3) motor patterns of the axial musculature during aquatic escape responses and terrestrial jumps. We compared adult *K. marmoratus* to size−matched non−amphibious juvenile largemouth bass, *Micropterus salmoides*, which make extremely rare forays onto land. We found *K. marmoratus* to use three behaviors when transitioning onto land: launch, squiggle, and pounce. Once on land, *K. marmoratus* jumps up to 10 body lengths by rotating its head over the long axis of its body and pressing its caudal peduncle against the substrate to launch into ballistic flight. *K. marmoratus* forces were in the anteroposterior and mediolateral orientations, whereas the bass generated almost all of their forces in the vertical direction with little lateral displacement. Terrestrial motor patterns differed from aquatic escape responses in adult *K. marmoratus*, whereas juvenile bass showed similar axial motor patterns in both media. *K. marmoratus* is capable of exploiting different environments without having any obvious morphological adaptations to move on land. We must revisit some of our understanding of the fossil record, as form does not always predict function.

P3.99 PERRAULT, JR*; SCHMID, JR; WALSH, CJ; YORDY, JE; TUCKER, AD; Mote Marine Laboratory, Conservancy of Southwest Florida; *jperrault@mote.org*

Brevetoxin exposure, superoxide dismutase activity and plasma protein electrophoretic profiles in wild−caught Kemp's ridley sea turtles (Lepidochelys kempii) in southwest Florida

Because of their vulnerable population status, assessing exposure levels and impacts of toxins on the health status of marine turtle populations is critical. From 2011−2013, two large blooms of the red tide dinoflagellate, *Karenia brevis*, occurred along the west coast of Florida USA. It is unknown how harmful algal blooms affected the Kemp's ridley sea turtles (*Lepidochelys kempii*) inhabiting the affected waters. It is essential to gather information regarding brevetoxin exposure in these turtles to determine if it poses a threat to marine turtle health and survival. From 2012−2013, we collected blood from 13 immature Kemp's ridleys captured in the Charlotte Harbor estuary. Nine turtles were sampled immediately after or during the red tide events (bloom group) while four turtles were sampled between the events (nonbloom group). Plasma was analyzed for total brevetoxins, superoxide dismutase (SOD) activity, total protein concentration and protein electrophoretic profiles. Brevetoxin concentrations ranged from 7.0−33.8 ng PbTx−3 eq/mL. Plasma brevetoxin concentrations in the nine turtles sampled during or immediately after the red tide events were significantly higher than turtles sampled between events. No significant correlations were observed between plasma brevetoxin concentrations and plasma proteins or SOD activity; however ±−globulins tended to increase with increasing brevetoxin concentrations. Smaller bloom turtles had higher plasma brevetoxin concentrations than larger bloom turtles, possibly due to a growth dilution effect. The research presented here improves the current understanding of potential impacts of environmental brevetoxin exposure on marine turtle health and survival.

72.7 PETE, A*; KRESS, D; LENTINK, D; Stanford University, Stanford; *aepete@stanford.edu*

Evidence for Passive Avian Head Stabilization during Flapping Flight

Birds stabilize head position with respect to the body to reduce retinal image blur during flapping flight. Relative head stabilization is needed because the vertical position of the body changes continuously during flapping flight. It rises and falls substantially due to the differences in lift force generated during the down− and upstroke of the wing. While bird head−bobbing during walking and whole−body stabilization on an oscillating perch have been studied, little is known about how birds accomplish head stabilization during flapping flight. To address the challenge of dissecting avian head stabilization, we decided to start out by ignoring the daunting anatomical complexity of the avian neck. We approximated it with a one−dimensional mass−spring−damper system for vertical displacements. We corroborated the model's dimensionless natural frequency and damper coefficient from high−speed video recordings of Whooper Swans (*Cygnus cygnus*) flying in their natural environment. The vertical body position was used as input and the vertical head position as output of the unknown transfer function of the neck. Remarkably, we find that the neck can be accurately modeled as a spring without damper. This suggests that avian head stabilization is passive within a wing beat. Our finding alludes to a solution for stabilizing cameras on bioinspired robots with similar large body oscillations induced by flapping wings: image blur can be much reduced by mounting the camera on a well−tuned spring.

5.2 PETERS, JM*; GRAVISH, N; COMBES, SA; Harvard University; *jcbptrs@gmail.com*

Ventilation behavior in honeybees: Linking biomechanics and group behavior

Honeybees exhibit fine control of the microclimate inside their nests. For example, nest temperature is maintained at approximately 36 degrees Celsius despite drastic fluctuations in ambient temperature. When temperature inside the nest rises above a threshold, worker bees assemble at the nest entrance and fan their wings, expelling warm, CO_2−rich air from the hive at flow speeds of up to 4 m/s. Fanning bees tend to form tightly clustered aggregates and establish clearly defined regions of inflow and outflow. We investigated the mechanics of individual fanning behavior and explored how local aerodynamic interactions among individuals influence energetic efficiency. We also explored how the positioning of fanning aggregates at the nest entrance can influence the global flow structure in the nest in response to ventilation challenges.

85.3 PETERSEN, A.*; EARP, N.; FITCH, C.; REDMOND, A.; YAN, Y.; BREMILLER, R.; DILLON, D. ; GARDELL, A. ; BUCK, C.L.; VON HIPPEL, F.; POSTLETHWAIT, J.H.; CRESKO, W.A.; University of Oregon, University of Alaska, Anchorage; *annp@uoregon.edu*

Perchlorate exposure alters gene expression in primary germ cells and developing gonads of zebrafish and stickleback fishes

The aquatic contaminant perchlorate is one of the few contaminants known to cause masculinization in some teleost model organisms (stickleback) and feminization in others (zebrafish). How can a single contaminant cause such divergent effects on primary sexual differentiation in different species? To determine the divergent effects of perchlorate exposure on gene expression, we raised 800,000 stickleback embryos for up to one year in four doses of perchlorate, and individuals from the Nadia laboratory strain and a transgenic *VASA*:GFP (AB) strain of zebrafish in two doses of perchlorate for up to 32 days post fertilization (juvenile stage). In stickleback, perchlorate caused increased embryonic androgen synthesis, increased gamete proliferation in both sexes, and sex−specific changes in primary germ cell apoptosis. In zebrafish, perchlorate exposure from fertilization caused reduced or delayed maturity in primary germ cells. Perchlorate also increased expression of the sodium−iodide symporter (*NIS*) gene during development in stickleback. A clade of genes closely related to *NIS* may be important to the systemic response to perchlorate during development, and we are investigating the role of these genes in gonad development using in situ hybridization and qPCR. These results contribute to the understanding of how genetic background and species−specific developmental programs contribute to health outcomes of contaminant exposure, and to the understanding of possible correlated response of evolutionarily related groups of genes (paralogs) to single contaminant exposures during early development.

P2.166 PETERSON, A.N.*; AKANYETI, O.; LIAO, J.C.; The Whitney Laboratory for Marine Bioscience, University of Florida; *anpetey@gmail.com*

The development of a rapid prototyping method for experimental studies of locomotion and flow sensing

Emerging rapid prototyping techniques are making it possible to explore how the body of a fish interacts with the surrounding fluid flow; revealing new insight into their locomotor efficiency and sensory biology. In live fishes, experimentally evaluating the contributions of individual parameters such as body stiffness, muscle activation timing, and lateral line sensitivity are exceedingly challenging. Simple physical models such as hydrofoils allow for isolation of individual parameters, however, fail to capture the complexity of biological systems. Motivated by this disparity, we 3D scanned a rainbow trout (*Oncorhynchus mykiss*) in order to fabricate biologically accurate physical models. We 3D printed trout heads outfitted with pressure transducers at the locations of the lateral line canal neuromast pores. By altering yaw and pitch of the fish heads, we found that the phylogenetically conserved canal lateral line arrangement along the head can play a distinct role in directional flow sensing. In another project, we molded whole fish models with 3D printed heads and a contrived back bone inside a flexible plastisol body. Using a force−measuring external actuator to manipulate the model, we compared implemented kinematics to those of live fish with high speed video. This approach indicates the importance of body stiffness and actuation parameters in optimizing swimming performance and efficiency. Our work highlights the value of using rapid prototyping techniques to gain novel insight into complex biological systems.

P1.202 PETIT, M*; VEZINA, F; Univ du Québec à Rimouski; BOREAS; CSBQ; *magali.petit@uqar.ca*

Reaction norms of metabolic performance: how does a small endotherm respond to natural weather variations?

Reaction norms reflect an organism's capacity to adjust its phenotype to environmental changes and allows for identifying trait values associated with physiological limits. However, shapes of reaction norms are usually unknown, especially in natural conditions, and this constrains our capacity to predict how organisms may cope with extreme climatic events such as those associated with climate change. Small endotherm species living year−round at high latitudes face highly seasonal environments and are therefore good models to study reaction norms of traits thought to influence fitness. We repeatedly measured basal (BMR, minimal maintenance costs) and summit (Msum, cold endurance) metabolic rates in 183 Black−capped chickadees (*Poecile atricapillus*) over a year to determine, for the first time in a free−living endotherm, reaction norms of these parameters across the natural range of weather variations. BMR was not related to weather parameters but varied consistently between individuals. Msum did not differ between individuals but was related to minimal temperature following a Z−shape curve, with a linear increase between 22°C and −10°C and was related to absolute humidity following a U−shape relationship, attaining its lowest point at a humidity level of 2.6 g.m−3. These findings suggest 1) that thermal exchanges with the environment likely have minimal effects on physiological maintenance costs, which may be individual−dependent and that 2) thermogenic capacity does not differ between individuals but is strongly affected by weather conditions. Our results bring support to the hypothesis that parameters of metabolic performance respond to different and likely independent constraints.

P1.179 PETTINELLI, KJ*; BERGMANN, PJ; Clark University, Worcester; *kpettinelli@clarku.edu*

Particle Size and Shape Affect Non−Steady State Locomotion in a Lizard (Eremias arguta)

Locomotor performance of all organisms depends on the interaction between an organism and its environment. Granular substrates are common in many environments. These materials can act both as a solid and a fluid when disturbed by moving organisms. A wide diversity of terrestrial animals run on, or burrow into granular substrates. In a granular substrate, small particles are displaced when disturbed. Displacement of these particles during running leads to wasted energy accelerating sand particles rather than the running animal. This has the potential to negatively impact running performance. Particle size may play an important role in this process because smaller, and therefore lighter, particles may be accelerated more easily, making locomotion more difficult for animals. Particle shape may also be an important factor because this determines how individual particles will pack together and, therefore, affect the load bearing capacity of the substrate. We tested for effects of particle size and shape on the performance and kinematics of the Steppe Runner lizard (*Eremias arguta*). We measured sprinting performance on six substrates composed of glass spheres varying particle diameter and six natural sand substrates varying average particle size and also particle shape. Our results show that performance is inhibited both by very small and very large particle sizes, with maximum performance observed on intermediate sizes. If particles are too small then too much of the lizard's energy is wasted by accelerating particles, resulting in decreased acceleration of the lizard. However if particles are too large, then the lizard's kinematics are affected by the uneven surface of the substrate, resulting in decreased average velocity. This suggests that optimal substrates for running are a balance between two opposing substrate characteristics.

108.2 PEYER, SM*; HEATH−HECKMAN, EAC; MCFALL−NGAI, MJ; University of Wisconsin−Madison; *smpeyer@wisc.edu*

Regulation of the crumbs gene in a squid light organ in response to symbiont luminescence

Initiation of the symbiosis between the squid *Euprymna scolopes* and its luminous bacterial partner *Vibrio fischeri* triggers profound cell−death mediated morphogenesis of the colonized organ. A rhythmic association follows in which the host controls the symbiont population over the day−night cycle. In this study, we examined whether symbiont luminescence affects host transcription of *crumbs*, a cell polarity gene involved in protecting against light−induced apoptosis of photoreceptive tissues. In the juvenile squid, we examined *crumbs* transcript expression and regulation in response to early *V. fischeri* colonization. At this stage of rapid morphogenesis the transcript was significantly down regulated in response to wild−type luminous *V. fischeri* relative to a mutant strain defective in light production and a control with no symbiont. In the mature squid, we examined transcript regulation over the 24−h day−night cycle. The transcript was significantly up regulated during the period of highest relative to lowest luminescence and did not correspond with environmental light. The results of our study indicate that the *crumbs* gene is regulated by bacterial luminescence, but this regulation differs depending on the stage of host development. In the juvenile squid down regulation of the transcript might be necessary for apoptosis induction, whereas in the mature squid up regulation of the transcript might be crucial for tissue protection during peak luminescence.

44.6 PFEIFFENBERGER, JA*; HSIEH, ST; Temple Univeristy, Temple University; *jpfeiffe@temple.edu*

Momentum as a possible mechanism for locomotor stability

The Atlantic ghost crab is found on sandy beaches, which are naturally−complex environments. Not only will sand shift and flow in response to the intrusion of leg, fragments of shells and rocks can perturb their locomotion. The goal of this study was to establish how ghost crabs respond to sudden changes in substrate properties. Crabs were exposed to three treatments: control (all sand), a low−traction hard surface, and a high−traction hard surface. Because crabs were running on a sand trackway, perturbations introduced changes to both surface friction and yield. Twenty crabs were filmed with a high−speed camera (500 fps) capturing dorsal and two lateral views. Kinematics were compared among strides before, during, and after the perturbation. We hypothesized that the perturbations would decrease locomotor performance among ghost crabs, and that slip perturbations have a greater impact on locomotor performance compared to non−slip perturbations. Contrary to expectations, results show that the perturbations had no impact on locomotor kinematics while in contact with either surface, regardless of traction ($P > 0.05$: running speed, body height, stride frequency, duty factor, body pitch and roll), despite all individuals slipping on the low−traction surface. However, the subsequent step back onto sand showed decreases in running speed and body height ($P < 0.05$: mixed model ANCOVA), potentially due to limb penetration into the surface. These results suggest that momentum allows ghost crabs to maintain stable locomotor dynamics when encountering hard surface perturbations of varying frictions for at least the initial perturbed footfall. Future studies with more sustained perturbation are necessary to determine if other corrective measures are necessary to allow continued stable locomotion following a surface transition.

P1.188 PHILLIPS, N*; MICHAELIS, D; NAGEL, H; BOMPHREY, R; Structure and Motion Lab, Royal Veterinary College, LaVision GmbH; *nphillips@rvc.ac.uk*

Towards a Fluid−Structure Interaction measurement technique for the biosciences: a combined measurement of fluid flow and tube wall deformation associated with a simplified aneurysm

Many examples exist in biology that involve a complex interaction between a flexible body and a surrounding fluid, such as the deformation of a fish fin, an insect wing, or the expansion and contraction of an arterial wall in response to a pulsing blood flow. Presently, this fluid−structure interaction (FSI) is acutely challenging to measure as separate measurement techniques are typically used for fluid flow measurement (e.g. Tomographic Particle Image Velocimetry [tomo−PIV]) and surface strains (e.g. photogrammetric methods; Digital Image Correlation [DIC]). A combined method incorporating simultaneous measurements would, therefore, be of widespread utility in biology as it would provide a more complete picture of observed phenomena as well as data for validating computational models. We conducted a series of experiments with the aim of developing a turnkey experimental FSI measurement system that combines the techniques of tomo−PIV and DIC. The first experiment focused on measuring the interaction between the pulsing blood flow in an artery and the deformation of a weakened section of the arterial wall simulating a highly−simplified abdominal aortic aneurysm (AAA). This was accomplished with a cast silicone elastomer model and a pulsing flow of glycerine−water fluid. The refractive index of the fluid and structure were matched to eliminate optical distortion. Simultaneous tomo−PIV and DIC measurements were accomplished using four highly sensitive sCMOS cameras to measure the fluid flow while two further cameras synchronously measured the aneurysmal wall deformation.

P2.15 PINEDA−ENRIQUEZ, T*; BOISSIN, E; PAULAY, G; University of Florida, University of Pretoria; *pinedae@ufl.edu*

Ten fold increase in species diversity revealed in integrative study of a common, widely distributed brittle star

Numerous cryptic species complexes are being revealed in large−scale marine biodiversity studies with molecular techniques. Cryptic complexes are especially prevalent among widely distributed species, emphasize the need to reexamine and revise much of marine taxonomy, and suggest that a large fraction of marine diversity remains to be discovered. We analyzed *Ophiolepis cincta* Müller & Troschel, 1842 a well−known tropical Indo−west Pacific brittle star, mainly found in shallow waters, from 1 to 40 m. While morphological variation has been noted in the past across the range, it has not been studied in detail, and only one of the forms has been described. We studied 140 specimens from across the range of this complex morphologically and sequenced a portion of the Cytrochome c Oxidase subunit I (COI) gene when possible. Morphological study revealed several novel characters, not only within the species complex, but also some that can be used to better characterize the genus and family. These new characters allowed separation of *O. cincta* into nineteen morphotypes. COI sequences revealed twelve deeply divergent, reciprocally monophyletic lineages, all corresponding to distinct morphotypes, demonstrating that these lineages represent different species. The current distribution of the species complex is ranging from Saudi Arabia to French Polynesia. Across its range we noted that some localities only have a single particular morphotype, while others consist of more than one.

32.3 PITTS, N.L.*; MYKLES, D.L.; Colorado State University, Fort Collins; *pittsn@rams.colostate.edu*

Nitric oxide production and sequestration in the sinus gland of the green shore crab, Carcinus maneas, using a copper−based fluorescent ligand

Molting in decapod crustaceans is regulated by molt−inhibiting hormone (MIH), a neuropeptide produced in the X−organ (XO)/sinus gland (SG) complex of the eyestalk ganglia (ESG). Pulsatile release of MIH from the SG suppresses ecdysteroidogenesis by the molting gland or Y−organ (YO). The hypothesis is that nitric oxide (NO), a neuromodulator that controls neurotransmitter release at presynaptic membranes, depresses the frequency and/or amount of MIH pulses to induce molting. NO synthase (NOS) mRNA was present in *Carcinus maneas* ESG and other tissues and NOS protein (~132 kDa) was present in the SG. A copper based ligand (CuFL), which reacts with NO to form a highly fluorescent product (NO−FL), was used to image NO in the ESG and SG and quantify the effects of NO scavenger (1 mM cPTIO), NOS inhibitor (1 mM L−NAME), and 1 mM sodium azide (NaN_3) on NO production in the SG. Preincubation with cPTIO prior to CuFL loading decreased NO−FL fluorescence ~30%; including L−NAME had no additional effect. Incubating SG with L−NAME during preincubation and loading decreased NO−FL fluorescence ~40%, indicating that over half of the NO release was NOS−independent. Azide, which reacts with NO−binding metal groups in proteins, reduced NO−FL fluorescence to near background levels without extensive cell death. Spectral shift analysis showed that azide displaced NO from a soluble protein in SG extract. These data suggest that the SG contains NO−binding protein(s) that sequester NO and releases it over a prolonged period. This NO release may modulate neuropeptide secretion from the axon termini in the SG. Supported by NSF (IOS−1257732).

18.3 PLACE, NJ*; ROOSA, KA; ZYSLING, DA; Cornell University; *njp27@cornell.edu*

Are means meaningless when using anti−Müllerian hormone to predict mating outcomes in old females?

We measured serum anti−Müllerian hormone (AMH) concentrations in 9−month−old female Siberian hamsters (*Phodopus sungorus*) to determine if this biomarker of reproductive age can forecast which females would produce viable offspring after mating. Our prior investigations determined that a substantial proportion of female hamsters experience reproductive failure when first mated at 9 months of age. In the present study we collected a small blood sample from 9−month−old females two weeks before pairing them with males and then measured AMH in the serum. Of the 26 females that showed signs of mating, 10 produced viable litters and 16 failed to litter. Mean (± SEM) AMH concentration in females that produced viable pups (25.3 ± 4.8 ng/mL) was significantly greater than in females that did not (13.9 ± 2.5 ng/mL). However, many females that failed to produce live pups had AMH concentrations that were well within the range of successful females. Nevertheless, AMH concentrations at the extreme high and low ends of the range (>35.0 and <8.0 ng/mL) were generally predictive of successful and failed mating outcomes, respectively. Whereas mean AMH values were informative of mating outcomes at the group level, an individual female's AMH concentration might only be predictive of her breeding potential if her test result deviates substantially from the mean. Our findings will be considered within the context of conservation biology, in terms of optimizing reproductive management decisions for endangered mammals.

96.2 PLACE, AJ*; DUNBAR, G; Northwestern Oklahoma State Univ.; *ajplace@nwosu.edu*

Ultraviolet Fluorescence of the Rattlesnake Rattle

Animal communication is a complex process that can occur in multiple sensory modalities. The rattlesnake rattle is known to be an auditory signal used in a defensive context. We present novel data suggesting that the rattle is also a visual signal when illuminated under ultraviolet light. The rattles of several species of rattlesnake were photographed while illuminated under a UV−LED array. Fluorescent intensity was quantified on the two proximal and two distal lobes of the rattle string using imageJ. We assessed variation in fluorescent intensity in a phylogenetic context and suggest some possible adaptive scenarios for rattle fluorescence.

P1.133 PLASCENCIA, M.*; CARSON, R.; HRANITZ, J.M.; BARTHELL, J.F.; ÇAKMAK, I.; GONZALEZ, V.H.; Univ. of California, Santa Cruz, Univ of Central Oklahoma, Bloomsburg University, Univ. of Central Oklahoma, Uludag University , Univ. of Kansas; *mplasce2@ucsc.edu*

Testing the pesticide avoidance hypothesis by bees and flies in a Mediterranean arthropod community

Pesticides are widely used for pest management in agricultural areas that support diverse arthropod communities. Recent research suggests that some arthropods, dipterans, display pesticide avoidance under natural conditions. We studied responses to pesticides by bees and flies in a Mediterranean plant community. We used pan traps and four pesticides commonly used in agriculture surrounding the Sea of Marmara region of Turkey to test for three behavioral responses (attraction, aversion, and neutrality) by arthropods. The pan trap experiment design sampled arthropods on four pesticides matched with controls in three pan trap colors (yellow, blue, and white). We used the standard high application rate of commercial pesticides in pan traps: 0.6 ml/L thiacloprid; 0.4 ml/L imidacloprid; 0.75 ml/L deltamethrin; 0.3 g/L acetamiprid. Arthropods were non−randomly distributed (P<0.05) among pan traps, showing a range of responses to color and pesticides. We compared responses to pesticides by bees and flies. Bees appeared randomly (P=0.160−0.849) distributed among four pesticide and control treatments. Flies appeared less (P= 0.001−0.026) often in pesticide than control treatments, which we interpreted as pesticide avoidance. Our study replicates pesticide avoidance by flies seen in another study and reveals that bees are neutral toward pesticides under natural conditions. Since bees do not avoid pesticides under natural condition, they are potentially more vulnerable to pesticide exposure than flies that have been studied for this effect.

100.6 POLI, DB.*; CARTIER, J.; DONOVAN, S.; EATON, C.D.; GOWER, S.; JENKINS, K.; LAMAR, M.D.; SHEEHY, R.; WOJDAK, J.; Roanoke College, Salem VA, Unity College, Unity MA, Univ. of Pittsburgh, Pittsburgh PA, University of Wisconsin−Madison, BioQUEST Curriculum Consortium, College of Washington and Mary, Williamsburg VA, Radford University, Radford VA; *poli@roanoke.edu*

QUBES: Bringing improved quantitative education to more undergraduates and faculty

Vision and Change stressed the importance of quantitative skills for the future of science in the United States. In response to this plea, biologists and mathematicians came together to discuss quantitative education, and QUBES (Quantitative Undergraduate Biology Education and Synthesis) was born. QUBES was recently awarded a five−year grant from the Improving Undergraduate STEM Education (IUSE) Program at the National Science Foundation, and aims to improve learning opportunities for all students enrolled in undergraduate biology courses. This presentation will focus on how QUBES plans to achieve this goal (for example, through mentoring networks and an online Hub of collaborating educators) and how you can get involved in this new community.

59.6 POLLOCK, H/S*; CHEVIRON, Z/A; BRAWN, J/D; University of Illinois at Urbana−Champaign; *hpollock@illinois.edu*

TESTING JANZEN'S HYPOTHESIS: VARIATION IN AVIAN THERMAL TOLERANCES ACROSS LATITUDE

Understanding the influence of abiotic environments on physiological traits has been a long−standing goal in evolutionary physiology. Janzen's hypothesis predicts that organisms from relatively seasonal environments (e.g. temperate latitudes) will evolve comparatively broad thermal tolerances to cope with greater environmental variation. In contrast, organisms from less seasonal environments (e.g. tropical latitudes) are expected to have narrower thermal tolerances, which may make less tolerant of environmental variation. Understanding how thermal tolerances vary across latitude is crucial in predicting whether tropical organisms have narrower tolerances and thus, greater susceptibility to climate change than their temperate−zone counterparts. We used the breadth of the thermoneutral zone (TNZ) to assay thermal tolerances in suites of tropical and temperate−zone resident bird species using flow−through respirometry. Temperate−zone species had significantly broader thermal tolerances than their tropical counterparts. Latitudinal patterns in thermal tolerance breadth were driven by variation at the lower end of the TNZ (Lower Critical Temperature: LCT), which was significantly lower in temperate−zone species. The upper end of the TNZ (Upper Critical Temperature: UCT) was not significantly different between tropical and temperate−zone species. Both UCT and LCT values were independent of body size and were consistent among individuals of the same species. Thermal tolerance (i.e. TNZ breadth) thus varies predictably with latitude and appears to be driven by exposure to cold temperatures. Our data confirm Janzen's hypothesis and suggest that environmental variation (i.e. past selective regimes and/or current environmental conditions) influences avian thermal tolerances.

84.3 PORATH−KRAUSE, AJ*; PAIRETT, AN; FAGGIONATO, D; SERB, JM; Iowa State University; *ajkrause@iastate.edu*

Structure and spatial expression differences among duplicated rhabdomeric opsins indicate functional change in photoreception of the scallop

Duplication of the photosensitive protein, opsin, is important for expanding visual and photosensory systems as it can provide the genetic foundation for adaptation. From our transcriptome data, we discovered four rhabdomeric (Gq−protein coupled or Gq−opsins) opsins expressed in the scallop, *Argopecten irradians*. Two of these were previously unrecognized. The four opsins appear to be the result of a series of gene duplication events in Bivalvia. We hypothesize that the four Gq−opsins have diverged since duplicating, and we test this hypothesis using genomic, bioinformatics, and protein−modeling approaches. We provide evidence that the four Gq−opsins 1) have dissimilar amino acid sequences, 2) differ in tertiary structure, and 3) vary in their spatial expression across tissues. Amino acid sequence comparisons between Gq−opsins showed overall percent identity values ranged from 41.3 to 64.6%, and key structural motifs differed in sequence composition. Protein homology modeling predicted four unique tertiary structures, with different amino acid residues interacting with the light−sensitive chromophore. Finally, gene expression data determined that Gq−opsins differ in spatial pattern and relative levels across photosensitive tissues, including the mantle and the eye.

65.4 PORTER, M/M*; ADRIAENS, D; MCKITTRICK, J; MEYERS, M/A; Clemson University, Ghent University, University of California, San Diego, University of California, San Diego; *mmporte@clemson.edu*

Bioexploration: How engineering designs help elucidate the evolution of seahorse tails

In most engineering disciplines, biomimicry often refers to the design process where engineers mimic or gain inspiration from biological systems to develop new technologies. Common examples include robots inspired by snakes or elephant trunks, adhesives inspired by gecko toes or mollusk byssi, and tough ceramics inspired by bone or abalone nacre. However, research in biomimicry can not only inspire new engineering technologies − *i.e., bioinspiration*, but also be used to further explore biological systems − *i.e., bioexploration*. Here, we introduce the first generation of artificial exoskeletons inspired by the prehensile seahorse tail. Mimicking the skeletal structure and function of the seahorse tail, we fabricated two prototypes of articulating structures with different cross−sectional profiles (i.e., square and circular). After exploring the mechanics of the two geometries, we learned that the square exoskeleton has several mechanical advantages over its circular counterpart. Linking that back to the biological system, this discovery helps explain the adaptive nature of the architecture of the bony−plated armor and the tail composed of square segments in relation to its protective and grasping capacities.

P2.164 PORTER, ME*; INGLE, D; PILLITTERI, JH; LONG, JH; Florida Atlantic University, Vassar College; *me.porter@fau.edu*

Region and ontogeny impact cartilaginous vertebral column mechanics

As swimming speed varies, body curvature changes along the length of the body, presumably as a function of body stiffness, skeletal stiffness, or some combination of the two. Since body curvature varies regionally, we hypothesize that the mechanical properties of the vertebral column also vary along the length of the body. The mineral fraction found in vertebral cartilage of elasmobranchs (sharks, skates, and rays) has been shown to influence the tissue stiffness, which varies by species. Based on previous research, we hypothesize that mineral content increases in these tissues throughout ontogeny and, in concert; the stiffness of the vertebral column will increase. Here we examine the effects of regional variation and ontogeny on the mechanical properties of vertebral columns from blacktip sharks (*Carcharhinus limbatus*). Specimens ranged in size from 52 to 113 cm, representing more than a doubling in animal size. We used a custom built bending rig to translate axial movement into bending on a dynamic mechanical tester over a range of frequencies (0.01 to 2.0 Hz) and strains (0.1 to 2%). Testing was done in an environmental chamber filled with elasmobranch Ringers solution to maintain cartilage hydration. We measured the apparent composite modulus, E (in MPa), an estimate of the contribution of material to the stiffness of the structure. Regional variation and the interaction between regional variation and ontogeny significantly influenced the composite modulus, but the effect of ontogeny alone was not significant. We found the same results for flexural stiffness, EI (Nm2), which takes into account the composite modulus and the second moment of area, I, a metric of the structure's cross−sectional distribution of material. We also found the same results for work out of the system (J), which is the energy released during elastic recoil.

82.6 POWDER, KE*; ALBERTSON, RC; UMass Amherst; *kepowder@bio.umass.edu*
Evaluation of species−specific ontogenetic trajectories for craniofacial morphologies in Lake Malawi cichlids
East African cichlids exhibit one of the most impressive adaptive radiations, and pivotal to this are species−specific craniofacial structures that allow ecological specialization. In order to understand the developmental origins for this morphological variation, we examined the growth trajectory for three aspects of craniofacial shape from the onset of osteogenesis through juvenile stages using geometric morphometrics. Specifically, we assessed variation in lateral, ventral, and lower jaw shape in six species (n>350 individuals) of Lake Malawi cichlids that span a major ecomorphological axis that distinguishes species that forage from the water column (pelagic) and those that feed from the rocky substrate (benthic). We find that, despite drastic differences in adult craniofacial morphologies, there is striking conservation in the direction of craniofacial ontogeny, suggesting that natural selection is working within a conserved developmental program. However, we also note species−specific differences in the timing and/or duration of particular trajectories (e.g., paedomorphism). Previous work in cichlids and other systems suggests that species−specific differences in adult morphology are due to changes in molecular signaling pathways that regulate early craniofacial development. In support of this, we demonstrate that modulation of Wnt signaling at early stages has discrete effects over extended periods of development, and can shift a developmental trajectory into morphospace normally occupied by another species. However, craniofacial shape recovers by juvenile stages, which underscores the idea that craniofacial development is robust and that adult head shapes are the product of many molecular changes acting over extended periods of development.

20.6 POWELL, T.H.Q.*; XIA, Q.; FEDER, J.L.; RAGLAND, G.J.; HAHN, D.A.; U. Florida, U. Florida, U. Notre Dame, Kansas State U., U. of Florida; *thqpowell@ufl.edu*
Dissecting the physiological basis of allochronic isolation in Rhagoletis
Much of the research on ecological speciation has focused on identifying traits underlying reproductive isolation and examining the resulting patterns of differentiation in the genome. However, drawing concrete connections between ecologically divergent phenotypes and genomic variation has proven difficult, particularly in the case of complex, polygenic traits. Closing the gap between ecological data and the genomic data may be accomplished by a physiologically−informed framework to identify the intermediate phenotypes involved in the manifestation of the trait under selection. Here we report results from a study aimed at examining the physiological basis for divergent life history timing in *Rhagoletis flies*. The two host races in the classic *Rhagoletis pomonella* system show strong differences in their adult eclosion phenology corresponding to phenological differences of their two host plants, downy hawthorn and domestic apple. In this study, we compared the post−winter metabolic trajectories of hawthorn and apple pupae to determine whether the allochronic isolation between the races is driven by the regulation of diapause termination or post−diapause development rates. We found that apple flies typically terminate diapause within the first few weeks of warm temperatures, while hawthorn flies stay in a state of metabolic suppression long into spring. Furthermore, timing of adult eclosion within each population was strongly correlated with the timing of diapause termination, with no evidence for differences in post−diapause rates of pharate adult development. Our results show that the precise stage of developmental divergence between the two races occurs shortly after the cessation of winter, allowing for finely focused studies comparing the transcriptomic, proteomic, and metabolomics profiles of the two races during this critical phase.

34.4 POWERS, D.R.*; TOBALSKE, B.W.; LANGLAND, K.M.; WETHINGTON, S.M.; WILSON, J.K.; WOODS, H.A.; George Fox Univ., Newberg, OR, Univ. of Montana, Missoula, HMN, Patagonia, AZ; *dpowers@georgefox.edu*
Heat Dissipation during Hovering and Forward Flight in Hummingbirds and the Potential Impact of Climate Change
Birds must dissipate large amounts of heat produced during flight. In forward flight this is a challenge because the skin is insulated by plumage that must stay aerodynamic. In passerines heat dissipation occurs where feather density is low (head, axial, and legs). To place these data in a comparative context, we analyzed surface−heat dissipation in hummingbirds flying at 0−12 m/s. Hummingbirds are unique in that they are capable of sustained hovering, yet also capable of speeds to >12 m/s including transition from limited convection during hovering to high convection in forward flight. We measured surface temperature (T_s) in hummingbirds both in a wind tunnel (0−12 m/s) and in the field using infrared thermography. Important regions of heat dissipation were the head/eye, axial, and legs/feet. Mean body T_s was highest during hovering. Mean T_s of the eye was constant across speeds, but decreased in size with notable transitions at 2, 8, and 12 m/s as convection increased. Heat dissipation through the legs/feet occurred during hovering, but only rarely during forward flight. Both the head/eye and legs/feet appear important when convection is low. The eye is located at what is likely an area of peak dynamic pressure, ideally placed for facilitating convection at all speeds. In free−living hummingbirds T_s increases linearly with environmental temperature. Because temperature is predicted to increase due to climate change in many hummingbird habitats it is possible that smaller thermal gradients will make heat dissipation during hovering more difficult and contribute to climate−change related shifts in distribution. Supported by NSF grants IOS−0923606 and IOS−0919799, and NASA 10−BIOCLIM10−009.

P1.126 POWERS, S.D.*; POWERS, D.R.; TOBALSKE, B.W.; WETHINGTON, S.M.; CHENG, B.; George Fox Univ., Newberg, OR, Univ. of Montana, Missoula, MT, HMN, Patagonia, AZ, Purdue Univ., IN; *seandpowers@gmail.com*
Does Body Size and Ambient Temperature Impact Heat Dissipation in Hummingbirds during Hovering Flight?
Hovering flight is used frequently by hummingbirds during foraging to meet fuel energy demands. Hovering is not only energy expensive, but heat generated by flight muscles imposes a thermoregulatory challenge. To dissipate excess heat birds rely on evaporation, conduction, and induced convection (caused by wing movement), of which the latter two depend on a thermal gradient. Increased temperature due to climate change might reduce this thermal gradient, making heat dissipation more difficult, causing heat management to be more challenging. To understand how body size and ambient temperature (T_a) impact heat dissipation in hovering hummingbirds we used infrared thermography to measure surface temperature (T_s) in 5 hummingbird species ranging in size from 2.8−8.0g over T_a ranging from18−29°C during hovering flight. Consistent with previous studies mean body T_s was relatively low (25−30 °C) as plumage insulates the skin surface, with heat dissipation occurring primarily from regions around the eye, axial, and legs/feet where feather density is low. Except for the use of legs/feet, mean and maximum T_s, and relative size of heat dissipation regions did not vary with body size suggesting that heat dissipation strategies were similar for all species. Smaller species (<3.5 g) dangled their feet while hovering whereas feet remained tucked in larger species (7.5−8.0 g). It is not clear why heat dissipation from legs/feet is less important for larger species. Except for mean body T_a, all mean and maximum T_a values were positively correlated with T_a suggesting that environmental temperature can reduce the thermal gradient. The size of heat dissipation areas was not correlated with T_a and is perhaps restricted more by feather density.

24.7 PRADHAN, DS*; CONNOR, KR; PRITCHETT, EM; GROBER, MS; Univ. of California, Los Angeles, Georgia State Univ., Atlanta, Univ. of Delaware, New Jersey; *dpradhan1@student.gsu.edu*

Permissively loaded: confluence of social context and androgen treatment in a sex changing fish

During the lifetime of an organism, key events are orchestrated by a confluence of environmental, social, and physiological factors to promote reproductive success. In the bi−directionally sex changing fish, *Lythrypnus dalli*, stable haremic groups maintain a linear social hierarchy. Status instability follows immediately after male removal, causing transiently elevated agonistic interactions and increase in brain and systemic levels of a potent fish androgen, 11−ketotestosterone (KT). Coupling KT implants with a socially inhibitory environment for protogynous sex change induces rapid transition to male morphology, but no significant change in social behavior and status occurs. Here, we examined whether coupling a social environment permissive to sex change would influence KT effects on agonistic behavior. We implanted cholesterol (control) or KT in the dominant individual (alpha) undergoing sex change (on d0) and determined the effects on behavior and the degree to which administered steroids altered the steroid load within tissues. During the period of social instability, there were rapid (within 2 h), but transient effects of KT on agonistic behavior in alphas, and secondary effects on betas. On d3 and d5, all KT, but no cholesterol−treated females had male typical genital papillae. Despite elevated brain and systemic KT 5 d after implant, overall rates of aggressive behavior remained unaffected providing no evidence for the notion that hormones drive behavior with an "on−off" switch mechanism. These data highlight the importance of social context in mediating complex hormone−behavior relationships.

S6.2 PRAVOSUDOV, V. V.; Univ. of Nevada Reno; *vpravosu@unr.edu*

Climate related variation in spatial memory and the hippocampus − what are the mechanisms of population−level differences?

Harsh environments and severe winters have been hypothesized to favor improved cognitive abilities used for successful foraging. Geographic variation in winter climate, then, is likely associated with differences in selection pressures on cognitive ability, which could lead to evolutionary changes in cognition and its neural mechanisms. As predicted under natural selection, two species of food−caching chickadees, which depend on stored food to survive winter and rely on spatial memory to recover their stores, exhibit extensive climate−related population variation in spatial memory and the hippocampus. Such population variation, however, could be driven by several potential mechanisms including natural selection, environment− and experience−based plasticity, and/or epigenetic differences. Extensive data on cognition and brain morphology in multiple populations along longitudinal, latitudinal and altitudinal winter climate gradients are consistent with the hypothesis that natural selection drives population−level differences in spatial memory. To date, however, there is no support for the hypotheses that environment−induced plasticity or developmental differences are the main causes of population differences across climate gradients. Available published data on epigenetic modifications of memory ability are also not consistent with the observed patterns of population variation, with birds living in more stressful and harsher environments having better spatial memory, larger hippocampus and larger number of hippocampal neurons. Overall, existing data indirectly suggest that differences in winter climate drive the evolution and maintenance of population differences in cognition and the brain via natural selection, at least in food caching parids.

90.2 PRESNELL, J.S.*; BROWNE, W.E.; Univ. of Miami; *j.presnell@umiami.edu*

Expression of Kruppel−like factors during embryonic development of the ctenophore Mnemiopsis leidyi

The *Kruppel−like factor (Klf)* gene family consists of two closely related groups of transcription factors, Klf and Sp factors. Klf/Sp proteins are defined by a highly conserved DNA binding domain composed of three C−terminal C2H2 zinc fingers that bind GT box and GC−rich DNA sequences associated with gene regulatory regions. Collectively the *Klf/Sp* genes play key roles in a variety of critical biological processes including metabolism, cell proliferation, stem cell maintenance, embryonic development, and tissue differentiation as well as being implicated in a number of human diseases and cancers. There are 26 *Klf/Sp* genes found in mammals divided into six groups; *Klf1/2/4* and *Klf6/7*, *Klf3/8/12*, *Klf9/13/14/16*, *Klf10/11*, *Sp1−4*, and *Sp5−9*. The *Klf* gene family has been well documented in mammals, and gene expression studies have been performed in a few classic bilaterian model organisms. However, very little is known about the *Klf* gene family and its expression during development in non−bilaterians. Here we provide the first description of *Klf* gene expression in a non−bilaterian metazoan, the ctenophore *Mnemiopsis leidyi*. *Mnemiopsis* has two *Klf genes*, *MleKlfa* and *MleKlfb*, that group with mammalian *Klf1/2/4* and *Klf6/7*. Both of these genes are ubiquitously expressed during early stages of development, with expression patterns becoming spatial restricted after gastrulation. Regions of high *MleKlf* gene expression correspond to areas of high cell proliferation. This includes the developing mouth and pharynx, the tentacle bulbs, and the apical organ. By investigating the expression of *Klf* genes in an early branching metazoan, we may gain insight into the ancestral function of this ancient transcription factor gene family in metazoans.

73.2 PRICE, E.R.*; ROTT, K.H.; CAVIEDES−VIDAL, E.; KARASOV, W.H.; University of Wisconsin−Madison, Universidad Nacional de San Luis; *eprice2@wisc.edu*

An approach for comparing qPCR data across species, applied to paracellular nutrient absorption

Bats have a high reliance on the passive, paracellular absorption of glucose. This contrasts with non−flying mammals that rely extensively on glucose transporters. This could derive from among−species differences in the permeability of the tight junctions across which paracellular absorption occurs. Tight junctions are complex structures composed of many proteins (particularly claudins), and the protein makeup of the tight junctions is thought to affect their permeability characteristics. We desired to use qPCR to investigate the pattern of claudin gene expression and how that pattern varies between bats and non−flying mammals, but could find no general protocol for comparing qPCR data across species. We will discuss the particular problems associated with making cross−species comparisons, including finding comparable normalization genes, differences in the efficiencies of reactions, and variable fluorescence of SYBR green with differing amplicons. Our solutions to these problems included: use of a functionally relevant reference gene, designing primers that work with multiple species when possible, accurate measurement of reaction efficiency for every amplicon, and controlling for variation in fluorescence via normalizing by AT content (adenine/thymine content) of the amplicon. We will also apply these methods to intestinal tight junction proteins in several bat and non−flying rodent species to understand how they are associated with differences in paracellular nutrient absorption. Supported by USA NSF and Argentina CONICET.

98.4 PRICE, S. A.*; WAINWRIGHT, P. C.; Univ. of California, Davis; *saprice@ucdavis.edu*

Phylogeny, ecology and the shape of reef fishes

Reef fishes are one of the most diverse vertebrate assemblages on earth, exhibiting a remarkable variety of shapes, from elongate to deep−bodied and almost spherical to laterally compressed. What drives this diversity? Many ecologies and behaviours such as feeding, courtship and predator evasion are potentially linked to the geometry of fish body shape through its affects on the structural properties of the body and external fluid dynamics. We investigate how lateral shape as well as shape disparity are related to ecology and phylogeny across reef fishes. We used 17 previously published landmarks related to the shape of the head and body for 791 reef acanthomorphs and analyzed them using phylogenetic comparative methods that explicitly incorporate the high−dimensional multivariate nature of geometric morphometric data. Across acanthomorphs shape shows a significant phylogenetic signal (K=0.44 p−value=0.001) but it is weaker than expected under Brownian motion (K=1) and it is highly variable between families. There is also no consistent relationship between shape, shape disparity and feeding ecology across acanthomorphs. Within wrasses and parrotfishes herbivory/detrivory is associated with significantly faster rates and greater disparity but across Acanthomorpha there is no significant difference in the rate of evolution in carnivorous and herbivorous fishes. Similarly, the expectation that pelagic plankton feeders should be elongate is supported in some families (e.g. surgeonfishes) and not in others (e.g. damselfishes). Our results reveal that the relationship between shape and ecology is complex. Therefore, the primary axis of shape variation across fishes, which is one of elongation, is unlikely to have a single, simple ecological explanation.

112.2 PRICE, E R; BRUN, A; CAVIEDES−VIDAL, E; KARASOV, W H*; Univ. Wisconsin−Madison, Univ. San Luis, Argentina; *wkarasov@wisc.edu*

Bats and birds share digestive adaptations to an aerial lifestyle

Powered flight evolved at least twice in vertebrates. We tested for shared digestive adaptations in two extant volant lineages. Bats and birds, compared with nonflying mammals, share shorter intestines and smaller nominal intestinal surface areas (NSA), which lowers digestive mass carried and thus improves flight maneuverability and economy. The daily digestive "load" placed on the intestine (= ratio of daily energy needs to NSA) is at least twice higher in vertebrate flyers than nonflyers. Intestinal hydrolytic enzyme and nutrient transport activities appear similar among these groups per unit intestine, but lower over the entire intestine in the fliers, which translates to lower spare digestive capacity. Nutrients can also be absorbed paracellularly by passing through the tight junctions that link adjacent enterocytes. Seven bat species and 14 bird species, with a variety of natural diets, absorbed significantly more of ingested L−arabinose and other similarly sized, metabolically inert, nonactively transported monosaccharides than 18 species of nonflying mammals. These differences in nutrient−sized probe absorption were demonstrated at the tissue level comparing results from perfusion experiments (7 bat species, 1 bird, 5 nonflying mammals) that control for several potential confounding factors. Greater amplification of digestive surface area by villi and differences in expression patterns of junctional proteins (i.e., claudins and occludin) may provide mechanistic explanations for the observation of higher paracellular absorption in bats and birds relative to nonflying mammals. Supported by USA NSF (IOS−1025886) and Argentina CONICET.

12.2 PRITCHARD, A.C.; Stony Brook University; *adam.pritchard@stonybrook.edu*

Extreme modification of the tetrapod forelimb in a Triassic reptile

The bones of the tetrapod forearm have maintained a conservative pattern of relationships in the over 300 million years since their initial evolution. The radius and ulna have parallel shafts of roughly equal length that meet proximodistally short carpal bones. Despite extreme changes in the forelimb function (e.g., terrestrial locomotion, swimming, flying, manipulation), this general pattern has remained consistent. A Late Triassic drepanosaurian reptile exhibits a radical deviation from the stereotypical tetrapod pattern. *Drepanosaurus* is an enigmatic diapsid known from Italy and New Mexico. In this taxon, the forearm exhibits a broad, flattened, and crescent−shaped ulna that has its long−axis oriented perpendicular to that of the radius. The ulna distally contacts two slender carpals, which are proximodistally longer than the radius. The manus supports a gigantic, recurved claw that is longer and more massive than any other forelimb bone. Reconstruction of muscle attachment sites suggests substantial expansion of attachments for digital flexors and extensors, potentially a consequence of the massively expanded unguals.

S3.3 PRITZ, Michael B.; George Mason University; *michael.pritz@denlabs.com*

Crocodilian Forebrain: Evolution and Development

The forebrain consists of the telencephalon and diencephalon. This area in crocodilians, the reptilian group most closely related to birds, is compared with homologous regions in other amniotes from the perspective of both evolution and development. The forebrain of crocodilians shares many features in common with that of birds although the forebrain of most avian species is more complex than that of crocodiles. Forebrain organization in crocodilians and birds differs markedly from that of mammals. These features are reflected in: neuronal populations in the dorsal thalamus; fiber connections between the dorsal thalamus and telencephalon; and organization of the thalamic reticular nucleus. How this has come about through evolution and development remains unclear. However, early forebrain development among amniotes is similar. Specifically, early diencephalon development follows a common pattern. This suggests that later development is the time when the diencephalon undergoes changes that produce the different patterns of organization seen in adult amniotes. These data in crocodilians are reviewed and compared with other amniotes. In addition, experiments to address some of these unanswered questions are presented.

P2.51 PRUETT, J.*; CAMPOS, S.; SOINI, H.; NOVOTNY, M.; VITAL, C.; ZÚÑIGA−VEGA, J.; MARTINS, E.; HEWS, D.; Indiana State University, Terre Haute, Indiana University, Bloomington, Univ. Autonoma de Ciudad Juarez, Mexico, Univ. Nacional Autonoma de Mexico; *jpruett1@sycamores.indstate.edu*
Variation in volatile compounds of femoral gland secretions from four Sceloporus species differing in abdominal coloration and effects of androgen implants
Male *Sceloporus* lizards mediate social interactions through multimodal signals involving chemical secretions and visual displays of motion and color. Several independent evolutionary losses of a key visual signaling trait (blue abdominal patches) have occurred in *Sceloporus*, and previous studies suggest species that have lost the visual signal may use chemical information more than do species with the coloration. In response to elevated androgens, femoral glands (FGs) of breeding season males exude waxy secretions containing volatile organic compounds (VOCs), lipids and proteins. We predicted loss of the blue signal would be associated with increases in the relative proportion of some VOCs, and exogenous androgens would also increase relative proportions of some VOCs. We analyzed VOC components of FG secretions from four *Sceloporus* spp. (2 blue, 2 white) with gas chromatography−mass spectrometry. We tentatively identified 25 compounds including linear carboxylic acids and methyl ketones. The abundance of carboxylic acids varied among species but showed no distinct pattern associated with abdominal patch color. The abundance of methyl ketones was higher for one white species relative to the more closely related blue species, however, the opposite pattern was observed in the other species pair. Finally, exogenous testosterone implants in males of a blue species, *S. occidentalis*, increased production of FG secretions as is commonly found, but also increased the relative proportions of some steroid compounds.

P3.80A PUSCH, E.A.*; NAVARA, K.J.; University of Georgia; *epperfectchoice@gmail.com*
The effect of stress on heat shock protein expression in two strains of laying hens
It has now been well established that animals with reactive versus proactive personalities also show differences in hormonal responses to stress. Reactive animals produce larger amounts of corticosterone when compared with proactive animals after stress exposure. We know less, however, about whether other physiological variables that change after stress exposure differ between personality types. In addition to corticosterone elevations, stressors also provoke a suite of other physiological changes, including redistributions of circulating white blood cells and the production of heat shock proteins (HSPs). In fact, it has been proposed that elevations in the levels of HSPs may be a more effective measure of long−term stress exposure.. Brown and white laying hens are excellent models of these two personality types: white layers are reactive and display high corticosterone responses to stress while brown hens are proactive and produce low levels of corticosterone after stress exposure. We predict that white and brown hens will also display differences in white blood cell distributions and levels of HSPs. Thus, the objective of this study was to determine whether brown and white hens differ in their alteration of heterophil lymphocyte (H:L) ratios and production of HSP−60, 70, and 90 in response to stress exposure and corticosterone elevations. Hens were exposed to food restriction, or were provided corticosterone in water for ten days. Control birds were given no treatment. We predicted that treatment will increase H:L ratios and HSP expression in both strains with white layers showing a greater response to treatment than brown layers. Results will be discussed.

S6.8 PUTMAN, N.F.; NOAA Southeast Fisheries Science Center; *nathan.putman@gmail.com*
The role of geomagnetic change on the ecology and evolution of magnetic navigation systems in animals
Movement patterns in animals suggest an impressive ability to navigate and have fueled considerable interest in possible sensory mechanisms. Accumulating evidence indicates that diverse animals use information from the Earth's magnetic field for navigation over a wide range of spatial scales. In particular, a large−scale "magnetic map" from which animals derive positional information may underpin the life−history characteristic of many marine migrants: transiting between disparate oceanic regions and ontogenetic shifts in habitat utilization. However, there are several complications for such a navigational strategy. Due to high−frequency (e.g., weather) and longer−term (e.g., El Nino) processes, ocean currents experienced by individuals may vary substantially from what is "average", as will the optimal swimming trajectory. Thus the precision by which natural selection pairs geomagnetic information with meaningful orientation responses at particular locations, in the context of the ocean conditions encountered by individuals, may be limited. The challenge for animals is even greater given that the "map" they are attempting to overlay upon a variable ocean surface is, itself, gradually shifting across the globe and is prone to dramatic excursions and reversals every several hundred thousand years. The complex interplay between ocean circulation and geomagnetic dynamics offers a unique conceptual setting to test hypotheses for how animals deal with environmental change and the ecological and evolutionary implications of behavior. Moreover, recent work in salmon and sea turtles suggests that considering geomagnetic change is essential to mechanistically predict spatiotemporal variation in animal movement patterns and manage migratory species in the face of global climate change and widespread habitat alterations.

71.5 PUTNAM, H; RITSON−WILLIAMS, R*; GATES, R; University of Hawaii; *rrw33@hawaii.edu*
Coral recruitment in a high CO2 environment: A trans−generational perspective
As concentrations of CO_2 increase in our atmosphere, we have little information on how intensifying ocean acidification (OA) will impact coral recruitment, a process critical to reef persistence and recovery that encompasses three life history stages; larval supply, larval settlement and post−settlement survival. Furthermore, no studies have integrated across these processes to address the potential for trans−generational acclimatization to OA. We manipulated CO_2 concentrations in outdoor mesocosms using a pH−stat system (with daily pH fluctuations of 7.8−8.1 [ambient] and 7.5−7.8 [high]) to expose adult *Pocillopora damicornis* colonies to OA during the brooding period, and then exposed their brooded larvae in a reciprocal contrast after 10 weeks. After 6, 10 and 14 weeks of adult exposure, fecundity was consistently reduced in the corals exposed to OA. Larval survival was greater when adult corals were preconditioned at high pCO_2 for 10 weeks. Conversely, larvae exposed to OA conditions for 4 days had lower survival than those in the control treatment regardless of brooding conditions. After one month of post−settlement growth the recruits that originated from adults treated with OA had higher growth rates, but there was no effect of OA on the survival of new recruits. Overall, corals exposed to OA conditions as adults had fewer larvae but those larvae may have better performance. Our data highlight the importance of trans−generational studies for understanding the potential impacts that OA might have on demographic processes that drive reef dynamics.

65.5 QIAN, F*; ZHANG, T; KORFF, W; UMBANHOWAR, PB; FULL, RJ; GOLDMAN, DI; Georgia Tech, Univ. of California, Berkeley, Northwestern University, Univ. of California, Berkeley; *qianfeifei1114@gmail.com*

Principles of foot design in robots and animals determining terradynamic performance on flowable ground

Natural substrates like sand, snow, leaf litter and soil vary widely in penetration resistance. To search for the principles of foot design in robots and animals that permit high performance on flowable ground, we developed a novel ground control technique by constructing an air− uidized bed trackway in which penetration resistance of one millimeter granular substrates can be continuously reduced to zero by increasing the upward ow rate of air, *Q*, to the uidization transition. Using a bio−inspired hexapedal robot as a physical model, we systematically studied how locomotor performance (average forward speed, *v*) varies with ground penetration resistance and robot leg frequency. Average robot speed decreased with increasing *Q*, and leg frequency. A universal scaling model revealed that the leg penetration ratio (foot pressure relative to penetration force per unit area per depth and leg length) determined *v* for all robot ground penetration resistances and leg frequencies. Despite variation in morphology and gait, the performance of running lizards, geckos and crabs on owable ground could be predicted from leg penetration ratio. Foot designs resulting in decreased foot pressure can passively minimize leg penetration ratio as the ground becomes weaker, and therefore permits maintenance of effective high−speed running over a range of terradynamically challenging surfaces.

P1.77 QUESADA, P.R.*; MIRANDA, R.A.; ARJONA−SOBERON, J.; MARTINEZ−ACOSTA, V.G.; Univ. of the Incarnate Word; *pquesada@student.uiwtx.edu*

Development of a QPCR assay to evaluate gene transcripts encoding proteins involved in Lumbriculus variegatus regeneration

The aquatic oligochaete *Lumbriculus variegatus* possesses an exceptional ability to regenerate lost body parts. This species also has an organized central nervous system making it an ideal model system to study regeneration. The goal of our lab is to understand regenerative mechanisms in *Lumbriculus*. Previous studies in the lab have suggested an upregulation of ²−catenin protein in the ventral nerve cord of regenerating fragments. This dual function protein activates cell−specific transcription factors in the canonical Wnt signaling pathway or can function as a cell adhesion molecule. The increased activity of ²−catenin during regeneration suggests it may play an important role during Lumbriculid regeneration. Proteomic work is limited in non−traditional model systems like *Lumbriculus*. Thus we are currently developing a QPCR assay to evaluate transcripts encoding ²−catenin and other putative regenerative proteins during regeneration. Using bioinformatics tools, we have identified conserved regions of genes coding for regenerative proteins in other organisms. Using these regions we have developed consensus sequences and designed degenerative PCR primers to amplify coding sequences. Gel electrophoresis results indicate that we have PCR products of the expected size for reference genes including alpha tubulin, ²−actin and ribosomal protein L8. We are currently testing primer sets for the gene encoding ²−catenin and working to develop primers for genes encoding proteins (zicA, FoxD, and Wnt proteins) that are known to regulate regeneration in other model systems. After developing specific QPCR primers our results should help us better understand regenerative mechanisms of *L. variegatus* and potentially of higher order phyla.

P3.21 QUINN, M.M.*; NEUWALD, J.L.; KIRCHER, B.K.; CONGDON, E.R.; JOHNSON, M.A.; Trinity University, Colorado State University, University of Florida, Bethune−Cookman University; *mquinn2@trinity.edu*

Resource Allocation in Female Lizards: Reproduction vs. Growth After Tail Autotomy

Many species of lizards can autotomize their tail in response to the threat of predation. Tail autotomy is often followed by the regeneration of the tail, a process that is thought to be costly, although the costs of autotomy to females are rarely examined. In this study, we tested whether female *Anolis sagrei* lizards with an autotomized tail experienced lower reproductive fitness than a control group. To this end, we captured 30 gravid female *A. sagrei* early during the summer 2013 breeding season. Following a weeklong acclimatization period in the lab, we removed ~68% of the tails of 15 females, and the tails of 15 control females remained unmanipulated. For the next six weeks, all 30 females were housed individually, with access to a male every five days. All eggs laid were massed within one day of parturition, and once a week, we measured the mass, snout−vent length, and tail length of each female. Our results showed no difference between autotomized and control groups in the number of viable eggs laid, the average mass of those eggs, and the average change in female body mass or snout−vent length over the experimental period. However, during this time autotomized lizards showed an average regenerated tail growth of 26mm, compared to the average tail growth of 4mm in the control group. These results suggest that in this species where tails autotomize so easily, tail regeneration may incur minimal costs.

P1.13 QUIROLA, D/*; MARMOL, A/; TORRES−CARVAJAL, O/; MOORE, I/T; Pontificia Universidad Católica del Ecuador, Virginia Tech; *diegoctz@hotmail.com*

Use of the proboscis during social interactions in the Ecuadorian Horned Anole, Anolis proboscis

Sexual selection has resulted in numerous examples of exaggerated traits that often are the focus of investigation. These traits are typically used in mate choice, intra−sexual competition, or both. In males this can result in the evolution of exaggerated secondary sexual characters, which may be indicative of the animal performance. *Anolis proboscis* is a slow−moving cryptic species, endemic to the western slopes of the Andes in Ecuador that was rediscovered in 2005 after it was believed extinct for nearly four decades. Despite its rediscovery, most of the natural history of this species remains almost completely unknown. The males of the species (adults and neonates) have a laterally compressed, soft, flexible, fleshy nasal appendage which they can move at their will. We investigated use of the nasal appendage in social interactions. We captured free−living *A. proboscis* in the area surrounding the town of Mindo, Pichincha Provence, located on the western slopes of the Andes in Ecuador and conducted behavioral trials approximately 5 km away from the collecting sites. For each trial, two lizards (two males, or one male and one female) were placed on branches of a tree with two video cameras recording the interactions. We were able to observe and videotape 11 copulations and 2 male−male combat. The nasal appendage was not used as a weapon in these interactions but was used as part of the social displays. Further, the appendage is lifted during the social interactions although what role this movement plays is unclear. Our studies are providing new insights of the social behavior of this species as well as providing clues into the use of exaggerated sexually selected traits.

P2.26 RADER, JA*; DILLON, ME; MARTINEZ DEL RIO, C; UNC Chapel Hill, U. of Wyoming; *jrader@live.unc.edu*

Isotopic niches are not conservative and confirm Brown's resource breadth hypothesis

Brown's Resource Breadth Hypothesis posits that species that can exploit a broader range of consumable resources have broader geographic ranges. We tested the isotopic version of Brown's hypothesis in ovenbirds of the genus *Cinclodes* (family Furnariidae). Briefly, we used isotopic niches as surrogates for ecological ones. We predicted a positive evolutionary correlation between the width of the niches defined by the isotopic values of hydrogen and oxygen and those defined by the isotopic values of nitrogen and oxygen. The former describe the altitudinal and latitudinal range of a species, whereas the latter estimate the breadth of habitats and resources used. In support of Brown's hypothesis, we found that the width of carbon/nitrogen niches was positively correlated with that of oxygen/hydrogen. This result was independent of whether we accounted for phylogenetic relationships or not, and hence, appears to be a robust result. In *Cinclodes* the range of altitudinal and latitudinal ranges seems to be positively correlated with the breadth of habitats and resources used by species. We also estimated the phylogentic signal of both isotopic width and isotopic position. We found that *Cinclodes* niches are more evolutionary divergent than predicted by a Brownian model of evolution. This result suggests that the isotopic niches of *Cinclodes* are not phylogenetically conserved. To our knowledge these results are the first attempt using isotopic niches to test hypotheses about how ecological niches evolve.

46.2 RADZIO, TA*; O'CONNOR, MP; Drexel University; *tar55@drexel.edu*

Behavioral Thermoregulation and Thermal Constraints on Growth in Juvenile Gopher Tortoises

Many reptiles behaviorally regulate their body temperatures to increase energy assimilation and growth. However, some reptiles may limit thermoregulation due to increased predation risk associated with basking or other thermoregulatory activities. We investigate behavioral thermoregulation in juvenile gopher tortoises (*Gopherus polyphemus*), burrowing reptiles of the southeastern United States, and predict how thermoregulation and thermal environment influence growth. Since young tortoises are difficult to observe undisturbed, we used video cameras at burrows to quantify tortoise activities. Juveniles limit most basking activity to directly in front of their burrows from where they can quickly hide below ground to avoid predators. Juveniles shuttle in and out of burrows at predictable intervals to maintain preferred body temperatures. While juveniles generally only bask in front of burrows, they take advantage of most thermal opportunities available at these locations. In the lab, food intake and growth rate are highly temperature dependent across a narrow range of ecologically relevant temperatures and are greatest at the preferred body temperatures of fed tortoises. Therefore, by maintaining preferred body temperatures, juveniles can presumably increase their growth rates. Since young tortoises limit most basking to directly in front of their burrows, increased shading of their environment, stemming from fire suppression and other poor land management practices, may reduce tortoise growth rates and potentially result in adverse population−level consequences.

S3.11 RAINWATER, TR*; WOODWARD, AR; WILKINSON, PM; U.S. Fish and Wildlife Service; *trrainwater@gmail.com*

Evidence of determinate growth in American alligators (Alligator mississippiensis) based on long−term recaptures

Debate exists as to whether crocodilians exhibit determinate or indeterminate growth. Long−term mark−recapture studies appear to be the best method of determining long−term growth patterns in crocodilians, but because of the inherent difficulties in conducting decades−long mark−recapture studies on wild, long−lived species, only a few such studies have been successfully undertaken. However, each of these investigations has documented cessation of growth well before senescence in the species examined, thereby supporting the concept of determinate growth. In this study, we examined growth (total length) in a population of wild American alligators (*Alligator mississippiensis*) in coastal South Carolina over a period of 32 years (1980−2012). To ensure adequate time had passed for discernible growth to occur between the most recent recapture and the previous or initial capture, we included in our analysis only those alligators that were at least slightly below approximate minimal adult size at the previous/initial capture and recaptured >10 years later. No discernible growth was observed for 22 animals during the study. Discernible growth occurred in 34 alligators examined, but these animals were all well below asymptotic size when initially captured. These results provide evidence that alligators in the study population reach asymptotic linear length during the mid−part of their adult life and continue to reproduce for an extended period of time after reaching that point. Overall, this investigation complements findings of similar studies on other crocodilian species and further suggests that lineal growth in some, if not all, crocodilians is determinate.

67.3 RAM, YV*; IRIARTE−DIAZ, J; ROSS, CF; University of Chicago, University of Illinois, Chicago; *yashesvini@uchicago.edu*

Muscle Synchronization and Coordination During Rhythmic Mastication in Primates

Mastication is a complex and variable behavior that is also rhythmic. During mastication, the amplitude and timing of muscle activity demonstrates both stereotypy and flexibility. Current hypotheses suggest that groups of muscles are activated as units (Triplets) during specific phases of the masticatory cycle. The present study examines these claims by quantitatively evaluating the interaction between muscle pairs using Hilbert relative phase. Two muscles are synchronized if their relative phase is constant and events within their cycles occur in unison. Muscle coordination is defined here as modulation (adjustment or maintenance) of relative muscle activity (amplitude and timing) to achieve goal specific force production and kinematics. Two muscles are coordinated if they have low variation in relative phase either within a sequence or between sequences. Preliminary results based on 36 masticatory sequences in a single macaque (*Macaca mulatta*) show that the triplet muscles (left and right superficial masseters, medial pterygoids, and posterior temporalis) are synchronized within a sequence but not coordinated between sequences. Moreover, within a sequence, muscles in the same triplet have a lower relative phase than muscles in two different triplets. These findings suggest that the jaw closing muscles (especially muscles within the same triplet) are phase locked with each other, but they are also controlled independently.

102.5 RAMENOFSKY, M*; CAMPION, D; NEMETH, Z; University of California Davis, USA, Univeristy of Debrecen, Hungary; *mramenofs@ucdavis.edu*
Comparisons of the behavioral and physiological traits of migrant and resident White−crowned Sparrows: a common garden approach to studies of migration
To understand the physiological mechanisms and constraints associated with migration, direct comparisons of the migratory (*Z.l. gambelii*) and resident (*Z.l. nuttalli*) races of White−crowned Sparrow were made under experimental common garden conditions. Populations selected for the study reside at the same latitude (38°N) for 7 months of the year. For residents this period includes wintering and breeding while migrants undergo pre−alternate molt and vernal migration. The study was conducted for 5 months starting in December and included 11 resident and 12 migrant males held in individual registration cages under local photoperiod. Development of the breeding stage for residents was detected in January with elevated plasma androgens that later peaked in February and March along with lengthening of the cloacal protuberance. By contrast, pre−alternate molt started in migrants in February followed in March and April with increases in body mass, fat stores, flight muscle hypertrophy and color change. By mid−April migratory restlessness was observed. All are traits attributed to preparations for, expression of, and coincident with spring migration in wild birds. Plasma corticosterone was similar in both races except when migrants were undergoing pre−alternate molt. Under identical photoperiodic conditions, residents respond earlier to photoinduction culminating in breeding that in the field occurs two months before that of migrants. Therefore time constraints require that migrants prepare and complete migration before breeding and physiological conditions associated with molt affect glucocorticoid secretion both illustrating distinct selective pressures on each race at each stage.

P1.110 RAMIREZ, J*; CULBRETH, E; CRESPI, EJ; TRAVIS, J; Washington State University, Florida State University; *juan.ramirez@email.wsu.edu*
Examining variation in plastic responses to different selective agents in the least killifish
Most studies examining adaptive phenotypic plasticity focus on one environmental gradient; however, natural populations face combinations of multiple selective agents. Here we tested whether phenotypic responses of female least killifish depended on historical environmental conditions: one of high predation risk/low conspecific density and one of low predation risk/high conspecific density. We predicted that populations would have evolved a diminished response to the dominant selective agent to maintain fitness in these environments. First, we exposed female fish to either a caged warmouth sunfish for 30 min. or no predator. After 30 additional min. all fish were snap frozen and analyzed for whole−body corticosterone (CORT). In another experiment, we housed females from each population in 114 l tanks at two densities (3 or 15), and measured reproductive output, growth, and whole−body CORT at the end of the experiment. As predicted, fish with historical exposure to high predation threat exhibited a reduced CORT response to the predator than those from the population with high exposure. In the density experiment, only females from the low−density population had a dramatic reduction of offspring in the crowded conditions relative to those at low density; yet there were no differences in body weight or CORT between densities in fish from either population. Although females from historically high−density conditions maintained fitness, the reduction in fecundity in females from the low−density population was not mediated by changes in CORT secretion. We are currently determining whether the difference in the reproductive response to density between these two populations is associated with changes in reproductive hormones or gene expression profiles in the ovary/placenta.

P2.40 RAMIREZ−OTAROLA, N.N.*; ESPINOZA, J.; KALERGIS, A.M.; SABAT, P.; Lab. of Animal Ecophysiol., Univ. of Chile, Santiago, MIII, Pont. Cathol. Univ. of Chile, Santiago; *nat.rotarola@gmail.com*
Interplay between acclimation temperature and immune challenge on energy expenditure and immune response in the precocial rodent Octodon degus
We examined the influence of thermal conditions experienced at an early age on the immune response and the energetic costs associated in the precocial rodent, *Octodon degus*. Pups were acclimated to either warm or cold conditions (15 ° C or 30 ° C), from birth to weaning (day 30). Following the acclimation period, pups were randomly injected with lipopolysaccharide (LPS) or pyrogen−free saline. Samples of blood and measures of metabolic rate (BMR) were obtained 24h before and after the immune challenges. Individuals acclimated at 15 ° C and injected with pyrogen−free saline presented the lowest levels of Interleukin−1² (IL−1²), while the levels of Il−1² in individuals acclimated at 15 ° C and treated with LPS were similar to the individuals acclimated at 30 ° C and injected with LPS or pyrogen−free saline. Pups acclimated at 15° C and injected with LPS exhibited the lowest body temperature. Also, we did not find a significant effect of the interaction between ambient temperature and immune challenge on BMR. However, individuals challenged with LPS showed the highest BMR and the lowest body mass among treatments. We concluded that thermal conditions experienced at an early stage influence some aspects of the immune response in pups of *Octodon degus*. Nevertheless, ambient temperature at this developmental stage does not seem to affect energy expenditure associated to this response. Financial support Beneficio Apoyo de Tesis Doctoral CONICYT N°21110063 to NRO

P1.100 RAO, R.*; PARKER, C.E.; ROMERO, L.M.; Tufts Univ., Medford; *clare.parker@tufts.edu*
Daytime vs. nighttime incorporation of exogenous corticosterone in feathers of European starlings
In line with finding innovative and less invasive ways to quantify stress in animals, researchers have begun to look at feathers as a repository for corticosterone (CORT), the primary glucocorticoid in birds. It has been shown that CORT is incorporated into birds' feathers as they grow. However, scientists have found inconsistent relationships between levels of CORT in feathers and plasma CORT levels. We hypothesized that CORT would be incorporated into the feathers preferentially more at night than during the day, since evidence has shown that feathers may be growing more during the nighttime. This could explain why findings have been so inconsistent. In addition, we looked at whether administered CORT is incorporated locally or from the global blood supply. Initially, we plucked seven flight feathers from each wing from 24 European starlings (*Sturnus vulgaris*) to simulate molt, and reserved the secondary #2 feathers from each wing for analysis. We dissolved CORT in dimethylsulfoxide and applied the solution to the left feather tract. Our experiment had three groups: a control group that received no CORT, an AM CORT group that received a daily dose of CORT in the morning, and a PM CORT group that received a daily dose of CORT in the evening. While significantly more CORT was found in the AM and PM CORT group feathers than in the control group feathers, AM feather CORT levels were also significantly higher than PM feather CORT. There was no significant difference between CORT levels in right versus left feathers for any of the groups, indicating that CORT is incorporated in the feathers from the blood supply, rather than from locally administered or produced CORT. Post−treatment blood sampling showed that repeated CORT administration elevated baseline plasma CORT levels in the experimental groups.

40.5 RAVI, S*; MOUNTCASTLE, AM; COMBES, SA; RMIT University, Harvard University; *sridhar.ravi@rmit.edu.au*

Influence of load type on flight stability and maneuverability of bumblebees

Foraging bumblebees fly through complex wind and spatial environments while carrying up to their body mass in pollen and/or nectar back to the hive. Bumblebees carrying loads (pollen and nectar) back to the hive would be required to not only remain stable in unsteady wind conditions but also be highly maneuverable to fly through unsteady spatial environments and escape from predators. Bumblebees store pollen in pollen baskets located on the tibia of their hind limbs, while nectar is stored within the nectar crop located just posterior to the petiole. The location of the nectar or pollen carried by bumblebees has a significant influence on various morphological metrics including mass, location of center of mass, moment of inertia, etc. which can in−turn be expected to manifest as changes in flight performance depending on the load type being carried. The stability and maneuverability of bumblebees carrying different loads was investigated by attaching miniature steel balls to the tibia of the hind limbs (simulating pollen load) and on the abdomen near the petiole (simulating nectar loads). The "loaded" Bumblebees were tracked, using high speed cameras, as they flew in two flow conditions viz; in wake of a vertically oriented circular cylinder and tracking a moving flower in smooth flow conditions. Bumblebees carrying pollen were observed to be more stable in unsteady wind conditions, present in the wake of the cylinder, however they exhibited lower maneuverability when tracking the moving flower. These highlight the interactions between load type and trade−offs in flight stability and maneuverability.

60.4 READER, LL*; CARRIER, DR; LEE, DV; University of Utah, University of Nevada, Las Vegas; *L.Reader@utah.edu*

Force−torque measurements of an arboreal biped: The importance of substrate interactions

Because three−dimensional structure has long been recognized as an ecological driver of diversity, studying the ways in which animals physically navigate complex environments is paramount to the study of evolutionary transitions. Arboreal locomotion in particular has been understudied from a mechanistic standpoint, despite its role in the radiation and diversification of several vertebrate lineages. Locomoting vertically likely represents a substantial mechanical challenge contingent on interaction with the substrate. We focused on two types of substrate interactions − grasping and friction − in small parrots climbing instrumented ladder rungs. ATI nano−17 six−axis load cells enabled force and torque measurements in all three planes, and biplanar X−Ray video at 250 fps facilitated 3−D kinematics. We found an unexpected influence of the head and neck on upward locomotion and a considerable role of friction on torque application that is dependent on rung diameter.

64.4 REECE, J.S.*; NOSS, R.F.; Valdosta State University, Univ. of Central Florida; *jreece@valdosta.edu*

Sea level rise, land use, and climate change influence the distribution of loggerhead turtle nests at the largest USA rookery (Melbourne Beach, Florida)

Anthropogenic climate change adds to the existing suite of threats to species, such as habitat degradation, by increasing extinction risk and compromising the ability of species to respond adaptively to these stressors. Because threats from anthropogenic climate change often interact synergistically with other threats, integrated assessments of the factors and processes that affect species persistence and distribution are required. We assessed the influence of coastal land use and climate change (specifically sea level rise) on the spatial distribution of nests within the largest loggerhead *Caretta caretta* marine turtle rookery in the Atlantic Ocean, at Melbourne Beach, Florida, from 1986 to 2006. We generated a multiple regression model based on these factors that describes 47% of the spatial variation in loggerhead nesting. Nests have shifted northward (likely in response to warming temperatures), away from intensive coastal development, and, surprisingly, toward areas of increased erosion. Using the Bruun Rule (an approximation of the response of the shoreline profile to sea level rise), we modeled the impacts of sea level rise of 0.25 and 0.5 m in conjunction with extrapolations of coastal development and a continued northward shift in nest distribution. We project up to a 42% decrease in beach area with 0.5 m of sea level rise and predict that loggerhead nesting will shift northward and become increasingly crowded on narrowing beaches. The implications of this study are that areas currently protected for large rookeries may not overlap with their future distributions.

42.5 REED, D.A.; IRIARTE−DIAZ, J.*; DIEKWISCH, T.G.H.; University of Illinois Chicago; *jiriarte@uic.edu*

Variation in the craniomandibular joint and jaw adductor musculature in reference to the performance and evolution of the mammalian lower jaw

The transition from pre−mammalian cynodonts to true mammals involved the reduction of the post−dentary bones, changes in the site of the jaw articulation, and changes in the orientation and magnitude of the adductor musculature of the jaw. These changes are hypothesized to have occurred under distinct selective pressures. On the one hand, the auditory apparatus is hypothesized to require low joint reaction forces, while on the other hand, the feeding system is hypothesized to favor high bite forces. Crompton and Hylander (1986) employed 2D free body analysis to explore the relationship between joint reaction forces and bite force in the pre−mammalian cynodont, *Probainognathus*. Here we build on this landmark analysis using 3D free body analysis to evaluate the effect of changes in musculoskeletal configuration of early mammals, in a manner that mimics the broader evolutionary trends in mammalian fossil record. We show that low joint reaction forces and a high bite force can be achieved over a continuum of musculoskeletal configurations. We identify three key variables influencing the relationship between joint reaction forces and bite force: 1) the reorientation of the resultant adductor force in the anterior direction, 2) changes in the ratio of the tooth position to the position of the jaw joint, and 3) the elevation of the jaw articulation above the occlusal plane. This model predicts that the musculoskeletal configuration of the cynodont lower jaw can be evolutionarily labile without negatively impacting the performance of the auditory and feeding system, and it supports the hypothesis that the orientation of the adductor force and the position of the jaw articulation are functionally correlated on a broad evolutionary scale.

P3.162 REED, D.A.; PORRO, L.B.; ELSEY, R.; IRIARTE, J.*; ROSS, C.F.; Univ. of Illinois, Chicago, University of Bristol, Rockefeller Wildlife Refuge, Univ. of Chicago; *reedd@uic.edu*

The presence of the external mandibular fenestra in the lower jaw of Alligator does not substantially increase peak von Mises stress and is energetically negligible

The lower jaw of *Alligator mississippiensis* is the principal mechanism by which the muscle forces of the feeding apparatus are transmitted to the external environment. Since *Alligator* produces some of the highest bite forces ever recorded from a vertebrate, it is an ideal model for addressing questions of form and function in the feeding system. From a biomechanical perspective, one of the more intriguing characters is the presence of the external mandibular fenestra (EMF). The EMF represents a discontinuity in the lower jaw. In idealized beams, discontinuities result in larger normal stresses adjacent to the discontinuity in both bending and torsion. Following these predictions, the presence of the EMF can be considered mechanically disadvantageous from the perspective of peak stress values. Conversely, they represent a decrease in mass and can be considered energetically advantageous from the perspective of mass moment of inertia. Here we use finite element modeling to characterize the relative impact of the EMF on peak stress and energetics. This is achieved by modeling a lower jaw with and without an EMF. We find that when removed, the position of the EMF is located in a region of low stress. The presence of the EMF impacts peak stress locally within the model, but when the structure is considered as a whole the presence of the EMF has no impact. Since the addition of the EMF decreases mass by 1.19 g but does not impact stress magnitudes, a mandible including a fenestra can be considered more optimized than one without. The impact of fenestration on the energetics of the mandible is found to be negligible. The bone used to fill the EMF accounts for a low percentage of the total mass of the mandible (3.09%), and this difference is mass only decreases the mass moment of inertia by 0.61%. In sum, the presence of the EMF appears to have minimal impact on the performance of the lower jaw and can be considered mechanically neutral.

P1.149 REIF, M.S.*; FISHER, C.L.; MACKESSY, S.P.; SECOR, S.M.; University of Alabama, University of Northern Colorado; *msreif@crimson.ua.edu*

Testing the adaptive correlation between feeding habits and digestive physiology for snakes

Among snakes exists an adaptive relationship between feeding habits and the regulation of intestinal performance with feeding and fasting. Snakes that feed relatively frequently experience modest changes in intestinal performance from meal to meal, whereas infrequently feeding snakes downregulate intestinal performance upon the completion of digestion and thus rapidly upregulate performance with feeding. We tested this hypothesis by comparing the postfeeding responses in intestinal function and morphology between the frequently feeding Asian vine snake (*Ahaetulla prasina*) and the infrequently feeding prairie rattlesnake (*Crotalus viridis*). With feeding, vine snakes experience a 50% and 43% increase in pancreatic and small intestinal mass, respectively, whereas rattlesnakes exhibited 50−160% increase in the mass of the liver, pancreas, small intestine, and large intestine. Vine snakes experience no significant change with feeding in mucosal thickness or in the volume of intestinal enterocytes. Mucosal thickness and enterocyte volume increased by a respective 80% and 115% with feeding for the rattlesnake. Pancreatic trypsin and intestinal aminopeptidase and maltase activities did not vary with feeding for the vine snake, though the intestinal hydrolases increased postprandially for the rattlesnake, generating a 2− and 3.4−fold increase in total intestinal capacity for maltase and aminopeptidase activity. As predicted based on their feeding habits, these snakes exhibit the observed dichotomy in the regulation of digestive performance, with the infrequently feeding rattlesnakes experiencing wide regulation of intestinal performance, and the frequently feeding vine snakes exhibiting much more narrow responses.

P3.100 REIN, L *; WELCH, A; College of Charleston; *reinlc@g.cofc.edu*

Toxicity of Combinations of Naproxen and its Photodegradants to Toad Tadpoles

Pharmaceutical compounds have been detected in natural waterways, due largely to ineffective wastewater treatment procedures. When exposed to ultraviolet radiation, many pharmaceuticals are converted into related compounds. These compounds are often more polar and are therefore predicted to be more toxic than the parent pharmaceutical. For many pharmaceuticals, continual input results in pseudo−persistence, whereby enough new material is added that levels remain elevated in spite of degradation. Although pharmaceutical degradants are expected to co−occur with the parent molecule, particularly for pseudo−persistent compounds, the toxicity of combinations of drugs and degradants has not previously been tested. We investigated the effects of UV degradation and pseudo−persistence on the toxicity of naproxen, a common nonsteroidal anti−inflammatory frequently found in natural waters. Southern toad (*Anaxyrus terrestris*) tadpoles were exposed to naproxen, its two photodegradants, and combinations of the three compounds in proportions corresponding to laboratory observations of naproxen photodegradation. Daily observations of tadpole mortality, activity, and behavioral changes were used to assess toxicity. Naproxen's two photodegradants were significantly more toxic than naproxen itself, and combinations of naproxen and its photodegradants were particularly toxic. Thus, photodegradation of naproxen in the environment is predicted to result in increased risk for freshwater organisms. More generally, our data suggest that the ecological effects of pharmaceutical pollutants may be underestimated and that assessing toxicity of relevant combinations of pharmaceuticals and their degradants is important for evaluating the impact of pharmaceutical pollution.

P3.106 REIS, A.L.*; MILTON, S.L.; Florida Atlantic University, Boca Raton; *areis2012@fau.edu*

Sex Identification in Sea Turtle Hatchlings by HPLC Assay of Plasma Steroid Hormones

All sea turtle populations present in U.S. waters are considered to be either threatened or endangered and are protected by the Endangered Species Act. Sex ratio monitoring is vital to conservation research because sea turtles exhibit temperature−dependent sex determination, which means that the nest environmental temperature influences the sex ratio produced; warmer temperatures produce more female hatchlings while cooler temperatures produce more males. Variability in the environment caused by increasing global temperatures, increasing severity of storms, and anthropogenic changes such as beach renourishment may thus alter sex ratios, limiting future reproductive potential and hindering conservation efforts. Monitoring sex ratios allows us to minimize negative influences on reproductive potential. This research focuses on one aspect of conservation, a sex identification technique for hatchling sea turtles to monitor male: female sex ratios produced during incubation in the nest. As hatchlings do not exhibit external secondary sex characteristics, however, sex identification at the hatchling stage is difficult. As a result, several methods of sex identification in sea turtle hatchlings have been developed, though each has limitations such that a reproducible, less−invasive method would advance studies of sex identification. This study used High Performance Liquid Chromatography (HPLC) to separate and identify plasma steroid hormones (estriol, estrone, estradiol, progesterone, and testosterone) in a South Florida population of loggerhead *Caretta caretta,* and green sea turtle *Chelonia mydas,* hatchlings. Gender was ground−truthed by laparoscopy.

51.4 REISER, PJ*; BRUNDAGE, EA; BIESIADECKI, BJ; Ohio State University; *reiser.17@osu.edu*

Masticatory Tropomyosin − Novel Sequence and Gene Identification

Jaw−closing muscles of members of *Carnivora* express unique isoforms of several myofibrillar proteins that are not expressed in most other muscles. It is generally believed that the complement of myofibrillar isoforms in these muscles serves high force generation for capturing live prey and defensive biting. A unique, "masticatory", isoform of tropomyosin (TM−Mast) was reported to be expressed in cat jaw−closing muscles. The objective of this study was to obtain sequence information for the unique TM−Mast in the domestic dog. Samples of masseter (a jaw−closing muscle), tibialis (comprised predominantly of fast−twitch fibers) and the gastrocnemius (with a high proportion of slow fibers) were obtained from adult dogs. Portions of each sample were prepared for protein electrophoresis, immunoblotting and RNA extraction. TM−specific cDNA was cloned. Sequencing of clones identified cDNA identical to genomic predicted striated muscle TM−± and TM−² isoforms, as well as a novel 284 amino acid TM−δ isoform observed only in the masseter muscle. TM−Mast in dog masseter exhibits a unique electrophoretic mobility on SDS−PAGE gels containing 6 M urea compared to TM in other muscles. To validate that our cloned TM−δ isoform is TM−Mast, the E. coli expressed TM−δ isoform was electrophoresed in the presence of urea. Results demonstrate that TM−δ has the same electrophoretic mobility as the unique TM−Mast that is expressed in dog masseter and has a different mobility from that of muscle TM−±, −² or −³ isoforms. Based upon these findings, we conclude that dog TM−Mast is a product of the TPM4 gene (which encodes the TPM−δ family of proteins) and that the 284 amino acid protein product of this gene represents a novel TM isoform never before observed to be expressed in mammalian striated muscle.

S8.2 REMAGE−HEALEY, Luke; University of Massachusetts; *healey@cns.umass.edu*

An integrative look at acute steroid signaling in the nervous system

The central nervous system governs interactions between organisms and their environments. Traditionally, the brain has been viewed as a central integrator of circulating hormones, external cues, and internal states. It is clear now that the brain is both a source and a target of hormones like steroids. This has led to a revision of the basic view of the brain as a computational network that responds to steroid signals from the gonads and adrenal glands. Examples from several vertebrate lineages now show that steroid production in some brain regions can be fast, targeted, and locally responsive to external stimuli. This has bolstered the view that steroids can be neuromodulators in their own right. Here, I will explore recent work showing that steroids can fluctuate within brain on acute timescales, enhance sensory and sensorimotor representations, alter the information content of brain circuits, and potentially change their functional connectivity. The ultimate behavioral consequences of steroids as intrinsic signaling molecules within the brain are still unclear, but initial indications are that steroid signaling is important for behavioral discrimination, learning & sensory representations.

19.4 RENDON, N.M.*; RUDOLPH, L.M.; SENGELAUB, D.R.; DEMAS, G.E.; Indiana University Bloomington; *nrendon@indiana.edu*

The social adrenal: Evidence for a seasonal switch from gonadal to adrenal regulation of aggression in female Siberian hamsters (Phodopus sungorus)

Appropriate levels of aggression can ensure acquisition of territory and mates during the breeding season and acquisition of limited sources during non−breeding conditions. Unlike some seasonal breeders, male and female Siberian hamsters (*Phodopus sungorus*) display *increased* aggression when reproductively inactive (short days; SD), a time when gonads are regressed and gonadal steroids are low. It has been hypothesized that SD aggression is mediated by adrenal rather than gonadal steroids. This study tested this idea by examining adrenal responsiveness in reproductively active (long day; LD) and SD female Siberian hamsters in response to an ACTH challenge, and quantifying area of the adrenocortical layers and adrenal medulla across the seasons. SD females displayed significantly more aggression and a more robust adrenal response to ACTH, when compared to LD females. Specifically, DHEA levels in response to an ACTH challenge were significantly elevated in SD but not in LD females. Cortisol levels, in contrast, were significantly elevated in all females regardless of condition. The zona reticularis (adrenal source of DHEA), but not the other layers of the adrenal cortex, was larger in LD females, showing that there are dynamic steroid−specific morphological changes in adrenals across seasons. These findings support the idea that adrenal DHEA plays a key role in regulating SD aggression in female Siberian hamsters, and that there is a seasonal switch from a gonadal to an adrenal source of sex steroids across the seasons. More broadly, this work contributes to our understanding of environmental and neuroendocrine regulation of aggression in hamsters and likely other mammalian species.

88.5 REYES, M.L*; BAKER, J.A.; FOSTER, S.A.; Clark University; *mreyes@clarku.edu*

Early life compensatory growth and swimming stamina in threespine stickleback (Gasterosteus aculeatus)

Many organisms exhibit compensatory growth (CG), an accelerated growth rate during recovery from a total or partial food deprivation. However, many aspects of compensatory growth, such as its effects on future growth and aerobic performance, remain poorly understood. To explore these effects of early−life compensatory growth, we studied a model organism, the threespine stickleback (*Gasterosteus aculeatus*) across the first four months of life to assess longer−term physiological effects on growth and swimming performance during the juvenile and sub−adult stages. We hypothesized that fish exposed to a diet deficit during the second month of life, and then returned to an ad−lib diet, would take longer to achieve a normal growth trajectory than would fish exposed to diet deprivation in the third and fourth months of life. Our second prediction was that stickleback exposed to a diet deficit earlier in life would manifest lower swimming stamina levels during the sub−adult stage. Recent stickleback research suggests that the effect of CG on aerobic performance is time dependent and is much higher in stickleback just prior to the breeding season. Contrary to our above−mentioned hypotheses, our results show that younger fish that undergo a CG event are better able to regain optimal growth trajectories. The sticklebacks across the three dietary treatments also showed similar swimming stamina levels upon reaching the sub−adult stage.

P1.201 REYES, K. R.; HOCH, J. M.*; Nova Southeastern University; *jhoch@nova.edu*

The effects of wave exposure, tidal height, and crowding on cirri and penis morphology of the acorn barnacle, Tetraclita stalactifera

Exposure to wave action can alter the morphology of intertidal barnacles. We tested several hypotheses of morphological variation in the cirri and penises of the barnacle *Tetraclita stalactifera* at sites in south Florida differing for three factors: wave exposure, height in the intertidal zone and level of crowding. In wave exposed sites, cirri were shorter and thicker than in protected sites. Increased thickness may be an adaptation to reduce risk of breakage in rough environments. The longer cirri of individuals from sites with low wave action may serve as an adaptation to improve food capture in lower−flow environments. We found that barnacles from higher positions in the intertidal zone had thicker cirri than those from lower positions, suggesting that they experience more risks from wave action. Barnacles at high positions may accept greater risks as a result of less time available for feeding because of reduced time submerged. The increased risks of different thresholds to wave exposure may be compensated for by the increased thickness. Penises from wave−exposed sites and from higher positions in the intertidal zone were thicker than those from calm areas or from low positions (but there were no interactions between wave−exposure and tidal height). Thicker penises are likely stronger, reducing the risk of breakage and possibly more muscular, allowing them to retain function in rough conditions. None of the morphological variables changed with crowding. Our observations of differences in cirri and penis morphology among sites of varying physical conditions suggest that these traits, observed in several other barnacle species, are adaptations shared by the species *T. stalactifera*, although the pattern we observed with respect to height in the intertidal was opposite of that observed by other researchers for *T. japonica*.

P3.142 REYNAGA, CM*; AZIZI, M; Univ. of California, Irvine; *cmmreynaga@gmail.com*

Force transmission pathways in the axial muscles of the common carp, Cyprinus carpio

Fishes utilize their axial musculature to power undulatory swimming. Axial muscles produce forces, which are transmitted to the vertebral column to bend the body. These muscles are organized into discrete segments (myomeres), which can be individually recruited and have a three−dimensional shape resembling a series of interlocking chevrons. Our understanding of the mechanics of axial musculature has been hindered by their morphological complexity. In this study we use common carp, *Cyprinus carpio*, as a model system to better understand how myomeres from different regions of the body transmit forces to the axial skeleton. We use an *in situ* preparation to artificially stimulate individual myomeres in the anterior, medial, and posterior regions of an anesthetized fish, while measuring the location of forces being applied to the vertebral column. Muscle forces imparted on the vertebral column are measured using two force transducers mounted onto the clamps attached to either end of the vertebral column. The relative magnitude of the forces at either end of the vertebral column allows us to localize the forces generated by each myomere. Our preliminary results suggest the trajectory of forces produced by individual myomeres varies along the length of the body with anterior myomeres imparting forces more posteriorly. By investigating the mechanical role of muscles in various regions of the body, we aim to relate the structural complexity of fish axial muscles to the recruitment patterns observed *in vivo*. The results of this study will serve as an important step in developing a fundamental link between morphological features of the axial system and swimming mechanics of the most diverse vertebrate group.

52.4 REYNOLDS, KV*; THOMAS, ALR; TAYLOR, GK; University of Oxford; *kate.reynolds@zoo.ox.ac.uk*

Thermal soaring characteristics in a Steppe Eagle

Many birds soar cross country using thermal updrafts to gain or maintain altitude. Successful soaring requires the ability to detect and respond rapidly to subtle changes in the atmosphere, for example by sensing climb rate or vertical acceleration. Despite the extensive instrumentation available to human pilots to measure these quantities, birds are frequently able to outperform them whilst climbing in thermals. In this study we explore the soaring flight of a trained, captive Steppe Eagle *Aquila nipalensis* to determine the mechanisms and strategies that it uses when exploiting thermal lift. A customised instrumentation unit mounted on−board the bird was used to log GPS position, barometric altitude, linear acceleration, angular velocity, airspeed, and Earth magnetic field data over the course of 45 flights. Using an objective criterion combining yaw rate and climb rate thresholds, we identified over 175 sections of thermalling flight automatically from the data. Here we present data which characterise the thermal soaring behaviour of our bird such as circling radius, bank angle, lift coefficient, kinetic energy, potential energy, and wind drift. We also discuss our preliminary analysis comparing the soaring strategy of our bird with the various strategies employed by human glider pilots by analysing correlations between the bird's banking behaviour and possible sensory stimuli.

55.5 REYNOLDS, RG*; KOLBE, JJ; GLOR, RE; DE QUIEROZ, K; REVELL, LJ; LOSOS, JB; Harvard University, University of Rhode Island, University of Kansas, National Museum of Natural History, Smithsonian Institution, University of Massachusetts Boston; *robertreynolds@fas.harvard.edu*

PHYLOGEOGRAPHY OF THE LIZARD ANOLIS SAGREI ACROSS THE CARIBBEAN BASIN

What drives diversification within island species? A variety of evolutionary processes structure intraspecific genetic diversity on islands: from selection to allopatry to population genetic processes such as drift− all potentially leading to unique evolutionary outcomes. However, we have an incomplete understanding of how these processes might work together or in conflict to drive the attenuation or acceleration of intraspecific divergence in widespread island reptiles. For a species experiencing allopatry and drift in one part of its range and differential ecological selection in another, we might expect multiple evolutionary trajectories to manifest simultaneously, with an important regulatory role to be played by gene flow. The lizard *Anolis sagrei* has the broadest distribution of any Caribbean anole, occurring on islands of all sizes from the northern Bahamas to the Central American mainland. Populations of *A. sagrei* experience vastly different ecological and selective pressures, and many are morphologically distinct. For instance, dewlap color (a sexual signal) and body size vary greatly, and some populations are as genetically divergent as full species at mitochondrial loci. We collected samples from across the range of *A. sagrei*, from the Bahamas to Cuba to the Swan Islands and on to the mainland. Using multilocus nuclear and mitochondrial genetic data we assessed range wide phylogeographic patterns in this species, focusing on macro−level patterns in intraspecific diversification. We further interpret our findings within the context of Caribbean *Anolis* speciation.

103.5 RICE, A.N.*; MORANO, J.L.; Cornell Univ.; *arice@cornell.edu*

Changes in Ocean Temperature Impact Fish Acoustic Communication: Implications for Reproductive Timing and Acoustic Community Structure

Acoustic communication is a critical component of many animals' behavior, and sounds are often produced for reproductive advertisement. For many species of vocalizing fishes, reproductive calls form long−duration choruses and are the dominant biological sound within their habitats. Environmental cues often regulate the timing of behavior and physiology of individuals, but it unclear how this extrapolates to population and community levels. Through long−term acoustic recordings of wild populations, we can link organismal− and population−level processes in the context of reproductive behavior. We used fish sounds to understand how changing climatic conditions may impact the behavior of individuals and the ecology of populations. To address this, we looked at the seasonal chorusing patterns of two species of acoustically active fishes− black drum and oyster toadfish− over a five−year period off the coast of Florida, and we correlated these patterns with water temperature. Fish choruses lasted continuously for weeks to months and are the dominant sounds in this habitat. In a stable pattern across years, black drum began chorusing in early− to mid−spring, followed by toadfish. The calling pattern of co−located species forms a seasonal structure within their acoustic community. However, the onset of chorusing in both species positively correlates with water temperature: as water temperatures increase both faster and higher, species chorus earlier, and chorusing duration increases. Thus, continued increases in ocean temperature through climate change may continue to alter the calling behavior of these and other species, creating new patterns of acoustic interaction. Environmentally mediated changes in acoustic communication may ultimately impact reproductive success of these populations.

28.6 RICHARDS, C.T.*; RIVERA, A.R.V.; The Royal Veterinary College, West Chester University; *ctrichards@rvc.ac.uk*

A swimming robot controlled by a dual−muscle work loop rig

The work loop (WL) method measures muscular mechanical power underlying cyclical behaviours. A WL rig cyclically shortens and lengthens an *in vitro* muscle while electrically stimulating the muscle. By manipulating activation timing parameters (phase), one maps the relationship between neural input and muscle power output. However, such a map may be limited in that 1) it cannot predict locomotor performance and 2) differences in the mechanical load (e.g. water vs. land) distort the relationship between neural input and limb motion. Can shifts in WL phase modulate locomotor speed? We built a robotic *Xenopus laevis* frog foot remote controlled' by a modified WL rig housing the Plantaris longus (PL) and Tibalis anticus longus (TA) muscles. Extending a previous technique, PL extensor and TA flexor torques were transmitted to the foot to drive oscillating propulsion along a 2 m tank. Preliminary data suggest that shifting the PL phase earlier causes an apparent force enhancement due to activation during lengthening. However, this force enhancement did not result in faster robotic swimming speed. We speculate that speed modulation arises not by activation timing, but rather by other mechanisms such as the activation intensity and/or dynamic control of foot morphology.

P1.134 RICHARDSON, TM*; ZAYAS−BAZAN BURGOS, DM; GRAY, JP; HEART, E; Princeton University, University of Puerto Rico at Cayey, United States Coast Guard, New London, Marine Biological Laboratory, Woods Hole; *tmr2@princeton.edu*

Doxorubicin mediates toxicity in pancreatic ²−cells via activation of PARP pathway

Exposure to chemotherapeutic agents has been linked to the increased risk of type 2 diabetes (T2D), a metabolic disease defined as both the peripheral insulin resistance and impaired glucose−stimulated insulin secretion (GSIS) from pancreatic beta cells. Using clonal rat pancreatic &beta−cell line, INS−1 832/13 cells, we investigated the effects of the chemotherapeutic drug doxorubicin on pancreatic &beta−cell survival and function. We analyzed the effects of time− and dose−dependency of doxorubicin exposure on insulin secretion, cellular viability and toxicity. Toxicity (measured as leakage of intracellular protease and cell titer blue reduction) and apoptosis (measured as caspase 3/7 enzymatic activity) were both significantly increased after 6 h of doxorubicin exposure; glucose utilization was also impaired. Oxidative stress did not play a major role in the induction of toxicity, as doxorubicin failed to undergo redox cycling and appreciably increase hydrogen peroxide levels in INS−1 832/13 cells. Doxorubicin was reduced in vitro by cytoplasmic fractions in a NAD(P)H−dependent manner, indicative of bioreductive metabolism of this compound. In live INS−1 832/13 cells, doxorubicin caused a significant decrease in the total NAD^+ pool, consistent with the activation of the poly−ADP ribose polymerase (PARP) pathway, which consumes NAD^+ to repair DNA damage and leads to programmed cell death if activated in excess. Treatment of INS−1 832/13 cells with the PARP inhibitor MK−4827 ameliorated doxorubicin−dependent reductions in cell viability and NAD^+ pool. These data suggest that PARP activation rather than oxidative stress induction is the major mechanism of doxorubicin toxicity in pancreatic &beta−cells.

54.5 RIDDELL, EA*; PLASKON, J; APANOVITCH, EK; SEARS, MW; Clemson University; *eriddel@clemson.edu*

Reciprocal transplant of salamanders reveals potential local adaptation of acclimatization of water loss rates

Current mechanistic approaches use physiological traits to predict a species' response to climate change. In response to warming environments, some organisms modify physiology to attenuate stressful environmental conditions. By incorporating capacities of organisms to modify physiology, these mechanistic approaches may produce more realistic predictions. For terrestrial salamanders, warming temperatures may reduce activity due to an increased risk of desiccation. To counter the negative effects of desiccation, salamanders might acclimatize by reducing rates of cutaneous water loss (CWL). To determine the capacity of Southern grey−cheeked salamanders (*Plethodon metcalfi*) to acclimatize, we conducted a reciprocal transplant experiment along an elevational gradient. We collected salamanders from high, mid, and low elevations along a mountain and transplanted them to a high, mid, or low elevation site in a balanced experimental design. We measured CWL of individual salamanders throughout the summer in the lab under temperatures and humidities that salamanders experience during activity. Over the summer, we uncovered variation in CWL within treatments, suggesting acclimatization; however, individuals collected from low elevations exhibited a greater capacity to reduce CWL at low and mid sites compared to individuals collected from mid and high elevations. These results suggest that the ability to acclimatize to changing conditions might be limited by adaptation to local conditions. By incorporating limitations of acclimatization, mechanistic models may identify populations that are susceptible to warming temperatures. Future studies on the genetic basis of acclimatization may reveal potential mechanisms used to modify CWL and whether CWL has the potential to adapt in response to climate change.

P1.143 RIFAI, N.M.*; MYLES, D.L.; Colorado State University; *nadarifai2008@yahoo.com*
Characterization of cyclic nucleotide phosphodiesterases in the transcriptome of the crustacean molting gland
Cyclic nucleotide signaling mediates the suppression of the crustacean molting gland (Y−organ or YO) by molt−inhibiting hormone (MIH). When MIH level drops the YO transitions from the basal to the activated state and the animal enters premolt. During mid−premolt, the YO transitions to the committed state, in which the YO becomes insensitive to MIH. Phosphodiesterases (PDEs) hydrolyze the phosphodiester bond in cAMP and cGMP to AMP and GMP, respectively, and thus can modulate the response of the YO to MIH. In some species, PDE inhibitors decrease molting hormone (ecdysteroid) biosynthesis by the YO *in vitro*, indicating that PDE activity can keep cyclic nucleotide levels low. Increased PDE activity in the YO is correlated with a reduced sensitivity to MIH when the animal becomes committed to molt. In mammals, 21 PDE genes are organized into 11 families, designated PDE1 to PDE11. Each PDE family has specific catalytic and biochemical properties and tissue distributions. The number and types of PDE genes in crustaceans is unknown. A reference YO transcriptome from the blackback land crab (*Gecarcinus lateralis*), consisting of 3 biological replicates of intermolt animals, was analyzed for PDE sequences. Six different contigs encoding full−length PDE sequences were identified. Protein alignments and ClustalX analysis of the Gl−PDE sequences with orthogs from other species in the GenBank database showed that the sequences corresponded to PDE1, 2, 4, 6, 9, and 11. The next phase is to use transcriptomics and qPCR to quantify the expression of the 6 PDEs in the YO over the molt cycle with the goal of identifying the PDEs that modulate the response of the YO to MIH. Supported by NSF (IOS1257732).

62.2 RIFFELL, J.A.; University of Washington; *jriffell@uw.edu*
Flower discrimination by pollinators in a dynamic chemical environment
Pollinators use their sense of smell to locate flowers from long distances, but little is known about how they are able to discriminate their target odor from a mélange of other natural and anthropogenic odors. Here, we measured the plume from *Datura wrightii* flowers, a nectar resource for *Manduca sexta* moths, and show that the scent was dynamic and rapidly embedded among background odors. The moth's ability to track the odor was dependent on the background and odor frequency. By influencing the balance of excitation and inhibition in the antennal lobe, background odors altered the neuronal representation of the target odor and the ability of the moth to track the plume. These results show that the mix of odors present in the environment influence the pollinator's olfactory ability.

45.6 RINGOLD, PAUL L; None; *plrbeitam@yahoo.com*
Hedgehogs or Foxes
What kind of scientists will be in demand in the future? Should we be training generalists or specialists? For my dissertation, I looked at factors controlling the distribution and abundance of three species of *Uca*. I conducted the research in small plots and cages on a few acres of marsh in a single county. I selected sites for access, history, and whimsy. The conclusions were applicable to those organisms in those locations, although they laid out some concepts that might apply elsewhere. A few years later, I secured a position to ensure that EPA did not do anything egregious in managing municipal discharges to the ocean. Here the sites were a few km^2 surrounding 210 individual discharges. Although the subject matter was different, the analytical methods learned in grad school were directly applicable. My next position was as a senior ecologist and eventually interim director of the National Acid Precipitation Assessment Program. The ecological questions were of a different character. How many lakes are acidic? What happens if we change the acid loading to the lakes? People involved in this program pioneered a set of methods to answer these questions. Since then I've been involved in a range of research, critical loads of air pollutants in the US and Europe, assessment of aquatic resources in the western United States, and others. My most recent research has even involved collaboration with social scientists! While the methods and thinking learned in grad school provided a great foundation to make contributions to these efforts, I applied additional sets of methods to address new problems, especially ones at larger scales. Since the character of important policy questions is often at these larger scales, one wonders about whether to ensure that grad students are learning and exercising methods that allow them to function on issues requiring techniques and thinking different than those in their dissertations.

S8.6 RITERS, LV; University of Wisconsin−−Madison; *LVRiters@wisc.edu*
Steroid−opioid interactions and rapid changes in the motivation to communicate
Vocal signals convey information about an individual's motivational and social status. As circumstances change, individuals adjust vocal behavior accordingly. It is common for individuals that gain a territory to immediately increase the production of agonistic or courtship vocalizations. These behavioral changes are associated with rapid increases in steroid hormones, yet the mechanisms by which steroids modify motivation neural systems to adjust vocal production are not well known. I will present studies addressing this topic in male European starlings, *Sturnus vulgaris*. In spring, T concentrations rise and male starlings initiate breeding activities. However, not all males display courtship behavior at this time. Among males with elevated T, only males that obtain a nesting site (or nest box) produce high rates of sexually−motivated courtship song. These behavioral changes can occur rapidly (within minutes to hours after nest box acquisition) and are accompanied by an increase in circulating T and increased densities of androgen receptors in the medial preoptic nucleus (POM, a region in which T promotes male sexual motivation). A mechanism by which T in POM may rapidly modify motivational state (and status−appropriate song) is through its interactions with opioid neuropeptides. High singing males with nest boxes have low densities of mu opioid receptors and enkephalin opioids in POM compared to low singing males without nest boxes. Pharmacology studies further indicate that a low level of opioid receptor stimulation in POM is needed to facilitate sexually−motivated song but higher levels of stimulation inhibit singing behavior. We present evidence indicating that relatively rapid increases in T may fine−tune opioid−related gene expression in POM to promote status−appropriate singing behavior.

110.4 RITTSCHOF, C.C.*; GROZINGER, C.M.; ROBINSON, G.E.; University of Illinois, Pennsylvania State University; *ccr22@illinois.edu*

Social context during pre−adult stages influences aggression in adult honey bees

Understanding the mechanisms that connect a social experience to behavioral change is a fundamental issue in integrative biology. Honey bee aggression is socially responsive on an acute time scale: during a predator attack, guard bees release an alarm pheromone that induces an aggressive response in nest mates. Honey bee aggression also is socially responsive over a longer time scale; previous research has shown that bees cross−fostered in highly aggressive colonies are more likely to behave aggressively compared to bees cross−fostered in relatively docile colonies. However, no study has addressed whether honey bee larvae are similarly sensitive to colony aggression levels. Larvae and pupae are subjected to both direct and indirect social interactions during development: they are dependent on adult worker bees for food provisioning, and they are also exposed to a milieu of chemical and physical cues within the hive environment. We assessed whether individuals reared in relatively high or low aggression colonies as larvae show differences in aggressive behaviors once they reach adulthood. We cross−fostered eggs in colonies with high and low aggression levels until just prior to adult emergence. Using a lab−based test that measures aggressive responses to a non−nestmate bee, we found that eight−day−old adult bees reared in high aggression colonies showed higher aggression levels compared to sisters reared in low aggression colonies. These results suggest that larval experiences are retained through development to adulthood, with lasting consequences for behavior. Thus, the expression of aggression in honey bees depends on current social cues as well as both adult and larval experience.

29.5 RIVERA, J.A.*; BUTLER, M.A.; Univ. of Hawaii, Manoa; *julior@hawaii.edu*

Molecular Phylogenetics of Papuan Microhylids

The family Microhylidae contains over 250 species that are endemic to Papua New Guinea and have evolved great ecological diversity not commonly seen in other frog groups. However, the evolutionary relationships within the clade remain unclear. This is largely due to homoplastic morphological characters that result in taxonomic instability as well as the molecular phylogenies that lack support. Here, we present the largest and most robust phylogeny to date for the Papuan microhylid clade. We also explore potential problems that caused uncertainty within this large phylogeny and the approaches we took to resolve signal conflict. This phylogeny could also result in reorganization of the taxonomy to reflect their evolutionary history.

70.2 RIVERA, AS*; HABERKERN, N; ARUL NAMBI RAJAN, A; POSFAI, D; HILL, A; University of the Pacific, University of Richmond; *arivera@pacific.edu*

Elucidation of the Pax/Six gene regulatory network in the sponge Ephydatia muelleri

As one of the simplest metazoan model systems, the demosponges provide the opportunity to examine pared−down versions of the complex gene regulatory networks of other animals. We are using the freshwater sponge Ephydatia muelleri as a model for elucidating the evolution of the Pax/Six/Eya/Dac (i.e. retinal determiation) network. E. muelleri possesses a single copy of only two members of this canonical developmental network, Pax and Six. Using search methods informed by protein/DNA binding and RNAi data, we have found potential downstream targets of the Pax transcription factor in the Ephydatia genome. By testing these targets via RNAi, qPCR, and cell culture binding assays, we aim to uncover the components of this metazoan gene regulatory network in a simple animal lacking a nervous system.

23.1 RIVIE, A.*; MANZO, W.; MARTUS, K.; MENON, J.; William Paterson University; *riviea@student.wpunj.edu*

Plasma treatment accelerates tail regeneration in tadpoles Xenopus laevis

Atmospheric pressure plasma have found large application in regenerative medicine. Presently, we investigated the effect of plasma on wound healing and tail regeneration of tadpoles, *Xenopus laevis* especially role of reactive oxygen species (ROS). Tail amputation was carried out by removing 40% of the tail and the amputated region was immediately exposed to helium plasma (generated inside a quartz tube with a single electrode powered by an AC voltage (15kHz) having peak−to−peak voltages of 18kV) for 40 seconds. Here we report faster rate of growth of the regenerating tail following plasma exposure. By comparing results on in situ staining for ROS, nitric oxide (NO) and mitochondria between experimental and control groups, there is increased ROS (hydrogen peroxide and superoxide but not NO) production at 2h, 4h, 12 h and 24 h post amputation at the wound site in plasma treated tadpoles. However, these ROS species were not derived from mitochondria evident from double immunostaining. Growth of the blastema (5 days post amputation) in experimental group was higher than control with increased ROS, NO and catalase in plasma exposed group compared to control. Microscopically, in plasma treated tadpoles, cells of wound and blastemic epithelium showed blebbing of plasma membrane, increased cellular lipid droplets, hypertrophy of the cells, increased mitochondrial density, and reduced intercellular connections. These findings demonstrate that some of the free radicals might be acting as signalling molecules and these tadpoles possess sophisticated mechanisms to respond to stress of plasma and yet hastening the dynamics of wound healing and tail regeneration.
This work is partly supported by the National Science Foundation under Grant Number 1040108.

P2.144 ROBERGE, TM*; BIESER, KL; WIBBELS, T; University of Alabama at Birmingham, Northland College, Ashland, WI; *troberge@uab.edu*

Exogenous 17−^{2} estradiol disrupts gonadal differentiation in a turtle exhibiting temperature−dependent sex determination

The red−eared slider turtle, *Trachemys scripta*, exhibits temperature−dependent sex determination (TSD), where incubation temperature irreversibly determines the sex of the individual. Previous studies have used exogenous estrogens to successfully sex−reverse individuals incubated under male producing temperatures to examine the pathway and role of estrogens in TSD. It remains unclear, however, if exogenous estrogen is mimicking a natural event in sex determination, or if it is overriding the endogenous sex determination pathway. In the current study, *T. scripta* eggs were treated with 15µg of 17−^{2} estradiol in 5µl 100% EtOH under two dosing schedules during the temperature sensitive period (TSP) of development at both male− (26 °C) and female− (30 °C) producing temperatures. Eggs were allowed to incubate until embryonic stage 26 and were subsequently dissected and the gross morphology of the gonads were examined, sexed when possible, and compared across treatments. The sex and presence of the gonad were verified through histology of the adrenal−kidney−gonad complex. In a few cases, eggs treated with 17−^{2} estradiol exhibited ovary−like gonads that were reduced in size compared to the control. However, in the majority of cases, the treatment of eggs with 17−^{2} estradiol resulted in the absence of the gonad, and thus appeared to block normal gonadal differentiation. Collectively, these results indicate that relatively large doses of exogenous estrogens applied at the beginning of the TSP may disrupt the normal process of gonadal differentiation, and may be altering the natural sex−determination pathway instead of mimicking the native pathway. These findings provide an avenue for investigating the temporal and functional aspects of estrogen sensitive components in the sex determination cascade.

114.2 ROBERT, KA*; LESKU, J; PARTECKE, J; CHAMBERS, B; La Trobe University, Melbourne, Australia, Max Plank Institute for Ornithology, Radolfzell, Germany, The University of Western Australia, Perth, Australia; *k.robert@latrobe.edu.au*

Artificial light at night delays birth in a seasonally reproductive marsupial − A field study

Despite numerous species co−occurring with humans in urban environments, no study has documented the effects of human−made light pollution on free−ranging wild terrestrial mammals. This research examines the role of artificial light on reproductive activation in the Tammar wallaby (*Macropus eugenii*) from two populations with differing levels of light pollution on Garden Island, Western Australia. Change in day length is an important cue for reproductive activation in the Tammar wallaby to ensure optimal timing of greatest maternal investment with favorable environmental conditions. We collected reproductive data over a 5−year period to calculate birth schedules and blood samples for measurement of melatonin levels. Using micro−light loggers attached to GPS collars, we measured habitat use and light intensity experienced by wallabies at night in the two populations. The distributions of birth dates are significantly different between urbanized and natural populations (Kolmogorov−Smirnov two sample test; $D=0.351$, $P=0.001$). The median birth date for pouch young in the urbanized population was February 28th, while the natural population was February 1st. Wallabies from the urbanized population are subject to highly variable and significantly greater artificial light levels (t−test; $t=-2.31$, $P=0.04$) and attempt to avoid nighttime light but are restricted in their ability to do so. The shifts in birth dates are a result of suppression of melatonin production by light pollution at night and hence a delay in reproductive activation. Future work will employ manipulative experimentation (e.g. changes to light wavelengths) to isolate the mechanistic drivers of reproductive activation.

P1.48 ROBERTS, BW*; ESPINOSA, JI; HEILMAN, KJ; BRODIE, RJ; Mount Holyoke College, South Hadley, MA; *berylwroberts@gmail.com*

Southern males are bigger but northern males are more honest: Latitudinal trends in male claw traits of the fiddler crab Uca pugnax

Uca pugnax is the most abundant fiddler crab species along the east coast of North America. Because it has such a broad range, it experiences large differences in climate and community composition between populations. Thus the species has the potential to show clinal variation. Fiddler crabs are sexually dimorphic with the males having one enlarged claw used both as an ornament to attract females and a weapon in combat with other males. We sampled five populations periodically for a full year from Massachusetts to Georgia and took measurements of the body and claw, and dissected out the hepatopancreas, a fat storage organ. We also measured population density, operational sex ratio (OSR), food availability, and large claw morphology for the final set of collections. There were significant differences in both average body and claw size among the sites. Northern males were smaller than southern males but showed larger claws for their body size. Analysis of claw weight versus claw length revealed that southern populations had lighter claws for their length than northern populations. This indicates that there is a higher incidence of cheating with claws that are impressive ornaments but not effective weapons, in the south. Clinal variation in sexually selected characters has been sparsely explored and has not previously been documented in a character that is both an ornament and a weapon.

27.6 ROBERTSON, BD; NEWMAN, AEM; MACDOUGALL−SHACKLETON, SA*; Univ. of Western Ontario, Univ. of Guelph; *smacdou2@uwo.ca*

Perils and pitfalls of manipulating glucocorticoids with silicone implants.

The use of silicone (Silastic) tube implants to manipulate hormone levels in free−living animals was a key breakthrough for comparative field endocrinology. In particular, this method has been a reliable and minimally invasive means to chronically elevate sex steroid hormones in birds in the field and in the lab. However, using this method to elevate glucocorticoids (e.g., corticosterone [CORT]) has proved problematic. Often plasma CORT levels were not found to be elevated in CORT−implanted, leading to a view that CORT does not easily diffuse through silicone tubing. In many cases researchers report puncturing implants or leaving one end of the implant unsealed to facilitate CORT delivery. We have tested the utility of silicone tube implants to chronically manipulate CORT in two sparrow species: *Melospiza melodia* and *Zonotrichia albicollis*. *In vitro* silicone implants rapidly deliver high doses of CORT, even with no punctures. *In vivo* implants elevate baseline plasma CORT, but only for a few days before levels return to normal. Despite not having elevated baseline CORT, implanted birds appear to have a suppressed CORT response to restraint stress and a suppressed CORT response to ACTH challenge. Our results indicate that silicone tube CORT implants deliver high pharmacological doses of CORT to birds, and that birds respond by altering negative feedback and clearance mechanisms. Silicone CORT implants thus alter the HPA axis, but not in the way most researchers intend, and in a way that could have drastic consequences on HPA axis dynamics and far reaching physiological implications. As such, the utility of silicone tube implants to manipulate CORT is limited, and the practice of puncturing such implants is ill−advised.

P3.18 ROBERTSON, C*; ROBERTSON, J; Westminster College (PA); *robecd22@wclive.westminster.edu*

Localization of 5−prime nucleotidase in gills of largemouth bass (Micropterus salmoides)

5'nucleotidase (5'NT) is an apical plasma membrane ectoenzyme that catalyzes the breakdown of AMP to adenosine, and plays a role in purinergic signaling. Purinergic signaling is known to be active in hypoxic responses is different species. 5'NT activity is known to occur at high levels in fish gill tissue, and histochemical studies show that this enzyme is localized to gill pillar cells. Evidence indicates that pillar cells have contractile capacity, which may relate to local control of gill perfusion in response to environmental conditions. To investigate the possible function of 5'NT in the gill, a fish−specific monoclonal antibody will be used to immunodetect (Western blot) and immunolocalize (fluorescence microscopy) the enzyme in largemouth bass gill and control tissues. Based on prior work, I expect 5'NT to be found on the vascular−facing plasma membranes of pillar cells. In addition, localization of 5'NT relative to molecular contractile elements (collagen and myosin) in pillar cells can permit a better understanding of pillar cell structure and function, including any putative role of 5'NT in regulation of gill hemodynamics.

15.1 ROBERTSON, J.C.; Westminster College (PA); *robertjc@westminster.edu*

Development and growth of the rostrum lateral line system in paddlefish (Polyodon spathula)

Several weeks after hatching, larval paddlefish begin to grow a rostrum; within a period of several more weeks, this extension of the cranium has grown to represent one−third of the total body length of juvenile fish. This remarkable allometric growth also includes elaboration of large numbers of well−described electrosensory ampullae on the rostrum surface. Less is known about the internal pair of lateral line canals that extend along the length of the rostrum. These canals are outgrowths of the cranial infraorbital canal and terminate at the rostrum tip. As the canals elongate with rostrum extension, mechanosensory neuromasts are generated along the entire length of the rostrum lateral line system. Accessory canals also form at regular intervals on the ventral surface of the rostrum and establish communication between the sensory canals and the external environment. This work describes the structure and growth of the rostrum lateral line system in larval and young juvenile paddlefish. Through morphological analysis of the processes of canal elongation and genesis of associated functional components, a hypothesis for dynamic rostrum lateral line canal development and growth is proposed. Because the rostrum and rostral canals form relatively late in ontogeny, and involve *de novo* development of significant sensory capacity, paddlefish provide a seemingly useful model for examining vertebrate sensory plasticity and integration.

S11.1 ROER, RD; Univ. of N.C. Wilmington; *roer@uncw.edu*

A Morphological, Functional and Biochemical Comparison of Crustacean and Insect Exoskeletons

The exoskeletons of pancrustaceans, as typified by a crustacean, the blue crab (*Callinectes sapidus*) and an insect, the field cricket (*Gryllus pennsylvanicus*) demonstrate a high degree of similarity with respect to histology, ultrastructure, function, and composition. The cuticular envelope in insects and the outer epicuticle in crustaceans both serve as the primary permeability barrier of the exoskeleton, preventing loss of water and ions to the external medium. Prior to and following ecdysis, there is a sequence of expression and synthesis of different proteins by the cuticular epithelium for incorporation into the pre− and postexuvial procuticle of the insect and the exo− and endocuticle of the crustacean. Both exhibit regional differences in cuticular composition, e.g. the articular (intersegmental) membranes of insects and the arthrodial (joint) membranes of crustaceans. The primary difference between the cuticles is the ability to mineralize. Crustacean cuticles express a unique suite of proteins that provide for the nucleation and deposition of calcium carbonate. However, examples of mineralized cuticles exist in the insects and instances of non−calcified mineral structures are found in both taxa.

48.7 ROGERS, EJ*; REEDER, SM; MCMICHAEL III, JW; SIGLER, LE; VODZAK, ME; MOORE, MS; JOHNSON, JS; REEDER, DM; FIELD, KA; Bucknell University, Stony Brook University; *ejr025@bucknell.edu*

Gene expression analysis of immune responses in bats affected by white−nose syndrome

White−nose syndrome is a devastating disease affecting many North American bat species. It is caused by *Pseudogymnoasces destructans*, a fungal pathogen that colonizes the muzzles and wings of hibernating bats. Our study focuses on the differential expression of immune and metabolic genes in infected and uninfected *Myotis lucificus* and *Eptesicus fuscus*. In order to determine the strength and type of immune response triggered by the fungus, we have developed a quantitative PCR panel for cross−species bat cytokine genes. By comparing the relative expression of certain cytokine genes in the wing tissue, we can determine which subsets of T cells are mediating the immune response to the fungal pathogen. qPCR analysis of a subset of metabolic genes will give us additional insight into how this disease negatively impacts the ability of certain bats to survive hibernation. We are also analyzing the transcriptomes of infected and uninfected little brown bats in order to get a more comprehensive view of the genes involved in the response to WNS. Our research will shed light on the mechanisms by which some bat species have a higher survival rate, and this knowledge can be used to further develop strategies for protecting North America's bat population.

S2.5 ROHR, Jason R.; University of South Florida; *jasonrohr@gmail.com*

Using physiology to understand climate−driven changes in disease and biodiversity losses: lesson learned from amphibian declines

The relationship between climate change and biodiversity losses caused by the emergence of infectious diseases remains controversial. Part of the reasons for this controversy is that there are few mechanistic studies that explore the links among climate change, infectious disease, and declines of host populations. Host−parasite interactions are generally mediated by physiological responses and thus I submit that physiological models that address both climatic means and variances should facilitate predictions for how host−parasite interactions will respond to climate change. Given that changes to climatic variability and extremes is a hallmark of climate change but its impact on species interactions is understudied, I will highlight how temporal variability in weather can be used to predict the effects of climate on host−parasite interactions. I also will discuss the climate variability hypoth¬esis for disease−related declines, which posits that increased unpredictable temperature variability might provide a temporary advantage to pathogens because they are smaller and have faster metabolisms than their hosts, allowing more rapid acclimati¬zation following a temperature shift. I will provide meta−analytical evidence for the assumption that smaller organisms acclimate more quickly to temperature changes. I then will provide a case study on the role of climatic variability in amphibian declines associated with the emergence of the infectious disease chytridiomycosis. Finally, I will argue that the metabolic theory of ecology could provide the mathematical framework to integrate physiological mechanisms and large−scale spatiotemporal processes to predict how simultaneous changes in climatic means, variances, and extremes will affect infectious diseases and hosts of conservation concern.

P2.156 ROMÁ`EK, M*; SQUARE, T; JANDZIK, D; MEDEIROS, DM; Univ. of Colorado Boulder, USA, Comenius University in Bratislava, Slovakia; *marek.romasek@colorado.edu*

CRISPR/Cas system in the sea lamprey: A tool for understanding ancestral gene functions in vertebrates

Lampreys represent an ancient lineage of jawless vertebrates, giving us a valuable perspective on the origins of vertebrate and gnathostome characteristics. However, developmental studies of gene functions in lamprey have been limited by a lack of reliable tools for genetic perturbations. The CRISPR/Cas system is a powerful tool for RNA−guided DNA mutagenesis, and is known to work in several model organisms. Here we present a proof−of−principle application of this tool in the sea lamprey *Petromyzon marinus*. By targeting the lamprey *tyrosinase* gene, we successfully reduced pigmentation of embryos, obtaining a high percentage of completely albinotic individuals − a phenotypical confirmation of a successful gene knock−out. We also present preliminary data and perspectives to further use this method in evo−devo studies of the vertebrate head.

P2.198 RONAN, A.B.*; JONES, A.; GIBB, A.C.; Northern Arizona University; *br399@nau.edu*

Have substrate−feeding killifishes (Cyprinodontiformes) lost the ability to suction feed?

Have substrate−feeding killifishes (Cyprinodontiformes) lost the ability to suction feed? A. Ronan, A. Jones and A. C. Gibb Northern Arizona University br399@nau.edu The intramandibular joint (IMJ) is a secondary joint located between the dentary and angular−articular bones of the lower jaw, and this new joint has evolved independently multiple times in teleost fishes. The IMJ generates large gape angles that can reach 120° in some species; such angles are advantageous for herbivorous fishes because they allow increased contact between the jaws and attached food items. *Poecilia mexicana*, a teleost in the order Cyprinodontiformes, possesses an IMJ that allows it to feed on attached food items such as algae and detritus. We hypothesized that the increased lower jaw flexibility provided by the IMJ may inhibit a fish's ability to suction feed, although this is the primary feeding method for most teleosts. We predicted that the species most closely related to *P. mexicana* will rely on ram feeding over suction feeding, while those most distantly related to *P. mexicana* will rely on suction feeding. We calculated the ram−suction index (RSI) to quantify the tendency for each species to use ram or suction during food−capture from video of feeding events for *P. mexicana* and six other Cyprinodontiform species (*Gambusia affinis, Fundulus rubifrons, Cyprinodon macularis, Heterandria formosa, Xiphophorus helleri, Xiphophorus maculatus*). The calculated RSI values suggest that *P. Mexicana*, with a mean RSI of 0.67, and those species most closely related to it rely more on ram feeding, while those more distantly related to it, such as *F. rubifrons*, with a mean RSI of −0.59, rely more on suction feeding. We conclude that *P. mexicana* and its closest relatives have an increased reliance on ram−based feeding because species that possess the IMJ may have lost the ability to produce effective suction during prey capture.

P1.59 ROOF, K.E.*; SPANGLER, A.; COLLIN, R.; Northern Arizona University; *ker257@nau.edu*

Factors affecting plasticity in hatching time in the marine snail Nerita scabricosta

Hatching plasticity is a known phenomenon in several taxa. However, it is not well documented in marine invertebrates. In previous lab experiments, egg capsules of the marine snail *Nerita scabricosta* have been observed to take longer than expected to hatch. The cause for this is unknown. Potential causes include changes in the environment and threat of predation. To determine if wave force and water temperature change affect hatching time, we compared hatching time between egg capsules kept in the lab at a constant temperature and motionless water to egg capsules with moving water and temperature change. There was no significant difference. However, there was a significant difference between these capsules and capsules in the field at 30 days and at 45 days. To answer the question of whether hatching time varies between tide pools, we monitored capsules in 21 tide pools, recorded hatching time, and compared the pools. There is a significant difference between the pools. Last, to determine what factors influence the hatching time, we checked the temperature and salinity of the tide pools and counted predators in each pool. Presence of predators increased the time to hatch; however, temperature and salinity do not have an effect.

3.4 ROONEY, L.A.*; GUGLIELMO, C.G.; SHRINER, S.A.; WESTERN UNIVERSITY, LONDON, ON, NATIONAL WILDLIFE RESEARCH CENTER, FORT COLLINS, CO; *lrooney3@uwo.ca*

Sources of variation in blood parasite infection and its impact on immune function and flight performance in yellow−rumped warblers (Setophaga coronata)

Endurance flight during migration and immune system functioning are energetically costly activities for birds. Since nutritional resources are limited, there may be a trade−off between migration and immune system functioning. Avian blood parasites consume host resources, which may further decrease a bird's resource pool to the point where endurance flight and immune system functioning may not be possible simultaneously. Here, I examine and compare naturally occurring levels of blood parasite infection in a migrating songbird population by microscopy and molecular methods. The prevalence and intensity of infection is compared to measures of immune defense (plasma haptoglobin and IgY), and the impact of infection intensity on endurance flight performance in a wind tunnel is assessed. Studying host−parasite interactions within the context of migration will help to improve knowledge of the potential of birds to spread disease over large geographic distances.

111.1 ROS, IG*; BIEWENER, AA; Harvard U.; *ivo.ros@gmail.com*

Ruby−throated hummingbirds use optic flow in flight stabilization

Birds rely on visual cues for retinal image stabilization by negating optic flow, the movement of the visual panorama across the retina, through corrective eye and head motions. In combination with vestibular and proprioceptive feedback, birds may also use visual cues to stabilize their body during flight. Here, we test whether artificially induced optic flow generated through projected moving scenes results exclusively in vision stabilization or whether it also elicits corrective maneuvers to stabilize flight. To test this hypothesis, we present hummingbirds flying freely within a 1.2 m cylindrical visual arena with a virtual surround rotated horizontally and at different speeds. The birds responded robustly to these visual perturbations by rotating their heads and bodies and by flying with the surround rather than merely tracking the surround with head rotations. Thus, hummingbirds apparently use optic flow to control hovering flight maneuvers in addition to stabilize their vision. Similar visual−motor principles have been observed in insects, suggesting convergent evolution on robust visually guided flight strategies in both groups. (NSF IOS−0744056 & ONR N0014−10−1−0951)

P1.66 ROSE, CS*; WALLAGORA, M; ROSE, JA; MAHER, S; James Madison University; *rosecs@jmu.edu*

Quantifying and comparing shape change in the pharyngeal arch cartilages of salamanders

The amphibian pharyngeal arch (PA) skeleton is comprised of rod−, plate− and bar−shaped cartilages that support feeding and breathing in two habitats, an aquatic one followed by a terrestrial one. To accommodate its dual functions, the skeleton undergoes two periods of growth: larval and postmetamorphic, and two periods of development: embryogenesis and metamorphosis. Having multiple periods of growth and development suggests multiple opportunities for phylogenetic diversification. Functionally significant differences in PA skeletal shape arise in both embryogeny and metamorphosis, but how much allometric growth contributes to variation in larval and adult PA skeletons remains unclear. It is also unclear whether cylindrical cartilages adhere to fixed growth and static allometries in the way that bird and mammal long bones do. This study addresses these questions using developmental series of skeletally stained whole−mounts for 13 species of salamander belonging to eight families (Ambystomatidae, Salamandridae, Plethodontidae, Dicamptodontidae, Amphiumidae, Sirenidae, Proteidae, and Cryptobranchidae). PA skeletons including mandibles are dissected, photographed, and digitized to generate width and length measurements for all cartilages. The data for individual cartilages are averaged between sides, log−transformed and fitted to linear regression equations, the slopes of which are compared between larval and adult stages within species and between the same stages among species. Interspecific comparisons are also intended to reveal how variation in length of larval period and loss of metamorphosis affect the adult proportions of PA cartilages.

P2.155 ROSS, D.L.*; PERRY, K.J.; HENRY, J.Q.; SHUBIN, N.H.; University of Chicago, University of Illinois, Urbana Champaign; *darcylross@uchicago.edu*

Building snail shells: the role of dpp in shell coiling of a limpet−like caenogastropod

The gastropod shell has evolved diverse forms and is well preserved in the fossil record, inspiring a century of research on the rules that guide shell coiling. To understand how selection has shaped the diversity of shell forms over time, we must link models of morphology to the shell's underlying genetic basis. Shimizu et al. (*EvoDevo* 2013, **4**:15) noted that *dpp* (BMP2/4 homolog) expression was enriched in the direction of shell coiling in the shell gland of pond snails, but was expressed equally around the gland in limpets, a lineage of gastropods characterized by their secondarily derived non−coiling shells. Shimizu and colleagues hypothesize that changes in *dpp* activity may underlie the numerous evolutionary transitions from coiled to limpet−like shells seen across Gastropoda. To test for the generality of this mechanism, *dpp* needs to be examined in a variety of gastropod lineages. We evaluate *dpp* in the developmental model system *Crepidula fornicata* (the common slipper shell), which belongs to Caenogastropoda, a species−rich branch of gastropods that have not yet been examined for *dpp* expression. Like the distantly related non−coiling limpets of Shimizu et al.'s 2013 study, *Crepidula* has convergently evolved a flattened limpet−like shell morphology, yet it does have a coil of less than one whorl. Due to its intermediately coiled morphology, informative phylogenetic position, and wealth of molecular tools, we decided to use *Crepidula* to further investigate the role of *dpp* in shell coiling. In this study, we characterize *dpp* expression using whole mount in situ hybridization from the earliest stages of shell gland development through later growth of the larval shell. Over these stages, we also characterize *dpp* activity using immunohistochemistry of its activated signal transducer pSMAD1/5/8. Future work will carry out functional tests and expand analysis to other gastropod lineages.

42.6 ROSS, CF*; FAGAN, M; EVANS, S; HERREL, A; WALSH, T; PORRO, L; University of Chicago, University of Hull, University College London, Museum national d'Histoire Naturelle, University of Bristol; *rossc@uchicago.edu*

In vivo bone strain and the design of lizard crania

Mammal crania are characterized by steep strain gradients across the skull. During feeding frontal and parietal bones experience very low strains compared with the maxilla, mandible and zygomatic arch. This suggests that the top of the mammal cranium is not optimized for dissipating feeding forces, where optimality is defined as maximum strength with minimum material. In order to determine whether strain gradients are also seen in lizards, we documented variation in in vivo strain magnitudes across the crania of at least 3 individuals of Tupinambis merianae, Anolis equestris, Gecko gecko, and Iguana iguana during bite force transducer biting and, in some cases, feeding. Rosette strain gages were placed in various combinations on frontal, parietal and maxilla, principal strains calculated, and nested ANOVAs were conducted to examine the effects of gage location, bite point, and individual on maximum and minimum principal strain magnitudes within each species, with bite force included as a covariate. Factors of gage location and bite point were nested within individuals. Results reveal that individual effects on principal strain magnitudes are small or not significant, in contrast to large effects of gage location and bite point. Lizards experience much higher strains on top of the cranium (frontal and parietal) than recorded from homologous sites in mammals. These results reveal that mammal and lizard crania are under different design constraints, with lizard crania being better designed (maximum strength with minimum material) for dissipating feeding forces than mammals. Funding was provided by joint BBSRC grants to M. F. and S.E. (BB/H011668/1 and BB/H011854/1), a research grant of the Research Foundation − Flanders (FWO) to A.H

87.1 ROSS, C; Univ. of North Florida; *cliff.ross@unf.edu*

Nitric oxide and heat shock protein 90 co−regulate temperature−induced bleaching in the soft coral Eunicea fusca

Coral bleaching represents a complex physiological process that is affected not only by environmental conditions but by the dynamic internal cellular biology of symbiotic dinoflagellates (*Symbiodinium* spp.) and their cnidarian hosts. Recently, nitric oxide (NO) has emerged as a key molecule involved with the expulsion of *Symbiodinium* from host cnidarian cells. However, the site of production remains under debate, and the corresponding signaling pathways within and between host and endosymbiont remain elusive. In this study, using freshly isolated *Symbiodinium* from the soft coral *Eunicea fusca*, I demonstrate that thermally induced stress causes an upregulation in *Symbiodinium* heat shock protein 90 (Hsp90). In turn, Hsp90 shows a concomitant ability to enhance the activity of a constitutively expressed isoform of NO synthase. The resulting production of NO constitutes a signaling molecule capable of inducing *Symbiodinium* expulsion. Using nitric oxide synthase (NOS) and Hsp90 polyclonal antibodies, thermal stress−induced Hsp90 was shown to co−immunoprecipitate with a constitutive isoform of NOS. The specific blocking of Hsp90 activity, with the Hsp90 inhibitor geldanamycin, was capable of inhibiting NO production implicating the involvement of a coordinated regulatory system. These results have strong evolutionary implications for Hsp90−NOS chaperone complexes among biological kingdoms and provide evidence for a new functional role in symbiotic associations.

S6.1 ROTH, TC*; NEMETH, Z; Franklin and Marshall College, UC Davis, Univ. of Debrecen; *troth@fandm.edu*

Thinking about change: an integrative approach for examining cognition in a changing world

We live in a changing world. Whether natural or exacerbated by human−induced factors, our climate is in a state of constant fluctuation. Understanding how animals respond to climate change at a cognitive level might reveal important and unknown aspects of how selection works in harsh or variable environments and gives us a more complete picture of the future of animal populations in our changing world. The goal of our symposium is to integrate physiological mechanism, behavioral and psychological responses, and the ecological and evolutionary consequences of those responses to understand the cognitive strategies that animals may use to cope with a rapidly changing world. Traditionally, strictly physiological approaches have been used to consider how animals will respond to environmental perturbation and (at a large scale) global climate change. However, we know that behavioral plasticity can facilitate a rapid and efficient response to perturbation and may be an equally relevant measure of a species capacity to handle change. By taking an integrative approach to cognition, we will be better able to understand which aspects of cognition might be most relevant for the response to environmental change and understand more fully the processes involved in its selection. Thus, we will be better able to predict the effect of large−scale climate change on a wider variety of species.

17.4 ROZNERE, I.*; WATTERS, G. T.; WOLFE, B. A.; DALY, M.; Ohio State Univ.; *roznere.1@osu.edu*

Health assessment of relocated freshwater mussel using metabolomics

Freshwater mussel conservation often requires the animals to be relocated to other habitats or brought into captive research facilities. Although critical to the success of this endeavor, knowledge of the impact of relocation on freshwater mussel health remains extremely limited. The objective of this study was to assess the effects of stress in captive and relocated mussels using metabolomics techniques. Freshwater mussels of the species *Amblema plicata were collected from the Muskingum River in Washington Co., OH, in June 2012. Half of the mussels were brought into captivity inside the Freshwater Mussel Conservation and Research Center in Powell, OH and half were transported to Big Darby Creek in Franklin Co., OH. Hemolymph samples were taken in the wild immediately upon collection in June 2012 and subsequently in August and October 2012 and May and August 2013. The samples were analyzed on gas chromatography−mass spectrometry and liquid chromatography−mass spectrometry platforms. Biochemicals involved in energy and carbohydrate metabolism showed similar seasonal variation among all groups of mussels. The stress of relocation was evidenced in changes in polyamine and nucleic acid metabolism. While levels of metabolites involved in polyamine synthesis were elevated in the wild mussels later in the year, these same metabolites decreased or remained unchanged in both groups of relocated mussels. Similarly, metabolites indicative of nucleic acid turnover and degradation tended to increase in the wild mussels and decrease in the relocated mussels. The significantly lower levels of polyamine and nucleic acid metabolites suggests decreased cell growth and proliferation, which in the long−term may impair tissue maintenance and cause decreased rates of growth.*

83.7 RUHR, IM*; BODINIER, C; MAGER, EM; ESBAUGH, AJ; TAKEI, Y; GROSELL, M; University of Miami, RSMAS, University of Tokyo; *iruhr@rsmas.miami.edu*

The physiological effects of the guanylin peptides on the posterior intestine of Gulf toadfish (Opsanus beta) exposed to hypersalinity

The homologous peptides guanylin, uroguanylin, and renoguanylin (RGN) affect osmoregulation in the posterior intestine of the Gulf toadfish by reversing short−circuit current, due to net Cl^- secretion, which leads to fluid secretion and inhibition of HCO_3^- secretion, and is likely facilitated by basolateral NKCC1 and apical CFTR in the posterior intestine. These observations contradict the established osmoregulatory function of the marine teleost intestine in fluid absorption, but may facilitate the release of $CaCO_3$ precipitates. To test this hypothesis, fish were exposed to hypersalinity (60 ppt), which increases intestinal $CaCO_3$ production. At 60 ppt, the posterior intestine expressed elevated mRNA for NKCC1, CFTR, and the guanylin peptides' receptor, and resulted in a greater secretory response to RGN by this tissue, in support of the above hypothesis. To test whether the elevated HCO_3^- secretion in 60 ppt is due to increased transport by the basolateral Na^+ / HCO_3^- −cotransporter (NBCe1) or increased CO_2 production by the enterocytes, HCO_3^- −free serosal saline was exchanged for serosal saline during experiments. Results demonstrate an expected decrease in HCO_3^- secretion in tissues after serosal saline was exchanged with HCO_3^- −free serosal saline, confirming transepithelial HCO_3^- secretion via NBCe1. Conversely, tissues exposed to 60 ppt revealed higher HCO_3^- secretion rates than control tissues in absence of serosal HCO_3^-, indicating a higher metabolic rate. Moreover, when in the absence of serosal HCO_3^-, RGN decreased baseline HCO_3^- secretion in tissues exposed to either treatment, suggesting action on apical HCO_3^- transporters.

37.8 RUIZ, C.A.*; ORTEGA, G.; THEOBALD, J.; Florida International University; *carlosruiz78@gmail.com*

Characterization of flight patterns in long−legged flies of the genus Condylostylus (Diptera: Dolichopodidae).

Long−legged flies spend most of their time chasing each other and their prey in fast but complex flights. These bursts of activity are usually initiated by a visual stimulus, the nature of which determines the motor response of the fly and the particular pattern of flight that follows. Using high−speed digital videography and 3d track reconstruction, we studied the interaction among long−legged flies of the genus *Condylostylus* and characterized their flight behavior according to particular parameters: distance to the target, length of the pursuit, yawing velocity and 3d velocity. We found that for these flies, we can characterize three distinct flight patterns: territorial flight, predatory chase, and mating pursuit. The interplay of three relatively simple behavioral patterns, dynamic visual targets, and fast flight, can then explain much of the complex flight behavior observed in these flies.

75.2 RUIZ−JONES, GJ*; PALUMBI, SR; Department of Biology, Stanford University, Hopkins Marine Station; *gjrj@stanford.edu*

5−day linear extension growth rates in corals living a reef with high environmental variability

Coral growth rates are often used as a metric of coral health and have been measured extensively in the lab under controlled conditions to better understand the potential impacts of future climate change. However, in the field corals live in dynamic environments, which can have extreme daily variability. Most field−based studies have measured growth rates over periods of time that are greater than the time over which environmental conditions vary. On Ofu Island in American Samoa, corals living in the back−reef can experience a range of conditions within a day due to the structure of the reef and the tide. Data from continuous−recording pH sensors show that, during high tides, the pH in the back−reef is very close to the pH in the fore−reef. However, during low tides, the pH in the back−reef is higher during the day and lower during the night, due to an imbalance between CO2 consumption and respiration. We have recorded pH ranging from 7.78 to 8.31. There are also diurnal fluctuations in dissolved oxygen availability and temperature. We measured linear extension growth rates in *Acropora surculosa* for three consecutive 5−day periods, each with different environmental regimes. As far as we are aware, this is the first study to use skeletal staining techniques to measure fine−scale growth rates in the field. Linear extension rates were measured using confocal microscopy of skeletal thin−sections of stained coral branches. These results are a first attempt at elucidating the impact that large, natural environmental variation may have on coral fine−scale growth rates. Preliminary analysis suggests that the amplitude of environmental variability does not have a negative effect on fine−scale linear extension growth rates.

BART.1 RUMMER, J.L.; James Cook University; *jodie.rummer@jcu.edu.au*

Lessons from the most successful vertebrates: Coping with stress and maintaining performance in a changing world

The fishes have 400 million years of evolutionary history, comprise over half of all extant vertebrates, and occupy nearly every body of water on the planet spanning an array of environmental conditions. For the teleosts, success is related in part to their unique oxygen transport system, which may be central to maintaining performance during stress or under challenging environmental conditions. Yet, we do not fully understand whether their capacity for acclimation and adaptation will keep pace with the rapid and large−scale changes occurring in their habitats, such as those associated with climate change. My research investigates how fish physiologically and behaviourally respond to and the mechanisms by which they acclimate and adapt to key environmental parameters (e.g., temperature, CO_2, reduced ambient oxygen, etc.) associated with yearly cyclic and climate change related stressors. My approach is based in ecological, evolutionary, and conservation physiology, and my experiments are both field− and laboratory−based, e.g. harnessing geographic gradients and local extreme environments as analogues for future change, investigating the extreme performers within aquatic environments, and integrating physiological, biochemical, and molecular techniques to gain insight into the various cellular and whole−organism responses. Currently, on the Great Barrier Reef, I am tracking metabolic and swimming performance of fishes under different conditions, across development and species, and over generations. This information is crucial for making predictions as to which species and/or populations may be most at risk from climate change and whether the fishes' long evolutionary history will be 'enough' to protect them from future changes in their habitat.

74.5 RUPP, TM*; MARTIN III, AL; Saginaw Valley State University; *tmrupp@svsu.edu*

The Effects of Shelter Abundance on Agonism in the Rusty Crayfish, Orconectes rusticus

An important outcome of agonistic interactions is the allocation of resources. Shelters are an important resource and animals will often escalate the intensity of an agonistic bout to obtain or sustain shelter ownership. However, the distribution of shelters in natural settings is often unknown, and in many animal systems it is not well understood how the abundance of shelters impacts aggressive behavior. Crayfish are known to readily compete with conspecifics in order to gain access to key resources, including shelters. For this reason, crayfish have often served as a model organism for examining both aggression and social relationships. In this study, populations of four size−matched (within 10%) male crayfish, *Orconectes rusticus, were presented with equally spaced arrangements of two, four, or six shelters. Video analysis was used to quantify shelter usage and evictions as well as the intensity, frequency, duration, and outcomes of fights over a 24−hour period. These observations were quantified and correlated between the three experimental designs. Data analysis has revealed that populations of crayfish generally exhibit a decrease in aggression as the number of available shelters is increased; rates of shelter evictions, fight intensity levels, and fight frequency decreased in the presence of abundant shelters, but fight duration increased. This study provides important information about the effects of resource abundance on social dominance and aggressive behavior within populations.*

P2.167 RUSCH, T.W.*; CAMERON, S.F.; BORCHERT, J.D.; WILSON, R.S.; Arizona State University, University of Queensland; *trusch@asu.edu*

Performing when it's hot − does increased oxygen help buffer the loss of performance?

When temperatures surpass a certain upper threshold, performance capacities drop sharply, and will ultimately be fatal if high temperatures persist. However, in aquatic environments, organisms face the additional challenge of plummeting oxygen levels with increasing temperatures. In these instances, is temperature really the limiting factor for performance? Or does reduced oxygen availability also play an independent role? To explore these ideas, we collected mosquito fish (*Gambusia holbrooki*) from three thermal environments; hot (38−42 C), sub−tropical (15−35 C), and cool temperate regions (5−30 C) . After acclimating all fish to normal oxygen at 22 C for 8 weeks, we measured three performance traits (burst speed, general activity, and mating success of males) during acute exposure to four different environmental treatments; 20 C normal oxygen, 30 C normal oxygen, 36 C normal oxygen, and 36 C high oxygen. We predicted that fish would perform best at temperatures that best represented their capture environmental temperatures. Additionally, we predicted that fish at 36 C with high oxygen exposure would exhibit a partial, if not full, increase in performance with the added oxygen. Thus, the amount of increased performance due to added oxygen will shed some light on how limiting oxygen, rather than temperature, is on performance measures of aquatic organisms.

P2.31 RUSH, S.L.*; WACHTER, K.L.; ROTH, T.C.; Franklin and Marshall College; *kwachter@fandm.edu*

Effect of habitat on hippocampal plasticity: a real world approach

A habitat's resource distribution should dictate how much time and energy an animal must spend foraging and may influence the level of spatial memory required to successfully remember foraging locations. As a result, hippocampal morphology (the region of the brain associated with spatial memory) may change depending upon habitat. Previous work suggests that birds utilizing less space and a reduced need for spatial memory show less hippocampal morphological advancement (region volume and dendrite structure), but this effect is reversible. To examine this phenomenon within an ecologically−relevant setting, we tested the hypothesis that wild dark−eyed juncos (*Junco hyemalis*) exhibit differences in the neural mechanisms that support spatial memory as a function of foraging area (rural vs. urban environments). Using radiotelemetry, we documented differences in space use by juncos in the different environments; home range sizes of rural birds were larger than those from the urban habitat. The rural birds traveled larger distances during the day, while urban birds remained close to residential feeders, even when roosting. We then sacrificed these birds and used Nissl stain along with stereological technique to analyze hippocampal volume and total neuron numbers. We found that the hippocampal volume of rural birds was significantly larger than urban birds; however, there was no difference in neuron number between groups. These results suggest that the distributions of resources within a habitat affect hippocampal volume but not neuron numbers. These differences in volume may be a function of connectivity within the hippocampus, demonstrating that animals' use of space in a natural setting can influence their hippocampal morphology and plasticity.

110.3 RUSSELL, A.L.*; LEONARD, A.S.; PAPAJ, D.R.; University of Arizona, Tucson, University of Nevada, Reno; *averyrussell@email.arizona.edu*

The Role of Experience in Floral Sonication Behavior by a Bumble Bee

Behavior may vary from being completely pre−programmed, to being readily and extensively modified by experience. When learning has costs, we expect that congenital expression of behavior will be favored. Foraging behavior is one essential activity where the costs of learning could impact the degree of pre−programming. While the majority of angiosperms offer two nutritionally complementary rewards to bees, pollen and nectar, most studies have focused on nectar foraging. Floral morphologies vary considerably and complex designs that offer nectar can require extensive learning. Little is known about costs of pollen foraging however, even though it is the sole protein source for larval and adult growth, and thus essential for survival. Six−8% of angiosperms offer only pollen, concealed in specialized poricidal anthers. Only bees that are able to vibrate the anthers and thus shake the pollen out (a complex behavior termed floral sonication) can access this essential nutrient. While we know a great deal about the function of sonication, the degree to which learning plays a role in shaping this behavior is an open question. In the Eastern Bumble Bee (*Bombus impatiens*) we find that the sonication motor routine is strongly congenitally expressed. Sonication behavior is rapidly released upon discovery of the androecium and is mediated by chemical cues from the anthers. We show evidence that a decrease in latency to sonicate with experience is likely a result of priming or imprinting, involving a heightening of responses to releaser stimuli. While anther cues appear to release sonication innately, petal cues release landing behavior innately. However, with experience, anther cues also promote landing.

28.7 RUTTIMAN, R.J.*; SLEBODA, D; ROBERTS, T.J.; Brown University; *roy_ruttiman@brown.edu*

Functional importance of fascia in the preservation of muscle tension

Many limb muscles are bound by thick connective tissue that surrounds groups of muscles to form muscle "compartments". These fascial compartments have clinical significance, as increased pressure within a compartment can compromise the blood supply and function of the tissues enclosed; however, it is unclear how fascial compartments influence normal muscle function. We explored the role of fascial boundaries in the wild turkey ventral interosseous a bipennate, distal wing muscle bordered by bone and enclosed within a fascial compartment. Using an *in situ* preparation, we characterized the muscle's length−tension relationship both before and after surgical removal of the ventral fascia that bounds the interosseous. Along the ascending, descending and plateau regions of the muscle's length−tension curve, fasciotomy resulted in an average decrease in muscle force output of approximately 17%. Additionally, as muscle length approached optimal length, the force deficit associated with fasciotomy increased. These results along with previous work on dog hindlimb muscles showing that fasciotomy reduces muscle force output (Garfin et al., 1981), suggest that fascia plays a critical role in preservation of muscle force production. The mechanism for fascia's effect on muscle force output is unclear. Supported by NIH grant AR055295. Garfin S R, Tipton C M, Mubarak S J, et al 1981. Role of fascia in maintenance of muscle tension and pressure. Journal of Applied Physiology 51 (2): 317−320

P2.132 RYAN, LM; CHANG, ES; CHANG, SA; COVI, JA*; Univ. of North Carolina, Wilmington, Bodega Marine Laboratory, Univ. of California Davis; *covij@uncw.edu*

Effect of commonly used pesticides on gene expression in pre−molt and post−molt Callinectes sapidus

Many currently used pesticides make their way into aquatic environments, and detrimentally affect non−target organisms. Because of its environmental and ecological importance, the blue crab, *Callinectes sapidus*, was chosen as a model species with which to study primary and secondary disruption of endocrine signaling by pesticides in decapods. Decapods, like all crustaceans, grow discontinuously by molting. Molting is a complex process that requires diverse physiological and structural modifications, including growth of the hypodermis, synthesis of a new exoskeleton, expansion of the body via water uptake, rupturing of the existing skeleton, and hardening of the new exoskeleton. This suite of events is orchestrated by a class of molting hormones termed ecdysteroids. Anthropogenic chemicals that disrupt the production, release or action of ecdysteroids will necessarily impact growth of the organism. In this study, we exposed fresh caught pre−molt (Stage D2) and post−molt (Stage A) blue crabs to physiologically and environmentally relevant concentrations of fenarimol, pyriproxyfen, and tebufenozide. After a 24 h exposure, hemolymph was collected and Y−organs, eyestalk ganglia, epidermis, claw muscle, heart, and hepatopancreas were preserved in RNAlater. The concentration of circulating ecdysteroids was determined by ELISA. Total RNA was isolated and DNase treated prior to reverse transcription. Quantitative PCR will be used to assess the effects of fenarimol, pyriproxyfen, and tebufenozide treatments on the relative abundance of ecdysteroid receptors in tissues from pre− and post−molt crabs.

P1.137 SABIR, NT*; ROARK, AM; Furman University , Furman University; *tasneem.sabir@furman.edu*

Sequencing of beta actin and retinoid X receptor genes in the sea anemone Aiptasia pallida

The retinoid X receptor (RXR) gene encodes a nuclear hormone receptor (NHR) important in development in both vertebrates and invertebrates. The retinoid X receptor binds 9−cis−retinoic acid and forms a dimer with multiple other NHRs. The purpose of our study was to clone and sequence RXR as well as a reference gene (beta actin) from pale anemones (*Aiptasia pallida*). Here, we report a partial sequence (approximately 600 nucleotides) of the beta actin gene. To date, we have been unable to determine the sequence of RXR from *A. pallida*, although partial sequences have been reported from several other species of cnidarians.

P2.113 SABOL, A *; AMBARDAR, M; GRINDSTAFF, J; Ohio State University, Oklahoma State University; *sabol.39@osu.edu*

Brood size manipulation affects plumage coloration but not growth rate of nestling Eastern Bluebirds, Sialia sialis

Plumage coloration can be an important signal of health, nutritional condition, parental quality, and reproductive success. In young birds, the development of plumage coloration is often condition dependent and based on factors such as amount of parental care and stress hormone levels. Offspring raised in small or large broods may differ both in the amount of parental care provided and stress exposure. In some previous studies, young raised in larger broods exhibited higher stress hormone levels and reduced growth rates; however, results have been inconsistent. We experimentally manipulated brood size of Eastern Bluebirds *(Sialia sialis)* and predicted that nestlings in enlarged broods would experience more competition for food, resulting in lower nestling body mass and less feather ornamentation. Contour feathers from the chest and rump were collected and coloration was measured with a spectrophotometer. Chest feather coloration in bluebirds is a result of melanin pigments and the blue−ultraviolet of the rump feathers is a structural color. Female nestlings in enlarged broods had more ornamented chest feathers, but less ornamented rump feathers. These opposing results may be due to differences in the source of coloration for chest and rump feathers. Coloration of male nestlings was not impacted by brood size manipulation. Growth rate for nestlings of either sex was unrelated to brood size, suggesting that parents may be able to compensate for a larger brood size. In conclusion, female plumage color in the first year may reliably signal stress exposure during development.

11.3 SADOWSKA, J*; GEBCZYNSKI, A; KONARZEWSKI, M; University of Bialystok, Poland; *julita.sadowska@uwb.edu.pl*
Metabolic risk factors in mice divergently selected for BMR fed high fat and high carb diets
Obesity and its concomitant health complications have become an epidemic all over the world, but the evolutionary sources of its origin still remain unknown. One of the most popular concepts in literature is the thrifty gene hypothesis (TGH) proposing the adaptive nature of a high fat gain. According to TGH individuals carrying the thrifty gens were able of enhanced fat storage making them less susceptible to periods of food scarcity. One idea is that thrifty genotype may underlie low basal metabolic rate (BMR), which increases fat storage through reduced metabolic maintenance costs, especially when physical activity is limited. We verified this prediction on mice artificially selected for divergent levels of BMR (high H−BMR, low L−BMR type mice). The animals were exposed to a 4 month long unlimited access to diets emulating the so called western diet (high fat and high carbohydrate) with no access to running wheels. Our preliminary results show that although H−BMR type animals consumed more food throughout the experiment they also showed higher levels of voluntary activity, gained less weight and had lower levels of blood triglycerides, cholesterol and glucose then the L−BMR individuals at the end of the experimental period. These basic indicators suggest that genetically determined low BMR may be a factor predisposing individuals to developing of a cluster of metabolic abnormalities occurring in response to a typical high fat/high carb western diet.

P3.86 SALAZAR, T.R.*; YOUNG, C; NARANJO, S.M.; PASTOR, M.J.; PLASENCIA, M; GUNES, N; CAKMAK, I; HRANITZ, JM; University of Chicago, Muhlenberg College, University of Central Florida, San Francisco State University, University of California Santa Cruz, Uludag University, Bloomsburg University of Pennsylvania; *tmthslzr@uchicago.edu*
Sublethal effects of Deltamethrin on Apis mellifera in Turkey
Fungicides and insecticides have garnered interest for their role in Colony Collapse Disorder (CCD), which is affecting honey bee (*Apis mellifera* L.) populations across the United States and Europe. Deltamethrin is a pyrethroid insecticide with applications in agriculture and pest control and it has been shown to be lethal to honey bees at high dosages. In this study we assessed the effects of sublethal dosages of Deltamethrin, as approved for commercial use by government agencies, on the motor control and central nervous system processing of honey bees. Experiments were conducted near Bursa, Turkey. We fed six sublethal concentrations, dilutions of the LD50 79 ng/bee in 1.5 M sucrose, to harnessed honey bees to measure adverse effects on motor control and central nervous system (CNS) processing. Bees were randomly assigned to a sublethal dose treatment, fed, and scored after four hours for motor response in their wings, legs, abdomen, and proboscis extension reflex (PER). A sucrose sensitivity assay was done to investigate the effects of deltamethrin on CNS control of the PER. We found that motor control was impaired at the two highest sublethal doses (1/5 and 1/10 LD50), but was not different from controls at lower sublethal doses. Sucrose sensitivity of the PER was reduced by the highest sublethal dose of deltamethrin. Deltamethrin therefore impairs physiological components of foraging, motor coordination and CNS processing, and may pose a significant risk to foraging behavior in *Apis mellifera*.

S8.1 SALDANHA, CJ; The American University; *saldanha@american.edu*
Buttons and Glue: novel forms of estrogen provision.
Estrogens (E) affect vertebrate brain and behavior throughout the lifespan. Given the diversity of E−dependent behaviors, targets, and sources, the spatial and temporal precision of E−delivery is of considerable interest. In the songbird, while aromatase is widely expressed, E−sensitive loci, such as the hippocampus (HP) and HVC have few to no aromatase−expressing neuronal profiles. Using immunoelectron microscopy, we detected aromatase in presynaptic boutons and post−synaptic dendrites in the zebra finch HP and HVC, areas where somal aromatase was low to undetectable. Thus, synapses may be provided with E with extreme precision, perhaps to the exclusion of adjacent structures. Local application of the aromatase inhibitor ATD to the HP, reduced local E, and impaired learning and performance on a spatial memory task. Thus, constitutive HP aromatization, likely at the synapse, is a critical modulator of HP−dependent function. We have also found that aromatase can be induced by mechanical damage in vimentin−positive reactive astrocytes and radial glia; cells that do not express aromatase in the unperturbed homeotherm brain. This induction is considerable, as mechanical injury almost doubles immunoreactive aromatase and almost quadruples local E around the injury. We now focus on the interaction between injury−dependent aromatase and the innate immune system. In adults of both sexes, mechanical injury first induces cytokine expression in microglia followed by the astrocytic aromatase. E, synthesized by glia is a potent inflammatory as its removal and replacement, sustains and reduces cytokine expression respectively. Taken together, these studies reveal the remarkable and dynamic specificity of E−provision in the vertebrate brain underscoring the considerable spatial and temporal precision of E−provision, and its influence on brain structure and function.

115.6 SAMSON, J.E.*; KHATRI, S.; MILLER, L.A.; Univ. of North Carolina, Chapel Hill, Univ. of California, Merced; *jesamson@live.unc.edu*
Lazy or hardworking, alone or together: the effect of grouping on pulsing behavior in Cassiopea and Xenia
Upside−down jellyfish (*Cassiopea*) and pulsing soft corals (*Xenia*) generate water flows by contracting their bells and polyp arms, respectively. This pulsing behavior is thought to increase nutrient flow to the organisms and allow for increased photosynthetic rates by the symbiotic zooxanthellae that both organisms harbor. Upside−down jellyfish are typically found in groups from 2 to over a hundred individuals of varying sizes. These groups are dynamic, with individuals changing their position within the group. Similarly, pulsing soft corals form colonies in which the stalked polyps can adapt their position relative to other polyps and to the background flow. The fluid dynamics of these groups and colonies might have an important role in the development and growth of individual jellyfish and polyps. Choosing a certain position or neighbor in the group, or adjusting one's position relative to one's neighbors, might benefit individuals and increase their fitness. In the lab, individual upside−down jellyfish have showed different pause lengths between pulses. When two jellyfish are put close together, their pulsing patterns change, often to reveal one individual to be more active and pulse more often than the other. The fluid dynamic effects of short vs. long pauses and of individual vs. pairs of jellyfish have been investigated using particle image velocimetry (PIV). Similar PIV experiments will be conducted with the pulsing corals, comparing the behavior and fluid dynamics of individual vs. pairs of polyps. Our results will shed light on the potential fluid dynamic advantages of group behavior in pulsing marine invertebrates.

47.1 SANBORN, AF*; CASTILLO, I; DUNCAN, C; LUKE, A; PACHECO, M; PAZ−CASTILLO, D; POECK, A; Barry Univ.; *asanborn@barry.edu*

Minimum Flight Temperature Relates to Wing Morphology in Cicadas (Hemiptera: Cicadidae)

Temperature significantly influences the physiology of organisms. Animals adapt their physiological systems to function efficiently at the specific temperatures that the animal will function. The thermal responses of cicadas show similar adaptation with animals from cooler environments selecting lower body temperatures for activity and possessing lower upper body temperature limits to activity. Early cicada studies demonstrated a relationship between habitat, and ambient temperature of the habitat, and the minimum body temperature necessary to produce a controlled flight. Further study showed many species did not follow this relationship. As a result, we investigated the influence of flight system morphology on the minimum flight temperature (MFT). We measured live mass, wing length, wingspan, wing area and wing loading in an attempt to correlate these morphological parameters to the MFT. We analyzed both intraspecific (in *Magicicada* spp.) and interspecific relationships of the wing morphology and the ability of the cicadas to fly in a large number of North American cicada taxa (n=109−120). A total of 111 species and 9 subspecies from 15 genera including all major North American habitats were studied. Analyses show that wing morphology (wing length, wing span, wing area and wing loading) scales to body size as predicted by geometric similarity (all $P<0.0001$). Mass, wing length, wingspan, wing area and wing loading all demonstrate a significant correlation ($P<0.05$ in all cases) to MFT as would be predicted by aerodynamic theory.

P3.107 SANCHEZ, A.*; SCHUMACHER, E.L.; REECE, J.S.; Valdosta State University; *asanchez@valdosta.edu*

Genetic sexing of the federally endangered Florida Grasshopper Sparrow

The Florida Grasshopper Sparrow (*Ammodramus savannarum floridanus*)is quite possibly the most endangered species of bird in North America, with fewer than 200 individuals in the wild. The sexing of individuals in captive breeding programs is vital for the conservation of this federally endangered species. Because grasshopper sparrows are not sexually dimorphic, we tested a PCR−based method to sex individuals. DNA samples were used from blood extracts of 26 individuals (many of known sex). Primers 2917F−3088R (Ellegren 1996), P2−P3 (Griffiths et al. 1996), 2550F−2718R (Fridolfsson and Ellegren 1999), and 1237L−1272H (Kahn et al. 1998) were tested for their ability to distinguish between sexes. Upon undergoing several rounds PCR and examination of electrophoresis gels we found that the primers used sexed the birds correctly. Agarose gel electrophoresis was used to display a single band for males, and two bands for females. Primers used in this study were previously found to correctly differentiate the sex across several different bird species of different families. This tool can be used as a rapid and cost−effective way of identifying the sex of individuals used in captive breeding programs.

P2.81 SANCHEZ, E*; TRACY, CR; California State University, Fullerton; *emilysanchez@csu.fullerton.edu*

Sex−based Differences in Summer Activity of Sauromalus ater (Common Chuckwalla)

Climate change may decrease the amount of time environmental temperatures are suitable for ectotherm activity, thus reducing time available for energy acquisition, territorial displays and reproduction. To assess potential impacts of climate change on populations, it is important to study how lizards use their time for activity. Male common chuckwallas (*Sauromalus ater*) do not use all of the time where temperatures are suitable for activity (outside of rock crevices), suggesting that climate change will have minor effects on their ability to perform such activities. However, sex differences in the use of suitable activity time could result in reduced reproductive output of the population in the face of climate change, so we studied female thermoregulatory behavior for comparison. We measured body temperatures (Tb) of 5 female and 1 male chuckwalla in a semi−natural enclosure every 15 min during summer. To determine how chuckwallas used the thermal environment, we compared Tb to environmental temperatures (Te), measured with copper models that mimic heat exchange of chuckwallas. The proportion of time females were active relative to the time with suitable Te (0.71 ± 0.127) did not differ from that of the male (0.78; $t= -1.176$, $p=0.305$). Further, the amount of time the male and females spent thermoregulating inside rocks vs. outside did not differ. The proportion of time the male was active relative to the time with suitable Te was greater than wild males (0.45 ± 0.210) from the previous study ($t= -3.850$, $p= 0.012$). Because the time used by female and male chuckwallas to be active does not differ during summer months, chuckwalla populations may not be greatly affected by minor reductions in suitable activity time as a result of climate change.

37.6 SANDERS, EJ*; WOODS, J; DICKERSON, BH; DANIEL, TL; Univ. Washington, Roosevelt High School; *elischasanders@gmail.com*

Laser localization of wing mechanosensory cells with multisite recording

Using a suite of sensory modalities, including vision and mechanoreception, insects process such information control flight. The precision, sensitivity, and rapid processing speeds of mechanoreceptors make them critical components of locomotor control. Further, anatomical, electrophysiological, and behavioral evidence confirms that the wings of the hawkmoth *Manduca sexta* inform the animal of its body dynamics. However, linking the wings' bending dynamic to information provided by mechanoreceptors (companiform sensillae) has been unsuccessful with previous intracellular methods. Moreover combined multi−channel extracellular recordings in wing nerves associated with of distributed sensillae did not permit mapping of multiple units to their projections on the wing. However, the strong temperature sensitivity of sensillae allows a novel method to elucidate their regional projections. We used a pulse−width modulated laser to heat and thus selectively deform sensillae on the wing. With simultaneous IR imaging we were able to determine both the location and temperature of the wing region excited by the laser with simultaneous multisite neural recordings. Moreover, using spike−sorting methods, we identified individual units. We showed a consistent increase in spike−rate as the local temperature increased. A maximum increase in spike rate of about 200% was observed for temperatures ranging between 40 − 50 degrees C. Any temperature above 50 degrees Celsius caused a severe decrease in the spike rate, and in some cases death of the cells. Ultimately, in addition to obtaining mechanically induced stimulus excitation of the forewing nerve from individual units, we have demonstrated a novel method to extract location information.

P2.61 SANDOVAL, J*; MCCUE, M/D; St. Mary's University − Texas; *mmccue1@stmarytx.edu*

Thermotolerance of cockroaches at upper lethal temperatures depends more on humidity levels than on the accumulation of CO_2 or reactive oxygen species

We previously demonstrated that the upper thermal limits of several species of terrestrial insects were not the result of insufficient O_2 delivery, raising the possibility that some other physiological limitation must be the cause of death. In the present study we measured thermotolerance (at 50ÚC; 2L min^{-1} air flow) in over two−thousand hissing cockroaches, *Gromphadorhina portentosa*, exposed to different relative humidity (RH) levels (0, 23, or 90%), ambient CO_2 levels (0, 5, 10, or 15%), or antioxidant treatments (glutathione, mercaptopropionyl glycine, ascorbic acid, or Trolox). The insects were injected with 1 or 10mMol of individual antioxidants or mixtures of antioxidants (0.3ml) 30 minutes before the thermotolerance trials. Contrary to our predictions, Kaplan−Meier log rank survival analyses revealed no diminished thermotolerance with elevated CO_2 − even at 15%, suggesting hypercapnia was not a critical issue. We were also unable to detect improved performance using any of the antioxidant treatments, suggesting reactive O_2 species were not the direct cause of death; although, we did confirm that treatments with H_2O_2 hastened death. We predicted that dehydration might be a contributing factor at these high temperatures. Surprisingly, thermotolerance at 0% RH was no different from 23% RH and the times required for half of those populations (LT_{50}) to succumb were ~35 minutes. Contrary to our expectations, thermotolerance was the lowest in the high humidity treatment where the LT_{50} was ~20 minutes. We do not attribute this response to reduced evaporative cooling, but rather to the fact that water vapor has a specific heat twice that of air and the increased net heat flux caused the cockroach to achieve thermal equilibrium sooner than in the other treatments.

S5.12 SANFORD, R, S*; DABE, E, D; BOSTWICK, C, J; RIVA, A; WILLIAMS, P, L; KOHN, A, B; MOROZ, L, L; Univ. of Florida, Gainesville; *rsanford@ufl.edu*

Epigenomics of Neuroplasticity in Invertebrates: Part 2. Probing relationships between memory, injury, and development

Epigenomic mechanisms, including DNA methylation and demethylation, underlie multiple forms of long−term plasticity. However, these mechanisms are poorly understood in invertebrates and the evolution of epigenetic regulation is currently elusive. Previous studies suggest that mechanisms of memory formation, differentiation and responses to injury share many similarities and, perhaps, the same molecular machinery[1]. Here we will present both transcriptomic and epigenetic approaches to characterize tissue and single−cell epigenomic responses and mechanisms in various invertebrate models. We will discuss what common mechanisms are shared between injury, memory and developmental processes.

[1] Walters, E. T. & Moroz, L. L. Molluscan memory of injury: evolutionary insights into chronic pain and neurological disorders. Brain Behav Evol 74, 206−218, doi:10.1159/000258667 (2009).

P1.72 SANFORD, R, S*; KOHN, A, B; WILLIAMS, P, L; NOREKIAN, T, P; MOROZ, L, L; Univ. of Florida, Gainesville, Friday Harbor Laboratories; *rsanford@ufl.edu*

Genomics of Regeneration in Ctenophores

Ctenophores amazing capacity of regeneration has fascinated biologists for centuries. These comb jellies have the ability to repair a wound in their epithelium in a matter of hours. *Mnemiopsis leidyi* can also regenerate a complex integrative center called the aboral organ, or "elementary brain", in a matter of days. Here we are using next generation sequencing technology to study the transcriptomic response during regeneration. We are using both Ion Torrent and Illumina technologies to perform deep RNA−sequencing of various time points during regeneration. We then analyzed this data using RPKM expression levels to look at various signaling pathway expression in these projects. Here we show molecular mechanisms that might give us hints as to why these animals have such an exceptional ability to regenerate.

106.1 SANGER, T. J.*; GREDLER, M. L.; COHN, M. J. ; University of Florida, University of Florida, Howard Hughes Medical Institute; *th.sanger@ufl.edu*

Resurrecting embryos of the tuatara, Sphenodon punctuates, to resolve vertebrate genital evolution

Amniote genitalia exhibit wide diversity in adult anatomical form with species possessing one phallus or two, an open sulcus or a closed urethra, and many additional differences in internal and external anatomy. Some amniote lineages, including the tuatara, *Sphenodon punctuates*, lack external genitalia altogether and mate using cloacal apposition rather than through penile copulation. It remains unknown whether external genitalia evolved only once at the origin of Amniota or independently in squamates, mammals, and archosaurs. We have surveyed genital development in six amniote species and found many similarities in early genital morphogenesis among species with distinct adult anatomies. This suggests a single evolutionary origin to the amniote phallus followed by later lineage−specific modification. However, the lack of a phallus in the tuatara remains difficult to reconcile because of its phylogenetic position between lineages possessing one midline penis and paired hemipenes. To further resolve the evolutionary history of amniote genitalia we performed three−dimensional reconstruction of *Sphenodon* embryos. These embryos were collected in 1898 and histologically prepared as serial sections for the Harvard Embryological Collection before being misplaced for the majority of the 20th century. Despite the lack of a phallus in the adult, *Sphenodon* embryos possess similar genital and cloacal swellings to other amniote species during embryonic stages. Therefore, it appears that the early stages of genital development are conserved across the whole of Amniota and lend greater support to the hypothesis of a single evolutionary origin of amniote external genitalia.

30.2 SANTANA, SE; University of Washington; *ssantana@uw.edu*

Quantifying the effect of gape on bite force: Comparisons between in vivo measurements and biomechanical modeling in bats

Maximum bite force is an important metric of feeding performance that defines the dietary ecology of many vertebrates. In mammals, theoretical analyses and empirical studies of muscle function, gape angle and bite force suggest a trade−off between maximum bite force and gape; cranial morphologies that enable high mechanical advantage have decreased ability to generate high bite forces at wide gapes, and vice versa. Nevertheless, very few studies have confirmed these relationships in free−ranging mammals biting voluntarily, and fewer have contrasted these measurements with those derived from biomechanical models to examine the morphological features underlying the gape−bite force relationship across species. I document the variation in bite force with respect to gape angle in a diverse sample of free−ranging bat species, and compare these results with predictions from 3D lever models of the feeding apparatus that simulate biting at increasing gapes. *In vivo* and model data corroborated that bite force decreases significantly as gape angle increases across species, but there is substantial intraspecific variation in the data obtained from live bats. Bite force predictions from biomechanical models revealed that species with high mechanical advantage experience a steeper drop in bite force with increasing gape, despite a smaller loss in force due to negative moments about the temporomandibular joint. These bat species correspond to short−faced frugivores and insectivores that specialize on mechanically challenging prey. Interspecific differences also highlight the influence of jaw adductor stretch factors in these relationships. Altogether, these results suggest that gape−mediated changes in bite force can be explained both by behavioral effects and cranial morphology, and that these links are relevant for functional analyses of mammal dietary ecology.

98.7 SANTINI, F*; CARNEVALE, G; ALFARO, ME; Univ. of California, Davis, Univ. of Torino, Univ. of California, Los Angeles; *francesco.santini@alumni.utoronto.ca*

Origin and evolution of pufferfishes, triggerfishes and allies (Tetraodontiformes)

Tetraodontiform fishes represent one of the most peculiar radiations of teleost fishes. In spite of this, we do not currently have a consensus on the phylogenetic relationships among the major tetraodontiform lineages, with different morphological and molecular datasets all supporting contrasting relationships. We present the results of the analysis of tetraodontiform interrelationships based on a large matrix consisting of full mitogenomes, 20 nuclear loci (~ 30.000 combined nucleotides) and 250 morphological characters for 90 taxa, including representatives of all of the 19 currently recognized extant and fossil families. Bayesian and maximum likelihood analyses strongly support novel relationships among the major tetraodontiform lineages. The new analysis also suggests a key role of fossils in helping us understand how highly derived morphological structures found in extant clades may have originated. A second dataset, consisting of nine nuclear and mitochondrial loci sequenced for 255 species (~55% extant species) is then used for a time calibrated analysis that reveals a late Cretaceous stem origin for most families. This was followed by an Eocene−Oligocene radiation that was likely facilitated by the establishment of large scleractinian reef habitats across tropical and subtropical oceans.

26.6 SASSON, DA*; BROCKMANN, HJ; University of Florida; *dsasson@ufl.edu*

Geographic variation in sperm traits of the horseshoe crab, Limulus polyphemus

Why traits that strongly affect fitness vary is a standing question in evolutionary biology. Many such traits may vary across a species' range, including body size, life−span, development rate, song structure, and mating strategy. Variation in these traits have often been attributed to factors such as season length and temperature, localized ecological factors, and population specific sexual selection. While studies explaining changes in these types of traits across populations are common, few studies have investigated how gametes differ across a species' range. In particular, little is known about the extent to which sperm traits vary across populations and, if variation exists, the factors or selective pressures that lead to patterns of variation. Sperm traits are strongly linked to fitness, especially in systems with high levels of sperm competition, and thus an understanding of the factors that affect sperm trait evolution is essential. In this study, we examine differences in sperm traits across populations of the American horseshoe crab, *Limulus polyphemus*. We find that populations differ in average ejaculate size, sperm concentration, and sperm velocity. Population variation in the operational sex ratio and body size seem to influence most strongly the differences in ejaculate size and sperm concentration. These results suggest that populations may adapt to the local level of sperm competition risk.

P1.178 SATHE, E. A.*; HUSAK, J. F.; University of St. Thomas; *sath1503@stthomas.edu*

How Substrate Variation Impacts Locomotor Performance Capacity and Behavior of Terrestrial Lizards

During predator−prey encounters, maximal performance capacities often determine the outcome of whether the prey or predator survives. Performance is a direct result of an individual's morphology, so morphology is indirectly a predictor of individual fitness. Many studies have looked at individual morphology and performance capacities, but they have historically been conducted in a laboratory setting on standard substrates. Reality is more complex than a laboratory because there are many substrates available in nature that differ from a single, standard substrate. Performance may vary among substrates and different morphological traits may be favored on each. Thus, natural selection acts on different traits across substrates, and fitness is determined by performance on and among substrates as well as substrate choice. We explored the relationship between morphology and performance by examining maximal sprint performance and sensitivity of wild−caught six−lined racerunner (Aspidoscelis sexlineata) lizards on four simulated substrates that mimic natural substrates: sandpaper (rock), sand, pebbles, and grass. We also identified morphological predictors of performance on each substrate. We measured substrate use in these lizards relative to available habitats. Only performance on grass was found to be suboptimal, but all sensitivity measures were correlated with each other. Performance on different substrates was predicted by different morphological traits. Performance trade−offs were found between grass and sandpaper, grass and pebbles, and between sand and pebbles after correcting for overall individual quality. Lizards tended to use substrates that optimized performance.

S5.4 SATTERLIE, Richard; University of North Carolina Wilmington; *satterlier@uncw.edu*

Cnidarian Neurobiology: The Thrill of Evolutionary Advances and the Agony of Phylogenetic Constraints

Despite adaptations that include centralized nervous structures, giant neurons, elaborate sensory structures, striated muscle, and species−specific specializations in neural circuitry, cnidarian nervous and muscular systems are "constrained" by architectural features such as radial or biradial symmetry and broad, two−dimensional muscle sheets. The relatively simple neuroethology of sessile scyphozoan polyps is contrasted by the elaborate behavioral repertoire and neuronal circuitry exhibited by hydrozoan and cubozoan medusae. Comparative analyses of neuronal form and function is allowing an inventory of common and specific features within and between cnidarian groups which should provide a backdrop for comparison with genomic and transcriptomic data related to the phylogenetic relationships of cnidarian groups. The hope is this will help point to a common evolutionary past of the phylum, and to the rudiments of an ancestral nervous system.

36.2 SAUER, E.L.*; ROHR, J.R.; University of South Florida; *erinsauer@mail.usf.edu*

Interactions between Batrachochytrium dendrobatidis infection and behavioral thermoregulation in amphibians

Many animals, both endothermic and ectothermic, regulate their body temperature to cope with environmental stressors, including infection. Fever is a common host response to infectious or inflammatory agents. Ectothermic animals that exhibit a febrile response usually do so through behavioral thermoregulation. A febrile response by way of behavioral thermoregulation has the potential to be especially effective when the pathogen in question is sensitive to high temperatures. *Batrachochytrium dendrobatidis* (*Bd*), a fungal pathogen implicated in worldwide amphibian declines, dies when kept at constant temperatures above 28° C. In this study we aim to determine the desired temperatures of *Anaxyrus terrestris* and the degree of variability in temperature among individuals by observing animals in thermal gradient chambers. We then will determine how the thermal preferences of individuals change after exposure to *Bd*. Lastly, we will determine whether changes in behavioral preference reduce actual *Bd* abundance on toads relative to a scenario where toads are kept at their preferred temperature in the absence of *Bd* and cannot thermoregulate.

76.1 SAVAYA ALKALAY, A.*; SAGI, A.; Ben Gurion University of the Negev; *amitsavaia@gmail.com*

RNAi−based monosex prawns as sustainable bio−control agents over expanding snail populations.

Bio−control of prawns from the *Macrobrachium* genus over snails has been proven to be an efficient strategy under laboratory conditions, and is suggested to be used in field studies. We propose to use all−male populations of prawns generated by a temporary intervention via RNAi to silence the expression of the insulin−like androgenic gland encoding gene, creating broods with 100% male progeny. The advantages of the use of an all−male population lies in its temporal and non reproductive nature thus minimizing the risk of bio−invasions. Moreover, unlike females, male prawns do not tend to migrate and therefore will ensure predation within specific snail−infested sites. In addition, male prawns grow faster and larger than females, therefore a selective harvest of larger prawns would encourage the smaller prawns to grow faster and support the bio−control task while the larger prawns can be harvested as a byproduct for local human consumption. Here we present two case studies where all−male prawn populations could be used for different bio−control snail targets, snails carrying disease and invasive snail populations. The first case is the epidemiological challenge posed by the parasitic disease schistosomiasis (Bilharzia) that occurs mostly in Africa. The introduction of all−male populations of prawns is suggested in areas that suffer from high infection rates of freshwater snail *Biomphalaria* and *Bulinus spp.* , which serve as intermediate hosts of schistosomiasis. The second challenge is a globally devastating ecological and agricultural invasive species, the Apple snail *Pomacea spp.* The suitability of male prawns as bio−control agents has been studied under laboratory conditions with results suggesting that this can be a temporal sustainable solution from a conservation point of view.

P3.134 SAWYER, N. N.*; HALE, M. E.; Univ. of Chicago; *mhale@uchicago.edu*

Putting a new spin on turning behavior of fish.

Maneuvering turns are used by many fishes to navigate complex environments. Despite their prevalence in real−world situations little is known about the kinematics and mechanics of this behavior. We examined turning in zebrafish, a species that, as a model organism, can be investigated with a wide range of genetic and molecular approaches. We used high−speed imaging to film the fish from dorsal and lateral views as they turned around a 90° corner in a filming tank. Turns had two distinct kinematic stages. During stage 1 the body curved to one side and the head rotated. Often at the beginning of this stage the fish pivoted around the pectoral fin on the inside of the turn. In many trials stage 1 included a downward motion of the fins, which was associated with the fish rising in the water. During stage 2 the body straightened and propelled the fish out of the turn while the head held the orientation achieved at the end of stage 1. We found that turns could be categorized into three classes based on gaps in the distribution of turn angles. In shallow turns (below approximately 20°) the pectoral fin on the inside of the turn always adducted first and its pivot duration was short. The majority of turns fell into the intermediate class (between 20° and 45°). The coordination of fin movements in this class was more variable than in the others and the pivot duration was longer. Rising during both shallow and intermediate turns was common. Fish performing tight turns (above approximately 45°) had the shortest pivot durations and we did not observe rising in association with pectoral fin movement. Otherwise, the fin movement was similar to that of the intermediate trials. This study provides evidence that turning can be divided into classes based on turn angle, and that these classes differ in pectoral fin and body movements.

P3.114 SAWYER, S. J.*; PETERS, A; LESSER, M. M.; ROSE, A; MINICH, A. B. ; HARRIS, L; Glenville State College; *sara.sawyer@glenville.edu*

The relative timing of integrin loss and apoptosis initiation after temperature shock in the tropical sea anemone Aiptasia pallida

Temperature−induced cnidarian bleaching is becoming an increasing problem threatening the health of coral ecosystems, but the cellular mechanisms that lead to collapse of the cnidarian−algal symbiosis are not well understood. Studies have shown that increased water temperature can induce apoptosis in host and algal cells, and this is correlated to the loss of algae, but how temperature triggers apoptosis is not clear. We investigated how increased water temperature affected the distribution of the cell−substrate adhesion molecules integrins and the timing of the onset of apoptosis in symbiotic and aposymbiotic *Aiptasia pallida* . Anemones were temperature shocked from 25°C to 30°C for 0, 6, 12, or 24 hours. After temperature shock, anemones were preserved in 4% paraformaldehyde, embedded in paraffin, and sectioned. Sections were stained using either an anti−integrin antibody to show the distribution of integrins or using the TUNEL assay to determine apoptosis. The distribution of integrins was altered after a 12hr heat shock from 25°C to 30°C in symbiotic Aiptasia pallida but not in aposymbiotic anemones. Using the TUNEL assay to detect apoptosis, we show that this loss of integrin staining in symbiotic anemones is preceded by the initiation of apoptosis after four to six hr of heat shock. Apoptosis is also seen in aposymbiotic anemones after a four to six hour heat shock as well. These results suggest that temperature−induced loss of integrin staining is a symbiotic phenomena, but temperature−induced apoptosis is not. The signaling pathways that link apoptosis and integrin expression are being investigated.

16.1 SCALES, JA*; BUTLER, MA; University of South Florida, University of Hawaii; *jscales@usf.edu*

Targets of selection and potential constraints shape the evolution of the locomotor system in lizards.

Many complex phenotypes such as the locomotor system perform multiple, and sometimes conflicting functions. The evolution of traits underlying such phenotypes may therefore be shaped by different selective pressures, compromises between functions, or be limited by constraints. Studies of complex phenotypes, however, often examine underlying traits individually or with respect to a single selective pressure. Here, we use a morphological "meta−analysis" to evaluate whether locomotor traits from the cellular to the whole−organism level show similar patterns of evolution in lizards. We tested evolutionary models based on habitat use, predator escape, foraging behavior, and Brownian motion to assess whether selection acts across all levels of the locomotor system. We find that selection related to both predator escape and foraging behavior influences the evolution of traits spanning the cellular to whole−organism level. However, a global optimum model best explains the evolution of several muscular traits, indicating selection on musculature is similar across lizards, or may be a consequence of functional constraints in the muscular system. Interestingly, a Brownian motion model best explained the evolution of some leg segments. While this finding suggests portions of the limb may not be subject to selection, it may also result from compromises between competing functions. Overall, we find that traits show distinct patterns of evolution within a complex phenotype; some reflecting selection related to performance, while others are more limited in their evolution.

97.1 SCHIEBEL, P.*; GOLDMAN, D.I.; Georgia Institute of Technology; *pschiebel3@gatech.edu*

Limbless locomotion in heterogeneous terrestrial substrates.

Snakes can traverse heterogeneous terrain composed of rocks, foliage, soil and/or sand. Previous research elucidated how rigid obstacles influence snake locomotion by studying a model heterogeneous terrain symmetric lattices of obstacles placed in hard ground. We want to understand the benefits and tradeoffs of different substrate−body interaction modes during transit of substrates composed of rigid obstacles and flowable (granular) substrates in desert−adapted snakes. We hypothesize that, due to these snakes' ability to utilize granular resistive forces, introducing a granular medium (GM) to a peg lattice will improve performance (in terms of snake speed) compared to that in the same lattice on a hard substrate. We tested *Chionactis occipitalis*, the Mojave shovel−nosed snake, in a square lattice of 0.64 cm diameter obstacles arrayed on both a hard, slick substrate and in a GM of 270±4 ¼m diameter glass particles (comparable in size to natural sand). We challenged the snakes to move through lattices of different densities such that nearest−neighbor spacing ranged from slightly wider than the body diameter to larger than the snakes' natural amplitude. Increasing obstacle density in the GM lattices resulted in a decrease in mean forward speed above a critical density. Below this density, speed was constant and comparable to that on open GM. In lattices on hard substrates, density did not affect speed; the speed in the densest lattice was comparable to that on open hard ground. This speed was a factor of two lower than the speed on open sand (P=0.98). Kinematics were similar for both substrates but depended on lattice density: at low density, undulatory locomotion was typically used while at high density a more complicated time−dependent body shape emerged.

70.1 SCHIPPERS, KJ*; NICHOLS, SA; University of Denver; *klaske.schippers@gmail.com*

Using sponges as a model to study the evolution of the Wnt/beta−catenin signaling pathway

The discovery of conserved homologs of the Wnt/beta−catenin pathway in sponges (one of the earliest branching metazoan lineages) raised questions about whether a functional Wnt/beta−catenin pathway is present in sponges and what its role may be in organisms of such relative simplicity. To gain more insight in the role of beta−catenin in sponges, we identified tissue−specific and subcellular localization patterns of beta−catenin by performing immunostaining using a peptide antibody against beta− catenin of the freshwater sponge *Ephydatia muelleri*. The sponge body plan is composed of two primary tissues, the pinacoderm (outer epithelium) and the choanoderm (composed of choanoflagellate−like cells) that pumps water through a water canal system used for feeding and respiration. The area between these two tissues is called the mesohyl and is composed of ECM, spicules and migratory mesenchymal cells called archaeocytes. Our immunostaining data show that beta−catenin is detected in the nuclei of mesenchymal cells and pinacoderm cells, suggesting a conserved role as a transcription factor, possibly part of the Wnt pathway. We also observed staining at cell boundaries of the pinacoderm, which is consistent with a role in cell−cell adhesion. Staining was not detected in cell boundaries of the choanoderm, which could indicate this "ancient" tissue does not use cadherin/catenin adhesion mechanisms. To further test the role of beta− catenin in sponges, we will use Co−IP to identify binding partners of beta−catenin; Chip−sequencing to identify target genes that are regulated by the beta−catenin/TCF transcriptional complex; and develop techniques for studying gene function *in vivo* in sponges, so we can silence or overexpress beta−catenin *in vivo*.

P3.110 SCHIRMER , A.; FEGLEY, S.R.; SMITH III, J.P.S.*; IMS, Univ. of North Carolina, Winthrop Univ Rock Hill SC; *smithj@winthrop.edu*

A Comparison of Modern versus Historical Patterns of Meiofaunal Community Structure and Sediment Composition in an Exposed Beach

Nourishing exposed beaches with dredged sediment is a widespread practice globally to combat sea level rise. Because nourished beaches continue to experience erosion, an inevitable consequence of nourishment is a coarsening of the beach sediments and a change to the vertical sediment structure. Although the roles meiofauna play in exposed beach trophic dynamics is unclear, we know from studies conducted in low−energy environments that changes in sediment composition affect meiofaunal community structure. Such changes in community composition may alter any functional roles of the meiofauna in the habitat. The wide spread use of nourishing has left few undisturbed exposed beaches where we can compare faunal structure between nourished and unnourished habitats. This study uses an historical comparison of meiofauna community and sediment composition to reveal pre−nourishment (1969) and post nourishment (2013) conditions. Analysis of meiofauna densities and sediment composition revealed several statistically significant differences between the historical and present data with increases in harpacticoid individuals, an increase in median grain size, and a decrease in silt/clay content. Data were collected about the depth of a primary shell hash layer across sampling site. Laboratory trials also revealed alterations in water flow through sediment with the addition of shell hash. Findings indicate there is an impact of beach nourishment on sediment composition and sediment composition impacts the meiofauna community.

110.1 SCHMIDT, EM*; PFENNIG, KS; UNC−Chapel Hill; *schmide@live.unc.edu*

A behavioral syndrome in the house cricket (Acheta domesticus) varies across ontogeny

Behavioral syndromes, or "animal personalities," are correlations between one or more behavioral traits in a population. Although many studies have demonstrated the presence of behavioral syndromes in a variety of species, relatively few have examined the development of a behavioral syndrome. We measured boldness, exploration, and sociability in house crickets at different stages in development to determine a) whether there is a behavioral syndrome linking two or more of these traits in this species and b) if so, whether this syndrome varies across ontogeny. We found a behavioral syndrome linking boldness and exploration in both male and female house crickets; that is, bolder crickets were also more exploratory. However, we found this correlation only in subadult and adult crickets, and NOT in juvenile crickets. Our results suggest that a boldness−exploration behavioral syndrome emerges later in development in house crickets.

P3.8 SCHNEIDER, KR; FEDORKA, K*; BAHR, D; BURKETT, S; LUSTH, J; PRESSLEY, S; VANBENNEKOM, N; University of Central Florida, Univesity of Central Florida , Purdue University, University of Alabama, Washington State University; *krs@ucf.edu*

Tools for Launching Undergraduates into Research: Pre−Research Coursework in the Sciences

There are many benefits to getting students involved in research early in their career. However, first− and second−year students are often unaware of the research process and have no experience interacting with faculty, especially at large institutions. Three different one−credit course models devoted to preparing science and engineering students for successful research endeavors are currently offered at three institutions. Goals of this work include (1) involving students early in their academic career so they can gain the most out of subsequent research experiences, and (2) providing basic skills to make the transition into the research environment easier. These pre−research course models include a semester long seminar, a one−week faculty led "boot camp," and an intense three−day peer mentor led course. These models have been implemented at each institution several times with instructors from life science and engineering backgrounds. The multi−university team has prepared a set of best practices from their experiences while evaluating the pros and cons associated with each format. A pre− and post−test has been developed to help with the evaluation of the project. Initial results show similar gains in conceptual awareness between each course format and at each institution. This suggests that the educational models may be transferrable and easily adopted. Focus group discussions indicate that students are pleased with the programs and consider them useful, especially for students preparing to conduct research. Additionally, survey data indicates that students completing the program have a high placement into research experiences within one−year of completing the course. Since 2011, over 500 science and engineering pre−research students have completed the courses (33% in the life sciences), and a web site has been developed to disseminate information.

P2.38 SCHOENLE, L.A.*; GONG, S.; DUDEK, A.; ROCHELEAU, L.; VAN TOL, A.; WEINSTEIN, N.M.; MOORE, I.T.; BONIER, F.; Virginia Tech, Queen's University; *schoenle@vt.edu*

The relationship between corticosterone and haemosporidian parasites: are stress hormones key to tolerating infection?

Individuals vary in their responses to parasite infection, yet we do not understand what drives these differences, nor the proximate mechanisms that underlie them. When confronted with a pathogen, an individual can respond in part by tolerating infection − attempting to minimize damage and maintain normal function. Glucocorticoids are highly conserved steroid hormones involved in regulating responses to energetic demands and environmental challenges, including infection. Thus, these hormones might influence individual variation in tolerance of infection. We investigated the relationship between corticosterone, the primary glucocorticoid in birds, and tolerance to avian haemosporidian parasites in free−living male red−winged blackbirds (*Agelaius phoeniceus*). More than 90% of individuals in the study population experience infection with haemosporidian parasites, and individuals display substantial variation in a metric of disease tolerance (hematocrit for a given parasitemia). Males with higher corticosterone were more tolerant to haemosporidian infections than those with lower corticosterone. To establish whether or not the relationship between corticosterone and tolerance is causal, we experimentally elevated corticosterone in captive individuals and measured the resulting changes in tolerance and parasitemia. Our results provide support for a potentially adaptive role for corticosterone in mediating the response of a host to parasitic infection. When corticosterone is elevated in response to challenging environmental conditions, tolerance might be a strategy that reduces the costs of infection.

71.4 SCHRAM, J.B.*; AMSLER, M.O; AMSLER, C.D.; SCHOENROCK, K.M.; MCCLINTOCK, J.B.; ANGUS, R.A.; Univ. of Alabama at Birmingham; *jbschram@uab.edu*

Glimpses of assemblage resilience through an Antarctic ocean acidification mesocosm experiment

Anthropogenic atmospheric pCO$_2$ concentrations are increasing at unprecedented rates, resulting in declining seawater pH (ocean acidification − OA). Estimates of the global mean seawater pH indicate that pH has already decreased by 0.1 units, and is predicted to continue to decrease by another 0.4 pH units by 2100. The majority of OA research to date has focused on the effects of OA in single species experiments. To assess how OA may influence natural macroalgal−mesograzer assemblages we conducted a mesocosm experiment with a common chemically defended Antarctic brown macroalga, *Desmarestia menziesii*, seeded with natural densities of a *D. menziesii*−associated mesograzer assemblage, generally dominated by amphipods. We exposed these assemblages to three levels of pH representing present−day (pH 8.1), near future−2100 (pH 7.7) and more distant future (pH 7.3) conditions. Following a four−week exposure period, all mesograzers were collected from each mesocosm and preserved for identification. We found a modest but significant decrease in the percent species abundance in the lowest pH treatment (pH 7.3) compared to the other two pH treatments, but no significant differences between pH treatments for two standard measures of species diversity. These results suggest that benthic macroalgal−mesograzer assemblages of the WAP are likely to be resilient to near future decreases in seawater pH. This project was supported by NSF award ANT−1041022 (CDA, JBM, RAA).

P2.42 SCHREY, AW; MARTIN, LB*; Armstrong Atlantic State University, University of South Florida; *lbmartin@usf.edu*

DNA Sequence Variation in the Toll−Like Receptor 4 Gene Among House Sparrow Populations

Invasive species face several challenges when colonizing new areas, one of which is responding to novel pathogens. Toll−like receptors (TLR) are active in the innate immune response and might influence the spread of host species to new areas. Previously we showed that expression of two TLRs, TLR−2 and TLR−4, were related to range expansion in the house sparrow (*Passer domesticus*) colonizing Kenya. In the present study, we asked whether DNA sequence evolution was also related to range expansion in this species. We collected DNA sequence from a functional portion of the TLR−4 (exon 3) from 10 geographic locations across the global range. We divided locations into 3 categories: native, introduced/established, and recently introduced. Preliminary analyses identified 46 variable sites, including 27 single nucleotide polymorphisms, within 596 base pairs of TLR−4 sequence. There was a slight decrease in TLR−4 sequence diversity in more recently introduced populations, notably so in Kenya. Further, phylogenetic analysis detected two main clusters of individuals. The first cluster had the highest support and grouped all individuals from Kenya and two South Africa sequences. The second grouped individuals from Brazil; the remaining individuals formed a poorly supported collection of sequences. As these results and results from previous research suggest, variation in TLR−4 (sequence and expression) appear important to the success of the house sparrow as an invasive species. However, house sparrows from one of the most recent invasions, Kenya, are exceptional, as they still show the characteristics of ongoing range expansion. To capitalize on these findings, we recently have begun a next−generation sequencing based investigation of TLR−4 sequence variation among Kenyan house sparrow populations.

P1.124 SCHROEDER, R.J.*; SHANKAR, A.; POWERS, D.R.; CANEPA, J.R.; GRAHAM, C.H.; George Fox Univ., Newberg, OR, Stony Brook Univ., Stony Brook, NY; *rschroeder11@georgefox.edu*

Does High Nighttime Temperature Reduce the Energetic Value of Torpor in Hummingbirds?

Hummingbirds have a high daily energy requirement that makes energy storage difficult and balancing their energy budget daily a necessity. When daily energy intake falls below demand, hummingbirds can use torpor (nocturnal hypothermia) to balance their energy budget by reducing nighttime energy expenditure. Broad−billed Hummingbirds (Cynanthus latirostris) in SE Arizona used torpor less frequently when nighttime temperatures were well above (~8 °C) their minimum body temperature, suggesting that higher nighttime Ta might reduce the energetic benefit of torpor use. We tested the broad impact of higher nighttime temperature on torpor use by measuring torpor frequency in several hummingbirds at two mid−elevation sites on the western slope of the Andes Mountains in Ecuador during Summer 2014. We studied a combined 5 species at our lower elevation (1300m; mean nighttime T_a=23.4°C) and higher elevation (1900m; mean nighttime T_a=20.9°C) sites. We studied 3 species each at our low and high elevation sites. Throughout the study the difference between minimum and maximum nighttime Ta did not exceed 4−6°C at both sites. Torpor was observed in 5 of 8 (63%) hummingbirds at low elevation, and 3 of 12 (25%) hummingbirds at high elevation. Since torpor was used more frequently at the warmer of the two sites it is unlikely that temperature influenced torpor use in these tropical habitats. Instead, there may be taxonomic differences between species, or differences in energy demands between sites. It is also possible that tropical hummingbirds, which are generally resident, might be physiologically adapted to maximize energetic benefit from relatively shallow hypothermia.

109.6 SCHULTZ, E.M.*; KLASING, K.C.; HAHN, T.P.; Univ. of California, Davis; *emschultz@ucdavis.edu*

Effects of photoperiod and food availability on regulation of innate immunity in Red Crossbills

An organism's investment in costly physiological processes such as immune function is often variable and fluctuates in response to environmental and physiological changes in order to maximize fitness. The red crossbill *Loxia curvirostra* is a reproductively flexible songbird that times reproduction to coincide with booms in conifer seed abundance, an erratically available food resource. Consequently, environmental factors can have strong effects on crossbill physiological investment patterns across the annual cycle. Data from free−living crossbills have demonstrated that, like many vertebrates, investment in immunity varies by season and food abundance and ambient temperature likely contribute significantly to these patterns. However, it is difficult to disentangle the effects of food availability and temperature from photoperiodic changes in the field samples. To overcome this limitation, we examined how changes in photoperiod and food availability affect investment in innate immunity and the acute phase response in captive crossbills. Birds were separated into four treatments and exposed to long or short day lengths (16L: 8D; 8L:16D, respectively) for six weeks before continuing on an ad−libitum diet or experiencing a 20% food reduction for 10 days. Additionally, we induced an acute phase response in all birds both prior to and post diet change. Innate immune function was measured throughout the experiment to assess baseline levels, effects of photoperiod alone, and the possible interaction of photoperiod and food availability via hemolysis−hemagglutination, haptoglobin and microbial killing assays as well as utilizing differential white blood cell counts. Photoperiod and food treatment effects on immunity will be analyzed using GLMMs and AICc to assess weight and fit of all models.

P1.145 SCHULZ, H.M.*; PITTS, N.L.; MYKLES, D.L.; Colorado State University, Fort Collins , Colorado State University, Fort Collins; *hmschulz@rams.colostate.edu*

Expression of molt inhibiting hormone, mTOR, and NO signaling genes in the land crab, Gecarcinus lateralis

In decapod crustaceans, molting is negatively regulated by the release of molt−inhibiting hormone (MIH) from the X−organ (XO)/sinus gland (SG) complex in the eyestalk ganglia (ESG). The mechanisms controlling MIH synthesis and release in the ESG are poorly understood. MIH expression is relatively constant over the molt cycle, suggesting that MIH is regulated posttranscriptionally. As mTOR controls protein synthesis and nitric oxide (NO) is a neuromodulator, expression of mTOR (mTOR, S6K, Rheb, and Akt) and NO (NO synthase − NOS and guanylyl cyclase − GC) signaling genes were quantified over the molt cycle using qPCR. Animals were induced to molt by multiple leg autotomy and ESG were harvested from intermolt, premolt, postmolt, and blocked animals. There were no significant changes in NOS and NO−dependent or independent (GC−II and −III) GC mRNA levels over the molt cycle. Molting also had no effect on mTOR, S6K, Rheb, and Akt mRNA levels. However, expression of all genes, except Akt and GC−III, was significantly different between blocked and molting animals, suggesting that these signaling pathways are involved with molt induction. ESG is the primary source of MIH. However, other tissues, such as brain, thoracic ganglion, and limb regenerates may also express MIH. In *Carcinus maenas*, MIH is expressed in brain and thoracic ganglion and MIH mRNA is detected in *Uca pugilator* limb regenerates. Expression of MIH will be examined in *G. laterals* brain, thoracic ganglion, and limb regenerates. Supported by NSF (IOS−1257732).

P1.43 SCHULZE, A.; Texas A and M University at Galveston; *schulzea@tamug.edu*

COI sequencing in marine annelids: where do we stand?

DNA sequencing of the mitochondrial cytochrome c oxidase subunit I (COI) gene and other mitochondrial markers has long been a preferred method for molecular species identification ("DNA barcoding"), detection of cryptic speciation, phylogenetic analysis of closely related species, phylogeography and population genetics in a variety of taxa, including annelids. The recent trend for utilizing genome or transcriptome−wide data in many of these fields makes COI sequencing appear obsolete. However, while the costs of high−throughput sequencing are continuously decreasing, the techniques are still out of reach for many researchers due to processing costs, lack of access to instrumentation and significant analytical and bioinformatic challenges. Cases from marine annelids are presented that demonstrate that the comparatively straightforward sequencing of individual mitochondrial genes can still yield meaningful results, especially when used in combination with nuclear markers or with morphological or developmental data. The current and future potential and the limitations of the approach are discussed in the context of annelids.

P3.65 SCHUMACHER, M.K.*; JULIANO, S.A.; Illinois State University; *mkschum@ilstu.edu*

The reproductive cost of fighting an infection: an examination of Life History Theory in the mosquito

Investment in life history traits such as immune function, reproduction, and soma maintenance is determined by limited available resources, resulting in trade−offs within these traits to maximize lifetime fitness of an individual. One consequence of this is a cost of immune defense: wherein an upregulated immune response to combat an infection may further restrict energy investment into reproductive efforts and reduce reproductive success. Pathogenic infections may produce lesions or deficiencies that affect mating performance, or deprive the individual of energy necessary for high levels of exertion, metabolism, and locomotion necessary for male courting, thus reducing mating success. Alternatively, the Terminal Investment Hypothesis suggests that an infected individual may enhance energy investment in reproductive efforts to maximize terminal reproductive success in response to the survival threat inherent to infection. In the latter case, females are predicted to prefer mating with infected males, preferring dishonest epigamic signals despite the male's lack of immunological resistance (being infected by a pathogen). To determine whether infected males will display honest or dishonest reproductive signaling, binary−choice mating trials were conducted with an *Aedes aegypti* female and 2 males: a control (unmanipulated), and an immune−stimulated male (either infected with *Escherichia coli*, heat killed *E. coli*, or sham injected with saline). Male and female reproductive success and survivorship were monitored to determine fitness differences between treatments. Immune defense was measured 48 hours post−infection to compare immune responses between treatments. The outcome of this study may be important in understanding current population control efforts, especially those that that act to interfere with reproduction.

P1.109 SCHUPPE, ER*; SOLOMON−LANE, TK; PRADHAN, DS; THONKULPITAK, K; WILLIAMS, MM; THOMAS, A; LOCKHART, C; MILLIKIN, A; GROBER, MS; Georgia State Univ., Atlanta, Agnes Scott College, Atlanta; *eschuppe1@student.gsu.edu*

Organization of Dimorphic Genitalia: New Insights into the Evolution of Sexual Plasticity

Early exposure to androgens is necessary to organize male phenotype, and inhibition of androgen signaling adversely affects external genital development. However, vertebrates that remain sexually plastic throughout adulthood require mechanisms to prevent early fixation of phenotype and induce adult changes. In *Lythrypnus dalli*, a highly social hermaphroditic fish, sex differences in genital morphology can be maintained in the absence of dimorphic levels of a potent fish androgen. Since a functional androgen receptor (AR) is critical to the masculinization of phenotype across all vertebrates, local differences in the AR may be one mechanism to maintain dimorphic genitalia in this species. To examine the necessity of AR in maintaining male−typical genitalia, nesting males were intraperitoneally injected with 50µg/g/day of flutamide (AR antagonist) or vehicle for five days. Compared to control animals, flutamide treated males showed significant de−masculinization of their genitalia. In a second study, we demonstrated that AR expression was low or absent in the epithelial layers and body of female genitalia but high throughout the male genitalia. Animals with ambiguous genitalia exhibited higher AR expression within the body of the papilla than males. Elevated levels of AR in this region of ambiguous animals may be characteristic of multipotentiality, allowing for genital morphogenesis in either direction. In a species that remains inert to sexual canalization, our data suggest that regional differences in AR expression mediate important phenotypic differences.

108.1 SCHWAB, DB*; RIGGS, HE; MOCZEK, AP; Indiana University Bloomington; *schwabd@indiana.edu*

Symbiotic interactions influence development and survival in the dung beetle, Onthophagus gazella

Host−symbiont interactions are a ubiquitous component of animal biology. However, the developmental and ecological relevance of these interactions, as well as their role in evolutionary diversification, has only recently become the subject of intensive investigation. Here we explore the contribution of symbiotic microorganisms to development and survival in the dung beetle, *Onthophagus gazella*. *Onthophagus* beetles feed exclusively on nutrient−poor dung, and are thought to rely on a unique microbial community, or microbiome, to digest dung during larval development. Although it is unclear exactly how this microbiome is assembled, recent work has demonstrated that the *Onthophagus* microbiome can be vertically transmitted through the dung ball in which larvae develop to adulthood. In order to assess the functional relevance of the microbiome, we reared larvae under (a) sterile or non−sterile conditions, and replicated this approach for (b) both low and high levels of a relevant ecological stressor. We assessed the effect of these manipulations on growth, rate of development, and survival to adulthood. We find that under low stress conditions, sterile reared larvae exhibit significantly reduced adult size and take longer to develop to adulthood than non−sterile reared larvae. Under high stress conditions, we additionally recover a strong effect on larval mortality: only a subset of non−sterile, but none of the sterile reared larvae, survive to adulthood. Lastly, we report the effects of inoculating sterile reared beetles with culture−derived members of the vertically transmitted microbiome. Combined, these results demonstrate that microbial symbioses are a critical component of the *O. gazella* developmental environment, and may adaptively buffer development, in particular under stressful environmental conditions.

P3.172 SCHWAB, DB*; MOCZEK, AP; Indiana University Bloomington; *schwabd@indiana.edu*

The role of nutrient stress in resource allocation during ontogeny in two species of horned beetles

The elaboration of exaggerated, sexually selected weapons and ornaments often comes at a cost to other traits. For example, by sustaining the growth of an exaggerated weapon, resources may become depleted and limit the size to which other structures can grow. Such interactions are known as resource allocation trade−offs, and have the potential to constrain the production of phenotypic variation and bias evolutionary trajectories. Across many species of *Onthophagus* beetles, males produce extravagant horns of various sizes and shapes which are used as weapons in male competition over mates. Previous studies have reported resource allocation trade−offs between these horns and both proximally− (i.e. antennae, eyes, wings) and distally−located (i.e. genitalia) structures. However, more recent studies have largely failed to recover these patterns, leading to the hypothesis that trade−offs may manifest only in certain species, populations, or under particular (e.g. stressful) environmental conditions. In order to test this hypothesis, we investigate (a) patterns of resource allocation into horns, eyes, and genitalia in *O. gazella* and *O. taurus*, two species that differ markedly in the average degree of investment into horns. We then assess (b) how these patterns of resource allocation are influenced by nutrient limitation during larval development. Specifically, we test the hypotheses that stressful conditions facilitate the emergence of resource allocation trade−offs, and that this should be most pronounced in species that invest disproportionately into secondary sexual traits. We present our most recent results and discuss their implications for morphological evolution and diversification.

4.2 SCHWALBE, MAB*; BODEN, AL; WISE, TN; TYTELL, ED; Tufts University; *margot.schwalbe@tufts.edu*

Neuromuscular control of rapid linear accelerations in the bluegill sunfish

The bodies of many fishes are very flexible. Flexible bodies may allow them to store and release elastic energy during steady swimming, but they also must accelerate and turn rapidly, behaviors for which a stiffer, stronger body would be better. Clearly fishes are capable of both types of behaviors; how do they balance these conflicting locomotor demands? One strategy fish may use to accelerate more efficiently is to contract muscles on both sides of their bodies to increase their relative stiffness. To determine the muscle activity during impulsive swimming, we implanted bipolar electromyographic electrodes in the superficial red axial muscle of bluegill sunfish (*Lepomis macrochirus*) and recorded muscle activation during linear accelerations and steady swimming between 0.5−3.0 body lengths/s. In addition, we used a new digital accelerometer that measures three−dimensional acceleration and rotational velocity to quantify the acceleration and 3D orientation of a fish's body. Linear accelerations resulted in higher amplitude rotations: fish moved their heads from side to side more and increased their tailbeat amplitude when accelerating forward compared to that during steady swimming. Duty cycles (percentage of strain cycle period) increased with swimming velocity. The timing of muscle activity relative to body motion will be discussed. By shifting the timing of muscle activation, fishes with flexible bodies can potentially control their effective body stiffness and enhance the efficiency of both steady and impulsive swimming.

P3.137 SCHWARTZ, N.S.*; HORNER, A.M.; BRAUN, P.T.; BONDS, B; MORRIS, M.R.; Cal State Univesity San Bernardino, Ohio University; *nicolas_schwartz@aol.com*

The Effect of Diet Quality on Xiphophorus Escape Response

A fundamental assumption of the theory of sexual selection is that sexually selected traits increase reproductive fitness. However, these traits may incur a survival cost; for example, in mosquitofish C−start escape performance improves with body size but is negatively correlated with gonopodium length. Among swordtail fishes, both the length of the sword (if present) and body size are sexually selected traits in males a reduction in adult size would potentially incur both decreased mating success, and a reduction in C−start performance. Here we examined the effects of diet (high protein, HQ, vs. low protein, LQ) on body size and C−start performances in three types of swordtail fish, *Xiphophorus variatus* (no swords) and two genetically distinct size classes within the genetically polymorphic *X. multilineatus*. To quantify escape performance we measured whole−body (relative to starting position) and relative (within−fish) maximum turn angles, turn rates, time to maximum body angles, and the total displacement of the center of mass. LQ diet fish mass in all three groups was significantly less than HQ counterparts. We found effects of diet only in relative maximum turn angle and turn rate, with LQ fish achieving greater turn angles and rates. However, when controlling for the effects of length only the relative maximum turn angle was significantly impacted by diet. Our results are somewhat surprising given the substantial differences in mass observed in these fish, and given that size seems to be a good predictor of escape performance in other fishes. For swordtails, smaller size due to a poor quality diet in the wild is likely to be detrimental to reproductive fitness, but perhaps less so to survivorship.

50.6 SCHWEIKERT, LE*; GRACE, MS; FASICK, JI; Florida Institute of Technology, University of South Florida, St. Petersburg; *lschweikert2011@my.fit.edu*

A Whale of a Tale: Intact Cone Signaling Pathways Found in the First Mammalian Rod Monochromat

A central tenet of retinal neurobiology holds that the "duplex" mammalian retina functionally requires both rod and cone photoreceptors. The implications of cone photoreceptor loss on the mammalian retina is completely unknown outside of retinal disease and induced mutations in model organisms, but the recent observation of cone opsin mutation in some cetacean lineages provides a novel opportunity to investigate the effects of a natural, photoreceptor−specific mutation on retinal organization. We sequenced right whale (Eubalaena glacialis) cDNA derived from cone opsin mRNA and found an early nonsense mutation of their single cone opsin gene, suggesting loss of cone cell function but maintenance of non−photosensitive, opsin mRNA−expressing cells in the retina (i.e., cone soma). Therefore, we investigated the Balaenid whale retina to determine how the unprecedented loss of an entire photoreceptor class affects light signaling pathways. Anti−opsin immunofluorescence demonstrated the total loss of cone opsin expression in the bowhead whale (Balaena mysticetus), while light microscopy, transmission electron microscopy and bipolar cell immunofluorescence (against PKC−± and recoverin) revealed the loss of cone photoreceptor outer segments but maintenance of both rod and cone bipolar cell types. These findings demonstrate for the first time a naturally rod−monochromatic retina in mammals and suggest that despite the loss of cone−mediated photoreception, the associated cone signaling machinery may be functionally maintained for multi−channel rod−based signaling in Balaenid whales.

P3.202 SCOTT, B.*; WILGA, C.; University of Rhode Island; *bradley_scott@my.uri.edu*

Bamboo shark as an extant analogue for locomotion of a primitive agnathan based on morphology

Osteostraci are the extinct jawless sister group to jawed vertebrates. As close relatives of early jawed vertebrates they share numerous characters, such as paired fins and an epicercal tail. Study of the functional morphology of this group has been restricted to qualitative discussion. Based on gross anatomical features, osteostracans have been proposed to have a benthic lifestyle. Study of the functional morphology of early vertebrates, such as osteostracans with contemporary benthic jawed vertebrates, will require suitable model organisms for the behaviours of interest. Dispersal, foraging ability, and escape responses of vertebrates are dependent on locomotor mode. The body and tail shape of a basal osteostracan, *Ateleaspis tessellata* is consistent with that of a modern benthic vertebrate and therefore might share similar locomotor mode. Here we suggest that some shark species represent suitable models for hypothesizing locomotion of osteostracans: they have similar body shape, an epicercal tail, and dorsal fins with a persistent shape and less control than ray−finned fishes. Here, the morphology of *Ateleaspis*, reconstructed from nearly complete specimens, is compared to four shark species including pelagic, demersal, and benthic taxa, to predict locomotor mode: dorsal fin position, heterocercal tail angle, aspect ratio of the tail, as well as the presence or absence of other anatomical features. *Ateleaspis* most closely resembles the benthic bamboo sharks, *Chiloscyllium plagiosum*, in aspect ratio, position of the first dorsal fin, and angle of the dorsal lobe of the tail and absence of a ventral lobe of the caudal fin. This is the first quantitative study of osteostracan functional morphology and locomotion.

P2.170 SEAMONE, S; Univ. of Calgary; *sseamone@ucalgary.ca*

Pectoral fin mechanics during escape responses in benthic stingrays

Fast−start behaviors are high−energy maneuvers and may provide valuable insight into anatomical design in animals. Benthic stingrays are a group of dorso−ventrally flattened animals that possess broad pectoral fins, pelvic fins and a whip−like caudal fin with minimal surface area. This unique anatomy, compared to more common caudal swimming fishes, greatly influences the mechanics of locomotion (punting, walking and rajiform swimming), however, little is known about how these fish perform fast−starts. We used high−speed video to investigate the mechanics of escape responses of Potamotrygon motoro, a freshwater stingray from the Amazon. Maneuvers were initiated by a prod, and captured by five cameras so that all points of the ray were visible during the response: four cameras filming along the horizontal separated by 90°, and one camera filming a dorsal view. In contrast to caudal swimming fishes, benthic stingrays appear very dependent on waves of bending in their pectoral fins for escape. Rays modulate direction and two−dimensional speed of waves, in addition to fin area involved in the response, which strongly influences escape trajectory, speed and acceleration. Modulation of pectoral fin movements enables escape in all two−dimensional directions. In result, benthic stingrays appear unique to caudal swimming fishes in anatomy and fast start performance.

63.4 SEARS, MW; Clemson University; *sears3@g.clemson.edu*

Thermal constraints on activity revisited: Can spatially−explicit estimates of activity predict growth rates of ectotherms?

As a null model, increased rates of activity should lead to increased rates of growth in ectotherms. A previous study in sagebrush lizards (*Sceloporus graciosus*) showed that, despite increasing potentials for activity, lizards at lower elevations grew more slowly. In that study, estimates of potential activity were spatially−implicit; yet, a recent model of behavioral thermoregulation suggests that the spatial heterogeneity of operative temperatures influences thermoregulatory performance and thus activity as much as temperature itself. Here, I use a spatially−explicit model of thermoregulation to predict potential activity for populations of sagebrush lizards along an elevational range. Dynamic thermal landscapes were created by coupling climatic and geospatial data with a biophysical model that predicts operative temperatures. An individual−based model of thermally−constrained animal movement was used to estimate potential activity and energetic expenditure in these landscapes. Further, a dynamic energy budget model was coupled with the individual based model to estimate potential growth for lizards across their lifetime. Here, I show that, although longer times are available for activity at lower elevation, spatial arrangements of microhabitats restrict activity and influence energetics leading to patterns of growth.

PLEN.1 SEBENS, Kenneth P; University of Washington, Seattle; *sebens@uw.edu*

Integrative and Comparative Ecology

The integrative and comparative theme runs through all areas comprising SICB, and is a hallmark of our approach to research. Ecologists have been almost forced to use this approach, given the complex nature of the systems they study. The Grand Challenges in Organismal Biology, which SICB helped to define over the past few years, focus on the interface between organisms and the environment, which can be investigated through research on physiology, behavior, mechanics, physics, genetics, and evolutionary biology, for example. These are all in some sense ecological studies, since the science of ecology is all about studying the organism in its environment, which then transitions to populations, communities and ecosystems as appropriate and interesting topics of research. Ecology is integrative, because it employs techniques and models from a variety of disciplines, and it is comparative because it seeks to find processes that structure biological communities, and that are common across disparate systems. Ecological studies integrate and compare across phyla, from microorganisms to animals and plants, at all size scales. Examples of comparative and integrative approaches are provided from several decades of research on energetics, population biology and community ecology in marine intertidal and subtidal habitats.

P3.149 SEGRETO, J.M.*; KIRCHHEFER, A.; HACKETT , E.E.; GUGLIELMO, C.G.; KOPP, G.A.; GURKA, R.; Coastal Carolina University, Western University; *jmsegret@g.coastal.edu*

Flow features in the near wake of freely flying European Starling, Western Sandpiper and American Robin

The interaction between turbulence and bird flight is presented using three types of birds: European Starling (*Sturnus vulgaris*), Western Sandpiper (*Calidris mauri*), and American Robin (*Turdus migratorius*) at The Advanced Facility for Avian Research, Western University, Ontario, Canada. The near wake of freely flying birds was measured using high speed, time−resolved, particle image velocimetry (PIV), simultaneously with imaging the wing kinematics, using high−speed cameras. The system samples the flow field continuously for 20 minutes, which enables us to capture the wake evolution over multiple flap cycles. The acquired PIV images were used to generate vector maps, which combined with the wings' kinematic images, enable the association of the near wake features with the wing configuration and bird's location in the wind tunnel. Time series of the vorticity fields have been expressed as composite wake plots, which depict segments of the wing beat cycle for various span−wise locations in the wake. The composite wake plots reveal various characteristics of the wake during the upstroke (US) and downstroke (DS) phase of the flapping as well as the transition between the US to DS and vice versa. In addition, some of the features presented are the result of stream−wise vortices interacting in the wake. Comparison between the near wake fields behind the three birds reveals remarkable similarity in their wake structure. We have identified over multiple wingbeat cycles the presence of what appears to be an inclined vortex ring, generated during the upper half of the wing beat cycle. The compositions of the measured vorticity fields provide a quantitative description of the vortex ring and other flow patterns.

P2.2 SEIBEL, B.A.; HOBBS, N−V.S.*; University of Rhode Island; *hamavos.niels@gmail.com*

An Oceanographer's Life for Me: An Undergraduate Course in Pelagic Ecology at Sea Aboard the R/V Endeavor.

A novel undergraduate marine biology course at the University of Rhode Island fully immersed students in the largest and least understood ecosystem on the planet − the pelagic realm. This intensive, primarily ship−based class brought a select group of undergraduate and graduate students to the deep waters off the continental shelf south of Rhode Island for a week aboard the 185' R/V *Endeavor*. While there are other field experiences available for undergraduates at URI and elsewhere in the country, there are few if any shipboard courses aboard ocean−going research vessels because of the expense and the limited availability of ship time for education. Given a rare funding opportunity through Rhode Island's *Endeavor* Program, this class afforded students exposure to a realm that undergraduates generally only study within the confines of a lecture hall. Likewise, hands−on experience with the standard tools and techniques of biological oceanography are not common in undergraduate courses. Using a one−of−a−kind Tucker trawl, students were exposed to the diversity of oceanic and deep−sea fauna, the likes of which few working oceanographers ever see, with bountiful samples that came up from as deep as 1800 meters. Additionally, some students were able to experience bluewater research diving as typically practiced by only a handful of researchers worldwide. Overall, students were exposed to invertebrate and vertebrate diversity, and relevant oceanic phenomena, such as diel vertical migration, depth donation and bioluminescence. Engaging in such immersive experiences not only greatly facilitates learning, but often proves life−changing for such fortunate students.

P2.128 SELF, K/A*; O'BRIEN, S; Radford University, Radford VA , Radford University, Radford VA; *kself4@radford.edu*

Exploring the synergistic effects of estrogen−mimicking endocrine disrupters on the physiology and behavior of Gambusia holbrooki

Endocrine disrupting chemicals (EDCs) are environmental chemicals that interfere with the normal function of the endocrine system. They are known to cause negative effects in hormone responsive target organs, tissues, and cells. Humans are exposed to EDC's in their everyday environment, especially through food packaging, food preservatives, and personal care products. Two EDC's that are commonly found are Bisphenol−A (BPA) and Butylated hydroxyanisole (BHA). BPA leaches into the food from the protective inner coating of canned foods and other food storage devices. BHA is found in food packaging as well as consumer and industrial animal feed to prevent rancidity. Both BPA and BHA are considered to be estrogenic mimicking chemicals. Previous studies have found that high amounts of external estrogen and estrogen like chemicals in a variety of organisms have resulted in morphological abnormalities and have been linked to early puberty, decreased sperm counts, sexual dysfunction, and higher relative frequencies of reproductive cancers (Jobling et al, 1995). Additionally, exposure to these EDCs may result in feministic behaviors in some species (Molina et al, 2011). Currently most EDCs have been tested on model organisms individually, however there is growing concern that humans and other organisms are exposed to a milieu of chemicals simultaneously. Our study examines the influence of BPA and BHA, both singularly and synergistically on the morphological and behavioral characteristics of the mosquitofish (Gambusia holbrooki). Using this ecologically relevant model, we begin to elucidate the physiological effects of living in a complex chemical exposome.

P3.160 SELLERS, KC*; DAVIS, JL; MONGALO, M; JACOBY, MJ; HOLLIDAY, CM; Univ. of Missouri, Univ. of Southern Indiana; *kcsty5@mail.missouri.edu*

Estimates of Three−Dimensional Cranial Joint Forces in the American Alligator

Vertebrate skulls are three−dimensionally complex structures in which muscles act about joints in complicated ways. The main components of jaw muscle, bite, and joint forces are usually oriented dorsoventrally during biting. However, the mediolateral and rostrocaudal components of forces may be equally important in cranial joints such as kinetic joints or flat−headed animals such as crocodilians. Historically, few studies have captured the three−dimensional relationships between muscle actions and joint forces during vertebrate feeding. Thus, an integrated understanding of the mechanical environment of the skull remains to be fully appreciated. Crocodilians have characteristically high bite forces, likely driven by muscles with significant mediolateral force components, mediated by a series of joints oriented in different axes. We developed three−dimensional, validated free body analyses of the American alligator to estimate bite forces and forces and pressures at key cranial joints including the jaw joint, mandibular symphysis, and pterygomandibular joint to better understand the ontogeny of joint forces within the head. We modeled anatomically accurate jaw muscles, segmented joint surface areas, and using a three−dimensional coordinate system we estimated joint forces and pressures in three canonical axes. This method allows researchers to estimate forces experienced by joints in any system for which muscular PCSA and attachment data are available. These methods will be employed to determine biomechanical patterns during the evolution of crocodyliforms and birds, which rely heavily on secondary articulations which likely experience substantial non−vertical joint forces during feeding behaviors.

P1.117 SENFT, R.A.*; FIRKE, M.; MEDDLE, S.L.; BAUGH, A.T.; Swarthmore College, Roslin Institute, University of Edinburgh; *rsenft1@swarthmore.edu*

Blood, brains and beyond: links between stress hormone receptor expression and plasma corticosterone dynamics in great tits (Parus major)

Despite considerable empirical and theoretical work on stress physiology in free−living animals, the relationships between stress hormone receptor densities in the brain and concentrations of circulating hormones in the blood are underexplored empirically. Testing these associations is important because the use of established field assays including dexamethasone− and ACTH−challenge are often assumed to provide a proxy estimate for the neural expression of the two types of hormone receptors: mineralocoritcoid (MR) and glucocorticoid receptors (GR). Here we tested these assumptions and quantitatively examined the relationships among the density and distribution of MR and GR and plasma concentrations of corticosterone (CORT). To do this we used a population of great tits (*Parus major*) housed individually in semi−natural outdoor enclosures that were characterized for individual differences in stress physiology and behavior. We measured initial and stress−induced CORT, as well as negative feedback (dexamethasone challenge) and adrenal sensitivity (ACTH challenge). Receptors were quantified using radioactive in situ hybridization. We explored these links in two regions of interest, the hippocampus and paraventricular nucleus, areas known to be involved in HPA regulation. Furthermore, we developed the first MR/GR distribution map for *P. major* based on sampling of multiple regions of the brain. By analyzing this blood−brain dataset, we were able to test a set of hypotheses about the relationships between the physiological dynamics of the HPA axis and patterns of neuroendocrine receptor expression.

1.2 SENNER, NR*; CONKLIN, JR; PIERSMA, T; University of Groningen; *n.r.senner@rug.nl*

Carry−Over Effects: Not All Trade−Offs are Created Equal

Inter−individual differences can arise during any stage of an individual's life and as a result of a variety of different processes. The identity and timing of those processes, however, ultimately dictate the ecological and evolutionary outcomes that they initiate. In recent years, increased ability to identify the causes and consequences of inter−individual differences has better enabled the identification of a number of general processes involved in their creation. Carry−over effects are among the more recently recognized of these processes, yet one of the most frequently cited. However, references to carry−over effects often conflate them with other processes especially those occurring during development that operate via fundamentally different mechanisms. This limits the proper identification of carry−over effects and constrains our ability to understand the evolutionary consequences of inter−individual differences. When redefined as a reversible process linking trade−offs between traits that affect future fitness, carry−over effects can be separated from other causes of inter−individual differences and applied to some long−standing problems in evolutionary ecology, such as understanding the trade−off between survival and reproduction. Carry−over effects thus represent a flexible process that can rapidly mediate an individual's response to its environment, affect a population's evolutionary trajectory, and potentially impact eco−evolutionary dynamics. As such, carry−over effects must be considered as distinct from other processes causing inter−individual differences and should be more fully integrated into theoretical frameworks connecting ecological and evolutionary processes.

84.1 SEVIGNY, J.L.*; THOMAS, W.K.; RAMSDELL, J.S.; SHARIFI, O.; GREWAL, S.S.; BAYSDORFER, C.; CURR, K.; MURRAY, J.A.; NEWCOMB, J.M.; New England College, University of New Hampshire, California State University, East Bay; *JSevigny_UG@nec.edu*

The mitochondrial genomes of the nudibranch mollusks, Melibe leonina and Tritonia diomedea, and their impact on gastropod phylogeny

The phylogenetic relationships among certain groups of gastropods have remained unresolved, especially in the diverse subclass Opishobranchia. There is a total of seventy mitochondrial genomes for gastropods published on GenBank, but the opisthobranch order Nudibranchia is not well represented. The mitochondrial genomes of the nudibranchs *Melibe leonina* and *Tritonia diomedea* have been sequenced as part of this study and both coded for the typical thirteen protein−coding genes, twenty two transfer RNAs, and two ribosomal RNAs seen in other species. *M. leonina* lacked a twelve−nucleotide deletion in the cytochrome oxidase 1 gene that is present in four other species of *Melibe*. For phylogenetic analysis, the thirteen protein−coding genes from the mitochondrial genomes of all gastropods, obtained from NCBI, were combined into a single data set. Two separate phylogenetic analyses were performed: one of the class Gastropoda and one of the subclass Opisthobranchia. Both Bayesian and maximum likelihood analyses resulted in similar tree topologies. In the Opisthobranchia, five distinct orders were distinguished as monophyletic (Anaspidea, Cephalaspidea, Notaspidea, Nudibranchia, Sacoglossa). In the Gastropoda, two of the three traditional subclasses, Opisthobranchia and Pulmonata, were seen as paraphyletic groups, whereas Prosobranchia was monophyletic. In contrast, the four more recently named gastropod clades − Vetigastropoda, Neritopsina, Caenogastropoda, and Heterobranchia − were all monophyletic, and thus appear to be better classifications for this diverse group.

S6.4 SEWALL, KB*; ANDERSON, RC; PETERS, S; NOWICKI, S; ROTH, T; Virginia Tech, Florida Atlantic, Duke, Duke, Franklin and Marshall ; *ksewall@vt.edu*

Social complexity as a driver of communication and cognition

The Social Intelligence Hypothesis posits that group living has driven the evolution of enhanced cognition necessary for navigating complex social environments. Specifically, high sociality has been associated with superior problem−solving and innovation in comparative studies across species. While large−scale evolutionary change can underlie enhanced cognition and perhaps also communication complexity, studies within species suggest that developmental processes and phenotypic flexibility (i.e., change within an individual's lifespan) can also contribute to cognitive abilities. Specifically, group size has been positively correlated with faster problem−solving within species. Social experience can enhance cognition and underlying brain function during an individual's lifetime by providing learning opportunities, or through mechanisms of environmental enrichment. We found that zebra finches reared in experimentally enlarged families, which could provide more complex social experiences to young birds, had superior inhibitory control compared to birds from smaller families. Given that inhibitory control is strongly predictive of problem−solving abilities, our findings suggest that group size could influence some general cognitive processes.

18.5 SHARABI, O.*; MANOR, R.; AFLALO, E.D.; WEIL, S.; SAGI, A.; Ben−Gurion University of the Negev, Beer−Sheva; *omrisha@post.bgu.ac.il*

In search of a receptor for the insulin−like androgenic hormone in crustaceans

In crustaceans, male sexual differentiation and maintenance of masculine properties are governed by an endocrine gland located in proximity to the gonopores, termed the androgenic gland. This gland exerts its function through an insulin−like androgenic gland hormone (IAG). Insulin−like peptides mediate their signaling through a superfamily of tyrosine−kinase receptors. While IAGs were found in many decapods, including in the prawn *Macrobracium rosenbergii*, an IAG receptor is yet to be identified. Using comprehensive transcript libraries, generated by next generation sequencing, we have identified few putative sequences for tyrosine kinase receptors. Two of the above showed high sequence similarity in their deduced protein to insulin−related receptors from other taxa and thus named *M. rosenbergii insulin receptors* (*Mr−IRs*). The genes were found to be expressed in several tissues and developmental stages. Ligand blot and phosphorylation assays suggested possible *in−vitro* interactions between Mr−IAG and Mr−IRs. Therefore, the role of Mr−IRs was studied by loss of function experiments through RNAi during the time frame of sexual differentiation. In the case of one of the transcripts, *Appendix masculinae*, a secondary male characteristic, was observed earlier in the *Mr−IR* silenced group concomitantly with AG hypertrophy and elevated levels of *Mr−IAG* transcript. Additionally, substantial amount of immature spermatids was observed in the distal *vas deference*. In light of the above, the involvement of insulin receptors in the regulation of sexual development and reproduction processes in crustaceans will be discussed.

P2.77 SHARMA, N*; LIWANAG, H E M; Adelphi University; *nehasharma@mail.adelphi.edu*

Effects of Submergence on the Thermal Function of Pinniped Fur

Pinnipeds are a group of marine mammals with three extant families: Otariidae, which includes fur seals and sea lions; Phocidae, the true seals; and Odobenidae, the walrus. They are unique among marine mammals because of their amphibious lifestyle and the retention of two forms of insulation, fur and blubber. Fur and blubber thicknesses are variable among the pinniped groups: fur seals have dense, waterproof fur and a moderate blubber layer; sea lions have non−waterproof fur with a thicker blubber layer; phocids have thin, non−waterproof fur with very thick blubber; and walruses have almost no fur and the thickest blubber. Fur seal and sea lion pelts have a similar thermal conductivity in air, whereas phocid seal pelts have a higher conductivity and therefore reduced function in air. However, the thermal function of the pelt in water has never been quantitatively compared between groups. This study examined the effects of submergence on the thermal function of pinniped pelts by measuring the thermal conductivity and thermal resistance of otariid and phocid pelts in water. Under conditions of submergence, fur seal pelts (N=17) had the lowest thermal conductivity; sea lion (N=21) and phocid (N=9) pelts had significantly higher thermal conductivities ($P<0.001$). Taking fur thickness into account, fur seal pelts had the highest thermal resistance in water ($P<0.001$), whereas sea lion and phocid seal pelts had lower and nearly equal thermal resistance values. Although fur seal and sea lion pelts function similarly in air, the ability of the fur seal pelt to trap air while submerged makes it a superior insulator in water. In contrast, sea lions and phocids must depend on their blubber for insulation when submerged. Overall, this has implications for the evolutionary transition from fur to blubber in these groups, especially within the Otariidae.

98.2 SHARMA, PP*; FERNÁNDEZ, R; GONZÁLEZ SANTILLÁN, E; MONOD, L; American Museum of Natural History, Harvard University, Universidad Nacional Autónoma de México, Muséum d'histoire naturelle de la Ville de Genève; *psharma@amnh.org*

Phylogenomic resolution of scorpions reveals discordance with morphological phylogenetic signal

Scorpions represent an iconic lineage of arthropods historically renowned for their unique segmental architecture, ancient fossil record, and potency of their venom. Considered to exemplify morphological stasis, scorpions have paradoxically been shown to harbor the most genes among all Metazoa, with accompanying sub− or neofunctionalization of novel gene copies. Higher−level relationships of scorpions, based exclusively on morphology, remain virtually untested, and no multilocus molecular phylogeny has been deployed heretofore toward assessing the basal topology. We apply a phylogenomic assessment to resolve scorpion phylogeny, for the first time sampling extensive molecular sequence data from all superfamilies, and examining basal relationships with up to 5,025 genes. Analyses of concatenated supermatrices as well as species tree approaches converge upon a basal topology of scorpions, and unanimously support a single origin of katoikogenic development, a form of parental investment wherein embryos are nurtured by connections to the parent's digestive system. All analyses reject the monophyly of every superfamily with multiple constituent families; several families are also found to be non−monophyletic. These results suggest disutility of the few morphological character systems that are not prone to stasis in resolving higher−level relationships. Intriguingly, relationships based on the largest and sparsest supermatrix recover a topology in greater accord with traditional systematics. However, we demonstrate that support for this alternative topology is derived from non−randomly distributed missing data in sparsely sampled genes. Our findings are advocative of wholesale reevaluation of scorpion relationships grounded in molecular sequence data.

35.5 SHELDON, K.S.*; DILLON, M.E.; University of Wyoming; *kimberlyssheldon@gmail.com*

Beyond the mean: biological impacts of cryptic temperature change

Studies on the biotic impacts of climate warming have overwhelmingly focused on the potential impacts of shifts in mean temperatures. Though changes in mean temperatures correlate with shifts in, for example, phenology and geographic ranges, other "cryptic" changes in temperature may be equally important. Yet, these cryptic changes have received relatively little attention, in part because the organism−appropriate temperature metric is often elusive. As an alternative to defining arbitrary temperature metrics, we evaluated the biotic impacts of cryptic temperature changes by viewing organisms as physiological filters. Thus, we filtered global hourly temperature data through three classes of cryptic temperature effects: 1) non−linear thermal responses using thermal performance curves of insect fitness, 2) hysteresis of thermal effects using degree−day models for corn development, and 3) threshold temperature effects using critical thermal maxima and minima for diverse ectotherms. We then contrasted biotic impacts based on mean temperatures with estimates using hourly temperature data. We found that, using this physiological filter approach, mean temperatures can mask hidden, or "cryptic", changes in temperature and greatly alter predictions of the biotic impacts of climate change.

64.1 SHERIDAN, N.E.*; FAUTIN, D.G.; GARRETT, M.J.; Florida Fish and Wildlife Conservation Commission, University of Kansas; *Nancy.Sheridan@myfwc.com*

Implications for conservation of Condylactis gigantea, the giant Caribbean sea anemone, in Florida

The giant Caribbean sea anemone, *Condylactis gigantea,* is an ecologically important member of the benthic community. It provides habitat for numerous species and is recognized by many reef fishes as a cleaning station cue. Adverse environmental conditions, coupled with increasing harvest pressure, have resulted in declines of *C. gigantea*. Implementing efforts directed at population management and other protective measures for this anemone could conserve these valuable ecosystem services and ease pressure on the population. Previous research suggested that *C. gigantea* spawned in the late spring, which was questioned by the aquarium trade industry. We therefore examined specimens of *C. gigantea* collected monthly from October 2011 to September 2012 in the Florida Keys. We ascertained that the anemone is gonochoric and has a 1:1 sex ratio. Spermatogenesis was synchronous, whereas oocyte development was asynchronous. Low−level spawning occurred between October and April with a peak in May, in good agreement with earlier research.

27.1 SHERIFF, MJ*; CHABY, L; Penn State University; *mjs72@psu.edu*

The adaptive potential of adverse, stressful early−life conditions

The stress axis (hypothalamic−pituitary−adrenal axis) plays a central role in how vertebrates integrate environmental change and implement decisions on when to reproduce, grow, and allocate energy into storage. It allows animals to cope with change and challenges in the face of both certain and uncertain environments. Furthermore, the stress axis may play a central role in developmental plasticity, via prenatal exposure to maternally derived stress (MDS) hormones or via early post−natal exposure to stressors. Both situations are sensitive periods of development and exposure to stress hormones at these times can permanently alter an individual's physiology and behavior for life. Given the large contribution by the medical community to the literature, many of the phenotypic responses to early life stress (pre− or early post−natal) are viewed as unavoidable negative outcomes by the ecological community. However, the ecological and environmental contexts of such effects are often overlooked and thus the adaptive potential is largely underestimated. Here I will present emerging evidence across a variety of taxa that prenatal exposure to MDS can result in adaptive phenotypes in offspring. Further, I will present results from rats showing that exposure to chronic stress during adolescence has life−long effects, adaptively altering adult foraging behavior and performance. Critical to our understanding of these effects is the adaptive potential of these phenotypic responses for future environmental contexts: the greater the match between early and future conditions, the greater the adaptive potential of the offspring's phenotypic response.

98.1 SHERRATT, E.; ADAMS, D.C.; SERB, J.M.*; Iowa State University; *serb@iastate.edu*

Macroevolution, phylomorphospace and directional evolution in recessing scallops

Examining patterns of change in natural systems offers the opportunity to understand how biological diversity is both created and maintained. Bivalved scallops (Pectinidae) are a particularly good system to study evolutionary patterns of morphological change: they are a speciose clade, display an array of shell morphologies, are found in a wide range of habitats, and are broadly organized into five functional groups which vary in their level of mobility. Previous work has shown that scallops have strong convergent evolution in shell shape among unrelated long−distance swimming species. In this study, we characterized morphological patterns of shell shape in 121 species representing lineages from all functional groups to gain a more complete picture of the degree of morphological similarity among these groups. We combined morphological data on shell shape derived from landmark−based geometric morphometric methods with a phylomorphospace approach, a phylogenetic comparative method to infer evolutionary change along branches of a phylogeny. We evaluate the predictions that the scallop morphospace is partitioned according to shell morphologies defining the five functional groups. Our results find species of two of the five life−habits have evolved similar morphological shape from inhabiting similar environments at different geographic locations. We affirm convergent evolution of long−distance swimming among multiple lineages and find convergent evolution among species that are recessers (a burrowing behavior). Furthermore, our results find a striking trend of directional morphological evolution in one clade of recessers, along an axis that describes a progressively convex shell shape. We discuss these results in terms of the implications for understanding scallop biology and evolutionary history, and more broadly, in terms of evolutionary processes driving invertebrate diversity.

P2.197 SHERRY, R.S.*; WHITENACK, L.; Allegheny College; *sherryr@allegheny.edu*

Temperature Effects On Suction Feeding In Lepomis macrochirus : A Possible Independent Compensation Mechanism

As temperature is a controlling factor of physiological performance in ectotherms, it is important to examine possible mechanisms in compensating for varying temperatures. Bluegill sunfish *Lepomis macrochirus are fish native to North America that can experience water temperatures ranging from sub−0°C to above 30°C. This makes them model organisms for observing temperature change effects on physiological processes. The present study focuses on the effects of temperature on physiological processes that directly effect prey capture kinematics in bluegill. In this study we will compare the results of previous studies looking at Floridian bluegill and compare them to bluegill from northwestern Pennsylvania. We will look at times of kinematic feeding variables such as time of lower jaw depression, maximum gape, and jaw closure. Two treatment of eight fish will be exposed to environments of 18°C, 24°C, and 30°C while being filmed feeding at high speed. We expect that as temperatures decrease, kinematic times affecting prey capture will increase, and as temperatures increase, kinematic times will decrease. We also hypothesizes that in comparison, Q10 values of L. macrochirus from Pennsylvania will be lower than those of L. macrochirus from Florida, as the temperature fluctuations in Florida are not nearly as high as those in Pennsylvania. The results could show the implications of acclimation to an organism's environment, and show how organisms in an environment can be physiologically plastic.*

14.3 SHINE, CL*; HARMON, L; MCGOWAN, CP; University of Idaho; *shin0453@vandals.uidaho.edu*

Three−dimensional geometric morphometric analysis of functional morphology of plantigrade carnivorans.

Morphometrics have been used for decades to answer functional morphology questions, especially with regards to skeletal structures. Many studies used linear measurements, although landmark based geometric morphometric datasets are becoming more common. However, even with this approach, a large amount of variation is missed due to the complex three dimensional shape of a bone. Areas of great functional interest, e.g. articulation surfaces and muscle scars, are reduced to very few landmarks. Members of the order Carnivora have been extensively studied with regards to skeletal adaptations to locomotion. However, the majority of studies have neglected to address the foot posture of the species in question. Plantigrade species lack the specializations for cursoriality present in digitigrade animals, but this leads to many more adaptations for other modes of locomotion, such as swimming and digging. The forelimbs of species with this plantigrade posture are of special interest due to their increased dexterity and ability to manipulate objects. This study aims to identify and quantify the areas of forelimb long bones that characterize locomotor mode in plantigrade carnivorans using 3−D geometric morphometrics. Data were collected from the Museum of Comparative Zoology, Harvard University, the Idaho Museum of Natural History, Idaho State University, and the Charles R. Conner Museum, Washington State University. Three−dimensional laser surface scans were taken of the scapula, humerus, ulna and radius for one specimen of each of fifteen species. Preliminary analysis of results suggests that the 3−D approach of this study is capable of categorizing species with similar accuracy as 2−D analyses but is able to identify new areas of interest for comparative studies.

P3.151 SHOLTIS, KM*; SHELTON, RM; HEDRICK, TL; Univ. of North Carolina at Chapel Hill; *ksholtis@live.unc.edu*

The Flight Dynamics of Hummingbirds during Territory Encroachment and Defense

Hummingbirds are capable of extreme maneuverability and use this maneuverability to defend food resources from encroachment by conspecifics and other potential resource consumers. These competitive intraspecific interactions provide an opportunity to quantify the biomechanical aspects of hummingbird flight performance during ecologically relevant natural behavior. Here we used multi−camera videography to determine the three−dimensional flight trajectories of Ruby−throated Hummingbirds (*Archilochus colubris*) defending, being chased from and freely departing from a feeder and use these trajectories to compare natural flight performance to earlier laboratory measurements of maximum flight speed, flight force and power requirements. We found that the hummingbirds only rarely approached their maximum flight speeds from previously reported from wind tunnel tests and they never did so in level flight conditions, but rather used gravitational acceleration to boost flight speed. However, measures of acceleration and rates of change in kinetic and potential energy indicate that these hummingbirds likely operated near the maximum of their flight force and aerobic power capabilities. Finally, we found that although birds departing from the feeder while chased did so faster than freely−departing birds, they accomplished this by modulating their kinetic and potential energy gains (or losses) rather than increasing overall power output, trading altitude for speed during escape.

S9.11 SHTYLLA, Blerta; Pomona College; *shtyllab@pomona.edu*

Interdisciplinary team approaches to mathematical modeling in a liberal arts setting.

Continuous and targeted engagement of student teams with practitioners and community partners can help create an exciting framework for interdisciplinary mathematical biology inquiry. In this talk I will discuss our experiences teaching modeling through a series of active learning course modules and capstone team projects in a one semester advanced undergraduate modeling course In a small liberal arts college. Challenges in arranging cohesive student teams as well as embedding outside guest lectures and hands on lab and field activities will be discussed.

P3.68 SHUKLA, D*; WILCZYNSKI, W; Georgia State University, Atlanta,Georgia; *dshukla3@student.gsu.edu*
Differences in aggression levels in green anoles after acquisition of social rank
Under conditions of limited resources, a variety of animals including green anoles form dominance hierarchies. How the novel demands imposed by acquisition and maintenance of social status modulate behavioral responses in dominants and subordinates is not well understood. Upon pairing, anoles form stable dominant−subordinate dyads after an initial aggressive interaction. We investigated how dominants and subordinates differed in their respective levels of aggression to a simulated intruder following cohabitation in a stable dominance hierarchy. Size−matched male anoles were tested for aggression before and after acquisition of their respective social status. Individually housed males were administered a mirror aggression test for 30 minutes in their home cage to determine baseline aggression levels. Size−matched animals were then paired and allowed to form dominant−subordinate hierarchies. After 7 days of cohabitation, the animals were subjected to a mirror aggression test for 30 minutes. The aggression test was administered in the home cage of the focal animal while the dominant or subordinate half of the pair was removed during the test. Number of head−bobs and pushups displayed to the mirror image of the animals were quantified together as total aggressive events. Aggression was not different before pairing (P=0.13) but after a week of cohabitation, subordinates showed lower number of aggressive events as opposed to dominant animals (P=0.012). Both dominants (P=0.013) and subordinates (P=0.037) showed a decline in the number of aggressive responses after pairing in comparison to the number of responses displayed by these same animals when individually housed. In conclusion, subordinate animals showed significantly lower aggressive responses to a simulated intruder compared to dominant animals, and the difference was not due to preexisting tendencies.

P3.178 SHVIDKAYA, P*; SOLOMON−LANE, T.K.; THOMAS, A; WILLIAMS, M.M.; RHYNE, A; ROGERS, L; GROBER, MS; Georgia State Univ., Atlanta , Georgia State Univ., Atlanta, Agnes Scott College, Atlanta, Agnes Scott College, Atlanta, Roger Williams Univ., Bristol; *pshvidkaya1@student.gsu.edu*
Social regulation of juvenile sexual development in a sex changing fish, Lythrypnus dalli
In most vertebrates, sex is determined chromosomally; however, a number of teleosts rely exclusively on environmental cues. In the highly social, bi−directionally sex changing fish, *Lythrypnus dalli*, social status regulates sexual phenotype. While the control of adult sex change is well understood, this is the first investigation of sexual development and differentiation in juveniles. We first analyzed gonad and genital papilla morphology in wild−caught juveniles of different sizes and developmental stages. Second, we lab−reared juveniles together in social groups to test whether social status regulates sexual development, as in adults. Hematoxylin and eosin staining of the gonad revealed the presence of both sperm and egg in nearly all field−caught juveniles, demonstrating that the early gonad is bipotential and differentiates over time. Adult genital papilla morphology is a reliable indicator of gonadal sex, and most field−caught juveniles had either female−typical or ambiguous papillae. In lab social groups, juveniles formed a hierarchical social structure similar to adults. All dominant juveniles developed a male−typical papilla and a primarily male gonad, indicating social regulation of sexual development. On the reef, juveniles were observed in local social environments of varying complexities. The rarity of male juveniles in the field supports a primarily subordinate social role for juveniles. Together, these data demonstrate the fundamental importance of early−life social cues in regulating sexual development, which will have a long−term impact on fitness.

49.1 SILVA−MARIA, I.*; OLIVEIRA, M.I.B.; COSTA, O.T.F.; DUNCAN, W.L.P.; Federal University of Amazonas, Manaus − AM, Brazil; *mariaisa21silva@gmail.com*
Organ asymmetry: An analysis of correspondence between quantity and functionality in the reproductive organs of female freshwater stingrays (Potamotrygonidae: Elasmobranchii)
Freshwater stingrays possess a unique combination of the ovaries (OV) and epigonal organs (EPO) into a single ovary−epigonal mass (OEM) that demonstrates both morphological and physiological lateral asymmetry. We examined OEM and uteri (UT) of six species of potamotrygonids in order to quantify the volume of OV and EPO within the OEM, to describe OV histology and UT morphology during different reproductive stages, and to verify a possible correspondence of lateral asymmetry between OEM and UT. OEM and UT of all species were examined both macroscopically and microscopically. Stereological techniques were used to quantify volume in an unnamed Potamotrygon species ("cururu stingray"). All of the species examined demonstrated lateral OEM asymmetry. The left OEM of Potamotrygon sp. was ~55 times larger and contained more macroscopically visual ovarian follicles (averaging 4 per left OV vs. usually absent in the right). The right OEM was composed of 7.3% OV tissue and 92.7% EPO tissue by volume, whereas the left side was 51.2% OV and 48.8% EPO. Seven phases of follicular development were identified in the OV with different compositions of follicular stages in each side. UT were symmetrical and the fecundity ratio between the right and left sides was 0.9:1.1 (right:left). Despite the volumetric difference in OV between the two sides, UT fecundity suggests that both OV are functionally symmetric and that ovarian fecundity alone is not an accurate measure of reproductive potential.

8.5 SILVA−MARIA, I.; FINKLER, M.S.*; Federal Univ. of Amazonas, Manaus, Brazil, Indiana Univ. Kokomo, USA; *mfinkler@iuk.edu*
Patterns of resource consumption during embryonic development in the snapping turtle, Chelydra serpentina.
In order to assess differences in the efficiency by which snapping turtle embryos convert egg content into tissue at different intervals during development, we examined changes in the lipid, protein, and energy contents of snapping turtle eggs over the course of incubation at 29 °C. Total dry content (albumen and yolk) declined throughout incubation, with the rate of increase accelerating rapidly after Day 30 and corresponding with accelerated embryonic growth. Lipid and protein consumption demonstrated different patterns, with lipid content decreasing rapidly from Day 0 to Day 16, remained relatively constant between Day 16 to Day 40, then decreasing rapidly again after Day 40. In contrast, protein content remained relatively constant through Day 30 of incubation then rapidly declined after. The energy content of the eggs decreased parallel to the decrease in total dry content, with no significant change in energy density (kJ energy/g dry mass) over the course of incubation. The amount of dry embryo mass produced per unit egg content dry mass consumed decreased as development progressed, declining from 1.06 g/g between Days 16 and 30 to 0.64 g/g between Days 40 and 50. Our findings suggest a potential trade−off between accelerated growth rate and efficiency of resource usage during development.

P1.186 SILVERMAN, R. E.*; GIARRA, M.; GURSOY, D.; SOCHA, J. J. ; Virginia Tech, Argonne National Laboratory; *resilver@vt.edu*

Using TomoPy to reconstruct synchrotron micro−CT data from organisms

Three−dimensional imaging techniques can be extremely insightful for studying morphology. Classical methods such as histology have been essential tools for understanding interior structures, but these methods can deform tissues, potentially resulting in unrealistic 3D models. Synchrotron light sources use powerful x−rays to conduct non−invasive tomographic imaging of centimeter−sized samples with micron−scale resolution. Tomographic imaging works by capturing hundreds of projections of a sample at small angular increments over a 180 or 360 degree rotation. These projections can then be virtually reconstructed to create detailed image slices, which can be used to produce 3D models. Using modern high−speed cameras, a sample can be scanned extremely quickly (in seconds to minutes), producing large amounts of raw data that needs to be processed into a useful form. The tomographic reconstruction process has recently been offloaded to users via free software called TomoPy, a cross−platform and customizable Python program developed at Argonne National Laboratory. In TomoPy, multiple parameters can be varied for each reconstruction, which can lead to differences in image quality in the reconstructed slices and potentially to different interpretations of the data. There is currently no systematic guideline for choosing the correct parameters in TomoPy for biological or fossil data collected with specific beamline settings. Using systematic testing of the TomoPy software with our organismal data sets, we created general guidelines to allow users to more easily select suitable parameters to optimize reconstructed image quality. Overall, our aim is to provide user−friendly recommendations to help synchrotron users effectively process tomographic data using TomoPy, enabling the optimization of the reconstructed images that accurately reflect biological reality. Supported by NSF 0938047.

3.1 SILVESTRE, F*; DANIS, L; BAYAR, MA; DUBOIS, A; ADEYEMI, J; KLERKS, P; University of Namur, Osun State University, University of Louisiana, Lafayette; *frederic.silvestre@unamur.be*

Protein expression profiles in the least killifish, Heterandria formosa, exposed to copper during early life stage : can a stress proteome be inherited through generations ?

Nowadays, assessing the toxicity of chemicals in a single generation is no longer sufficient. One must take into consideration the possible inheritance of effects at the level of two or several generations. In the present study, we used the viviparous least killifish, *Heterandria formosa*, as a model species to test the hypothesis that an exposure to copper (Cu) in fish early life stage (ELS) can modify the protein expression profile in offspring. One week old least killifish were exposed to Cu at 15 ¼g/L for a period of one week, a condition inducing acclimation as previously reported using time−to−death endpoints. Fish were then held in clean water till breeding. After cytosolic protein extraction, their expression profile in 2 weeks old larvae was analyzed using 2D−DIGE followed by protein identification by nano−LC−ESI−MS/MS. A total of 50 protein spots have been differentially expressed in offspring whose parents have been exposed to Cu compared to offspring whose parents have never been exposed to this metal. After identification, these proteins have been categorized into diverse functional classes related to protein turnover, chaperoning, metabolic process, ion transport or oxidative stress. In conclusion, this study originally provides evidence that an exposure to a pollutant during ELS in a fish can affect the cellular phenotype in the offspring, assessed at the proteomic level. Ongoing researches will investigate the possible role played by epigenetics in this phenotypic inheritance and the adaptive and evolutionary consequences.

P2.95 SIMMONS, VA*; COUVILLON, PA; Univ. of Hawaii, Manoa; *simmonsv@hawaii.edu*

Oddity learning in honeybees (Apis mellifera) with geometric patterns

The results of recent studies with honeybees suggest that they are capable of learning relationships among colors and patterns. Relationship learning has been characterized in vertebrate species as abstract or conceptual learning. The traditional oddity problem was used here to investigate the discrimination of "same" and "different" geometric patterns. Free−flying bees were trained individually to visit a laboratory window for sucrose solution. In Experiment 1, honeybees were trained to discriminate the two patterns to be used in the oddity problem, black and white stripes and black and white concentric circles. For half of the bees, choice of stripes was correct and choice of circles was incorrect, and for the other half, the reverse. Correct choice was rewarded with sucrose and incorrect choice was punished with a stevia solution. The bees easily learned to discriminate the patterns and showed no preference for either. In Experiment 2, naïve honeybees were trained in the oddity task using the two patterns tested in Experiment 1. The bees were rewarded for choosing the odd stimulus from a set of three and punished for choosing either non−odd stimulus. Trials with two circle patterns and one stripe pattern were intermixed with trials with two stripe patterns and one circle pattern. Despite the difficulty of the problem, by the end of training, the bees chose the odd stimulus at a level greater than chance. This result suggests that they can learn to discriminate the "same" and "different" relationships in a set of three stimuli. It will be necessary in future studies to conduct a range of same−different discrimination problems with honeybees in order to understand the conditions that promote relational learning. It will be important as well to determine the conditions under which honeybees might use relational learning in foraging situations.

29.3 SIMMONS, M.D.*; MAHON, A.R.; Department of Biology, Central Michigan University, Institute for Great Lakes Research, Department of Biology, Central Michigan University ; *simmons.d.megan@gmail.com*

Genomic analyses of fish biodiversity along an invasive species gradient

Asian carp, specifically bighead (*Hypophthalmichthys nobilis*) and silver (*H. molitrix*) carp, have potentially begun entry into the Laurentian Great Lakes (LGL). With native aquatic communities at risk, additional invasion pathways outside of the Chicago Area Waterway System are a growing concern. Encompassing 20% of Ohio, the Muskingum River Watershed (MRW) is the largest watershed in the state. Considering the linkage of the Ohio River to Killbuck Creek and the Ohio−Erie Canal, the MRW is a possible invasion pathway for Asian carp into the LGL. The status of Asian carp in the watershed was determined using environmental DNA (eDNA) and digital droplet polymerase chain reaction technology (ddPCR). With positives found within the watershed, we attempted to understand the impacts of Asian carp invasion on fish assemblages using genomic technologies. To do this, we used high throughput sequencing to screen for all fish biodiversity in a number of reaches, from the impacted to the putative invasion front and beyond. The evaluation of fish community structure at each sample site within the MRW is helping to explain the changes occurring near Asian carp invasion fronts.

P1.184 SIMMS, M.H.V.*; PERLMAN, B.M.; ASHLEY−ROSS, M.A.; Wake Forest University; *perlbm0@wfu.edu*

Terrestrial habitat selection in the mangrove rivulus, Kryptolebias marmoratus

Kryptolebias marmoratus is a quasi−amphibious species living in upper intertidal zones of mangrove swamps that is able to survive outside of water for many hours, and on rare occasions, weeks at a time. *K. marmoratus* is often found living in burrows of land crabs and feeds on insects both in and out of the water. As vision in air versus water is necessarily different due to the change in refractive index of the medium, we asked what simple visual cues were used by *K. marmoratus* when moving on land. We hypothesized that the fish might prefer dark areas, or might prefer structures. A shallow kiddie pool was painted to have one quarter black, while the other three were painted white. The black quarter and one white quarter were left devoid of structures; the remaining sections had pieces of white and black PVC pipe, respectively, placed in them. The location of the structures was randomized from trial to trial. The pool was lined with wetted bench liner paper to prevent the fish from desiccating. Individuals (n = 13 fish; n = 4 trials per fish) were placed under a cup in the center of the kiddie pool, and a Kodak PlaySport camera was placed above the pool to record each two minute trial of the fish voluntarily moving around. Overall, *K. marmoratus* spent more time in the sections with the presence of a PVC pipe compared to the empty sections. Interestingly, specimens spent more time in the white empty section compared to the black empty section, which was opposite of our prediction. Fish spent more time in the sections with the white PVC pipe compared to the black PVC pipe. These results suggest that *K. marmoratus* is able to see in air with enough acuity that it is able to choose destinations containing potential hiding structures.

P3.123 SIMON, N.; LANDAU, M.*; Richard Stockton College of New Jersey, Galloway; *landaum@stockton.edu*

Categorizing Florida Coral Reefs Using Fish Assemblages

Reef fish assemblage is important in understanding fishery management. Fish survey data collected by the Reef Environmental Education Foundation was used with the following restrictions: (1) analysis limited to 26 reefs along the Florida Keys with a large number of "expert surveys", and (2) only "moderately common" fish species considered. Using several cluster analysis techniques, dendrograms were constructed; Ward's method, which is distinct from other methods because it uses an analysis of variance, gave the most distinct separation. Clusters were tested using discriminant analysis to "back−predict" a reef's cluster, using latitude, distance of a reef to the nearest neighbor reef, and shortest distance of a reef to one of the island chain Keys (an approximate index of depth). One significant factor was found; using that factor, 73% of the reefs would have been correctly classified if unknown. Additional physical characteristics might be used in the future to get even clearer partitioning.

S2.6 SINCLAIR, BJ*; BARTON, MG; MCFARLANE, ML; TERBLANCHE, JS; Western University, Stellenbosch University, Nature Conservancy of Canada; *bsincla7@uwo.ca*

What would happen if we used physiological tolerances to design protected areas? Implications of politics and climate change for conservation planning

Insects are small ectotherms with a high surface area:volume ratio, and as such are particularly vulnerable to the abiotic environment. Models based on thermal tolerances and water balance can therefore be used to predict potential distribution and response to climate change of insects of economic, health, and conservation significance. The rapid shifts in habitat distribution with climate change mean that conservation of current habitats in situ may not ensure long−term conservation of species and ecosystems. In many places, those shifts may lead to relevant habitat spanning political borders. Predictive mechanistic physiological modeling could identify species vulnerable to geographic range shifts with climate change, and predicting the distribution of suitable habitat in the future. Using hypothetical insects in Southern Africa as a model, we ask three questions: 1) Can we use mechanistic models based on thermal tolerances and water availability to identify current and future areas of significance for species conservation? 2) To what extent would it be possible to design reserves based on physiology that will protect insects in their current and future geographic ranges? and 3) What is the potential impact of shifts across political borders on the ability to identify and implement physiology−based reserve design? Our conclusions should be applicable to other small ectotherms (or species dependent on them), and also to other taxa, for example plants, whose distributions are primarily governed by abiotic variables. Our conclusions are also relevant at other spatial scales and geographical locations, particularly around the North American Great Lakes.

P2.78 SINGLETON, E.M.*; MCLELLAN, W.A.; KOOPMAN, H.N.; ALMEIDA, A.P.; PABST, D.A.; UNC Wilmington; *emn7070@uncw.edu*

Lipid composition and thermal properties of the blubber of Gervais' beaked whale, Mesoplodon europaeus

While most odontocete cetaceans store their blubber lipids as triacylglycerols, the deep diving kogiids, physeterids, and ziphiids store their lipids primarily as wax esters (WE). To date, the thermal properties of only one species (*Kogia breviceps*) with WE−rich blubber have been investigated (Bagge *et al.* 2012). Increased lipid content provides enhanced blubber insulation, and Bagge *et al.* (2012) provided the first data that increased WE content may also increase insulative value. We hypothesized that the blubber of ziphiids, which are the deepest recorded divers of all cetaceans, possess blubber with enhanced insulative properties, as compared to other cetacean species. We examined the composition of the WE−rich blubber of the ziphiid *Mesoplodon europaeus*. The blubber of adult *M. europaeus* (n=4) had a higher lipid (81.23±2.82% wet mass) and WE (99.33±0.40%) content than that of *K. breviceps* (56.64±1.73% wet mass lipid, 82.1±3.80% WE). Blubber's thermal properties were measured using a standard experimental setup (Dunkin *et al.* 2005, Bagge *et al.* 2012), and we present preliminary findings from two adult *M. europaeus* using the superficial heat flux disc method. The blubber of *M. europaeus* has conductivity (0.10−0.14 $Wm^{-1}°C^{-1}$) and conductance (2.95−3.60 $Wm^{-2}°C^{-1}$) values that are approximately half those reported for *K. breviceps* (Bagge *et al.* 2012). These results support those of Bagge *et al.* (2012) and suggest that both lipid content and lipid type influence blubber's thermal properties. It appears that the extremely deep diving ziphiids, which can maximally spend two to three times longer at depth than any other cetacean, possess a blubber layer with enhanced insulative capability to maintain body temperature against water temperature changes that occur while diving.

P2.100 SINKIEWICZ, DM*; WILCZYNSKI, W; Georgia State University; *dsinkiewicz1@gsu.edu*

Brain trainscriptome in the adult green treefrog, Hyla cinerea

The green treefrog, *Hyla cinerea*, is a unique model for studying vocal behavior. Having only one sex vocalize (male) allows us to identify traits that are specific to vocal production at a variety of levels. Furthermore, in this species, both calling and several aspects of auditory processing vary seasonally, and are sensitive to circulating hormone levels and social experience in addition to sex differences. We have begun to address what defines a vocal animal from the molecular and genetic level. In doing so we have produced a brain transcriptome. Transcriptome generation is a powerful diagnostic tool for understanding the role of gene expression in regulating behavior. The transcriptome for the treefrog brain was assembled from a total of 275 million bases and has an average contig length of 964 bases across 285,448 contigs. Prior to annotation contigs were BLASTed and reduced to those hits that returned with an E−value of 10−5 or less. A total of 90,000 contigs were processed through Blast2GO and 74,000 were successfully annotated. This transcriptome represents the entire adult brain of *H. cinerea* including both males and females. Additional assembly to identify gene expression patterns characterizing each sex and each of three major brain areas (forebrain, midbrain, and hindbrain) is in progress. This approach will enable us to target and measure specific genes relating to vocalization using both qPCR and in−situ hybridization. This work is supported by the GSU Brains & Behavior area of focus.

49.3 SIRMAN, AE*; AVERY, JP; DONOVIEL, Z; HOOD, WR; Auburn University, University of North Florida; *aubrey.sirman@my.ndsu.edu*

The effects of the developmental environment on reproductive effort and insulin−like growth factor 1 in the house mouse (Mus musculus)

The environment an individual experiences during development can have formative effects on physiology and as a result, impacts how energy is partitioned to key life history activities such as reproduction. Metabolic hormones, including insulin−like growth factor (IGF)−1, play a fundamental role determining how energy is allocated within the body and therefore are likely responsible for mediating these individual differences in pace of life. IGF−1 is responsive to diet and influences growth, reproduction and survival and therefore, may be an important mechanism by which the early environment impacts reproductive performance. We manipulated dietary protein intake in wild house mice (*Mus musculus*). Parents were maintained on a 10% low (L) or a 20% high protein diet (H). The F_1 offspring were then kept on the same diet or switched to the alternative diet at weaning, creating four treatment groups (HH, HL, LH, and LL). We predicted mice with the greatest reproductive effort (RE) would exhibit the greatest plasma IGF−1 concentrations. We observed no difference in RE among treatment groups. We measured plasma concentrations of IGF−1 in mice at weaning and at 1 year. At weaning, IGF−1 hormone concentrations similar between treatment groups (P=0.35). At one year and having the opportunity to mate for 8 months, mice in the HL treatment group had significantly greater concentrations of IGF−1 compared to the LH treatment group (p=0.04). Interestingly, circulating levels of IGF−1 were negatively correlated with reproductive effort (p=0.02). The results of this study suggest that RE is not influenced by maternal diet; however IGF−1 may still be important in matching RE to the current dietary conditions.

58.3 SKATES, D I*; OWERKOWICZ, T; EME, J; BLANK, J M; ELSEY, R M; HICKS, J W; California State University, San Bernardino, McMaster University, Hamilton, Canada, California State Polytechnic University, San Luis Obispo, Louisiana Department of Wildlife and Fisheries, Gran Chenier, University of California, Irvine; *skatd301@coyote.csusb.edu*

Locomotor exercise exerts no systemic effect on the dentary in the American alligator

Exercise appears to exert systemic effects on skeletal growth in mammals, causing increased bone deposition in skeletal elements not under direct mechanical loading. Such potential effects in non−mammalian vertebrates have not received much attention. We studied effects of locomotor regimen on the lower jaw histomorphometry in the American alligator (*Alligator mississipiensis*). Animals were assigned to one of three groups: sedentary, running, swimming (n=20 each), and exercised to exhaustion every other day for 18 months. Surgery was used to render the animals' circulatory system in−series (experimental n=24), or retain the original in−parallel design (sham n=36). Whole body growth of animals was tracked biweekly, with fluorescent dye injections used to quantify the mineral apposition rate (MAR). Periosteal MAR of the dentary correlated with both mass and linear growth at the lateral margin of the mandibular ramus, but not at the ventral margin. Exercise regimen and shunt ability had no effect on MAR at either site. This suggests that skeletal integrity of the feeding apparatus in crocodilians is not influenced by systemic effects of exercise. This may be of selective advantage in sit−and−wait predators, which rely on robust jaws despite long periods of inactivity. Similar experiments on modern birds are needed to discern whether non−avian dinosaurs showed systemic sensitivity to exercise. Supported by NSF IOB 0445680 to JWH.

85.1 SKIBIEL, A.L.*; HINDE, K.; Harvard University, Auburn University, Harvard University; *skibiam@auburn.edu*

Prolactin in mother's milk across lactation in a non−human primate model

Mother's milk contains numerous hormonal constituents but the magnitude, sources, and consequences of inter−individual variation remain largely unexplored. Here we report our investigation of milk prolactin (PRL) across lactation and as a function of maternal and infant characteristics. Milk samples were collected from 85 Rhesus macaque mothers at early, peak, and late lactation. Subjects were housed in the outdoor breeding colony at the California National Primate Research Center in Davis, CA. Using standard parallelism and recovery tests, we validated enzyme immunoassays to measure PRL in mother's milk. PRL concentration (ng/ml) was negatively correlated with milk fat (%) and protein (%) and gross energy density (kcal/g, GE). PRL was positively correlated with milk yield as we predicted given its integral role in lactogenesis. Interestingly, at the early lactation time−point, mean PRL concentration was highest (mean = 12.67 ± 0.44) and was significantly higher in milk produced for daughters (mean = 13.52 ± 0.64) than in milk produced for sons (mean = 11.78 ± 0.59) indicating sex−differentiated milk synthesis. Neither maternal parity nor maternal body mass were predictive of milk PRL concentrations, which was unexpected given that higher parity and heavier mothers in this population typically produce more milk. Similarly, milk PRL was not associated with infant body mass after controlling for milk yield and GE. These results suggest that the absolute quantity of milk PRL does not independently contribute to infant body mass. However, high concentrations and sex−differentiation of PRL during early lactation, when hormones may be most readily absorbed across the GI tract of the infant, may affect other physiological systems.

P1.21 SKINNER, J.P.*; PODOLSKY, R.D.; College of Charleston; *skinnerjp@g.cofc.edu*

Sexual dimorphism and size differences between mated and unmated males in the pycnogonid Tanystylum orbiculare

In most animal species the male's role in reproduction ranges from fertilizing eggs to participating with females in parental care. Because females have fewer and larger gametes, males often compete for access to females, and females are often choosier. Darwin recognized that either form of sexual selection can result in the evolution of sexual dimorphism for size or other traits that influence mating success. Pycnogonids (sea spiders) are atypical because males fertilize and collect eggs that they carry and care for on their own bodies. Females are also atypical in that the ovaries are displaced out into the walking legs, possibly in response to the limited volume of the body. These natural selection pressures could have opposing influences on the evolution of large body (male) and leg (female) sizes, in addition to the potential for sexual selection favoring these traits. To understand whether this reversal in parental care influences sexual dimorphism in the pycnogonid *Tanystylum orbiculare*, we compared size measurements between males and females and between males with and without eggs. Males were significantly smaller than females in leg size but not body size measurements. Mated males were larger than unmated males in body size and in most leg size measurements. Among mated males, body size was positively correlated with the volume of eggs being carried. The larger leg size of females is consistent with natural selection for accommodating larger ovaries. Although larger males appear to be favored in mating, this does not appear to have resulted in sexual dimorphism in body size as predicted by Darwin.

P2.3 SKRIP, M.M.; Univ. of Rhode Island, Kingston; *megan_skrip@my.uri.edu*

Science, communication, and the Broader Impacts criterion: a theory−based how−to for scientists striving to craft and evaluate impactful outreach activities

The National Science Foundation (NSF) requires all applicants to include a statement about the "Broader Impacts" of their work, but guidance remains sparse concerning what makes a Broader Impacts activity truly "broad" and "impactful." The proposed impacts of very different activities, furthermore, may be difficult to compare during peer review. Here I offer a new way forward for scientists struggling to competitively address the Broader Impacts criterion. Combining the experiences of successful practitioners and communication theory, I have synthesized a five−point framework of characteristics that I suggest can clearly and carefully define a Broader Impacts outreach activity's potential for "impact," no matter what form that activity takes. This "Broader Impacts Impact Framework" consists of five main factors who, why, what, how, and with whom and could be straightforwardly used by scientists and NSF during proposal writing and review. I describe the framework's justification and implementation, and include examples of use focusing on ecological research dissemination and outreach.

22.2 SKROMNE, I*; LEE, K; University of Miami, Coral Gables; *iskromne@bio.miami.edu*

Retinoic acid regulates size, pattern and alignment of neural and mesodermal tissues at the head−trunk transition

At the head−trunk transition, alignment of hindbrain and spinal cord territories to occipital and cervical structures is critical for coherent organization of neural and skeletal systems. Changes in neural or mesodermal tissue configuration arising from defects in territory size specification, patterning or relative axial placement can severely compromise system integration and function. Here we show that neural and mesodermal tissue coordination at the zebrafish head−trunk transition critically depends on two novel activities of the signaling factor Retinoic Acid (RA) specifying the size and axial position of the hindbrain territory relative to mesodermal structures. These activities are each independent but coordinated with RA's well−established function in hindbrain patterning. Using neural and mesodermal landmarks we demonstrate that RA function in aligning neural and mesodermal tissues temporally precedes the specification of hindbrain and spinal cord territories and the activation of hox transcription. Using cell transplantation assays we show that RA activity in the neuroepithelium is direct for hindbrain patterning but indirect for hindbrain territory size specification. This indirect function is independent of FGF and dependent on Wnts. Importantly, RA specifies and patterns the hindbrain territory by antagonizing the activity of the spinal cord specification gene cdx4; loss of Cdx4 rescues the defects associated with the loss of RA, including the reduction in hindbrain size and the loss of posterior rhombomeres. We propose that at the head−trunk transition, RA coordinates the specification, alignment and patterning of neural and mesodermal tissues essential for neural and skeletal system's functional organization.

P3.182 SLATER, G. P. *; HELM, B. R. ; YOCUM, G. D. ; BOWSHER, J. H. ; North Dakota State University , North Dakota State University, USDA ARS; *garett.p.slater@my.ndsu.edu*

Nutritional variation affects larval growth in honeybees

Nutrition heavily influences the physiology of developing organisms. In social insects, larval nutrition regulates profound phenotypic differences such as caste determination, as well as sublet differences in metabolism and health. Worker honeybees provision brood with a secretion from their mandibular and hypopharyngeal glands, which is called jelly. The nutritional content of these glandular secretions is a result of external factors such as forage and internal factors such as worker behavior, resulting in jellies that vary significantly in protein, sugar and water content. Systematic manipulations of larval diet in vivo will determine to what extent variation in Royal Jelly content affects within caste and between caste development. We manipulated a standard artificial diet for in vitro rearing and measured the phenotypic affects. The factorial design use nine diets that varied in the amount of sugar and royal jelly. We reared 24 larvae per diet and measured larval growth and length of each developmental stage. These results have implications for honeybee growth when foraging sources are limited or under monoculture cultivation.

51.2 SLEBODA, D.*; ROBERTS, T.J.; Brown University; *david_sleboda@brown.edu*

Confining compartments: restricting muscle bulging alters force and work production

Many skeletal muscles exist ensheathed in tight fitting connective tissue compartments comprised of epimysium and overlying fascia. It has been shown that freeing a muscle from this compartmental fascia via surgery has a negative impact on muscle force production; however, reports on the effects of introducing artificial constraining materials that exaggerate a muscle's in situ environment have been contradictory, with some reporting increases in muscle performance while others report decreases. Here, we sought to quantitatively describe the effects of artificially constraining a skeletal muscle during contraction. Using a force transducing servomotor and fixed−length contractions, we determined the length−tension characteristics of freshly dissected Lithobates catesbeianus (bullfrog) plantaris muscles in the presence and absence of snug−fitting plastic tubes that encased the muscle belly. We then explored the impact of these constraining tubes on work production during force−controlled, shortening contractions. Constraining the belly of a skeletal muscle decreased its ability to generate force across all regions of the L−T curve, with reductions as high as 25%. In shortening contractions, constricted muscles performed less work on the servomotor arm when compared with the unconstricted condition. Although the physiological mechanism by which muscle performance is influenced remains unclear, our results indicate that adding artificial constraints to the muscle belly can have a detrimental effect on force and work production. These findings, taken alongside reports of the detrimental effects of disrupting anatomical compartments that surround muscles in vivo, imply that there is an optimal shape in which to confine a contracting skeletal muscle that yields maximal muscle performance. Supported by NIH grant AR055295.

76.2 SLUTZKER, J.M.*; MOORE, P.A.; Bowling Green State University; *juliets@bgsu.edu*

You Shall Not Pass: Culverts As Mechanisms of Fragmentation of Crayfish Habitat

The wide scale increase in infrastructure associated with a growing human population has rapidly intensified habitat fragmentation, a primary contributor to biodiversity loss. Within aquatic ecosystems, one mechanism for fragmentation is the installation of culverts at road−stream intersections. These structures have the potential to alter ecosystem function by increasing flow velocity and turbulence within the water column. Crayfish are keystone organisms that often migrate upstream in search of resources and consequently need to move through culverts. To investigate whether culverts have the potential to fragment crayfish habitat, we conducted 24 hour behavioral studies wherein crayfish were videotaped in four mesocosms simulating a divided stream. Each mesocosm contained a channel filled with either corrugated pipe material or a gravel/sand mixture connecting an upstream and a downstream section. Additionally, we varied the flow in the mesocosms, with a faster flow treatment (3.30 L/s to 3.90 L/s) and a slower flow treatment (0.14 L/s to 0.22 L/s). Videos were analyzed for the number of crossings through the channel, the duration of each crossing, and whether the animal was moving upstream or downstream. The sex and sizes of the crayfish were also analyzed to determine if these factors influenced crossing behavior. Road−stream crossing surveys were conducted to investigate potential habitat heterogeneity and crayfish population demographic differences upstream and downstream of culverts and bridges. Results indicate that the degree of stream fragmentation varies with crossing type, creating potential divisions between reaches of a stream as well as a potential opportunity for the spread of invasive species.

S10.10 SMEE, Delbert*; SCHERER, Avery; LUNT, Jessica; DRAPER, Alex; Texas A and M − Corpus Christi; *lee.smee@tamucc.edu*

Turbidity triggers mesopredator release by altering chemically mediated trophic interactions

Biodiversity is often maintained by apex predators that alleviate consumption on lower trophic levels by controlling the abundance of intermediate or mesopredators. When top predators are removed, intermediate trophic levels proliferate. Known as mesopredator release, this phenomenon can decimate lower trophic levels and reduce biodiversity. In estuaries, fishes promote biodiversity by direct predation on crabs (i.e. mesopredators) and by releasing exudates that suppress crab foraging. Recently, we found that mesopredator release occurred by a previously unrecognized scenario. In estuaries, elevated turbidity attenuated predation by fishes that hunt using visual cues, causing fish abundance to decline while increasing the abundance of crabs that fish prey upon. Crabs locate prey by chemoreception and were unaffected by changes in turbidity. Increased crab abundance increased overall predation levels and significantly lowered biodiversity. Crab exudates are known to affect growth of bivalves and other organisms, and they were copious in higher turbidity. We found that eastern oysters (*Crassostrea virginica*) reacted to crab exudates by growing thicker shells at a cost of reduced growth and fecundity in turbid waters. Continued investigations regarding oyster responses to crab exudates has revealed that (a) oysters responded to cues emanating from crab predators and from injured conspecifics and heterospecifics, (b) while costly, oysters increased their survival by altering their shell morphology, (c) oyster responses were strongest to predator exudates, and (d) the duration of exposure to predator exudates had significant effects on oyster morphology. Thus, turbidity affected chemical signaling between trophic levels, altered the growth of an important ecosystem engineer, and significantly altered estuarine trophic interactions and biodiversity.

75.3 SMITH, K/M*; CHILDRESS, M/J; Clemson University; *kylie4@clemson.edu*

Assessing the effects of parrotfish grazing and macroalgal competition on coral cover in the middle Florida Keys

Coral cover in the Caribbean has drastically decreased over the past several decades. Previous studies have found evidence of competition between macroalgal species and reef building coral species. Studies have also found that reefs with higher parrotfish abundance tend to have higher coral cover. These studies suggest that parrotfish graze on this competitive macroalgae, indirectly having a positive influence on coral health. In the middle Florida Keys, coral reef ecosystems have also experienced a decline in overall coral heath and cover. We conducted surveys of reef substrate composition and parrotfish density across fourteen reefs in the Florida Keys National Marine Sanctuary. Our results show no evidence for linear relationships between coral cover, macroalgae abundance or overall parrotfish abundance. However, we did find significant regional differences in coral cover and individual species interactions. The abundance of striped parrotfish, *Scarus iserti*, was positively correlated with coral cover while turf algae was negatively correlated with coral cover. Additional research is being done to better understand the dietary preferences of each species of parrotfish, as well as the competitive relationship between corals, turf algae, macroalgae, sponges and octocorals. By understanding the characteristics of sites where corals are currently most abundant, we hope to identify the conditions that are essential for successful coral restoration.

41.1 SMITH, AM*; WILKS, A; RABICE, S; GARBACZ, H; Ithaca College, NY; *asmith@ithaca.edu*

What makes slug glue tough? Testing the double network mechanism in a dilute hydrogel

The terrestrial slug *Arion subfuscus* produces a sticky defensive secretion that is a dilute gel. It is unlike most commercial gels, which are either stiff and brittle, like gelatin, or easily deformable like most mucus secretions. *A. subfuscus* glue combines a relatively high stiffness with high extensibility, so that it requires much more energy to fracture. We tested the hypothesis that this toughness was due to a double network mechanism. In a typical double network, a loose, deformable network of polymers interpenetrates a stiff, highly cross−linked network. These two separate networks combine to give toughness that is several orders of magnitude greater than either network individually. To test this hypothesis, we characterized the structure of the glue to see if there were two separate networks. Then we tested the impact of disrupting each network separately. Our results confirm the existence of two networks. There are large, highly sulfated polysaccharides that appear to be cross−linked transiently by calcium. In addition, native gel electrophoresis and co−purification assays demonstrated that most of the proteins form a cross−linked network that is distinct from the carbohydrate network. Targeted disruption of each network separately, using disulfide bond breakage, calcium removal, imine bond disruption or enzymatic hydrolysis completely disrupted the glue. Thus, neither network on its own is sufficient to maintain the integrity of the glue. Although they are not tightly connected to each other, they both must work together as predicted by the double network mechanism.

50.3 SMITH, J.L.*; PALERMO, N.; THEOBALD, J.C.; WELLS, J.D.; Florida International University; *jsmit190@fiu.edu*

Comparison of eye morphology in Chrysomya megacephala males of differing sizes and the potential behavioral implications

The male *Chrysomya megacephala* eye has dorsal ommatidia that are more than twice as large as the ventral ommatidia. Based on physical properties, the enlarged dorsal ommatidia are associated with increased light capture. Aside from that optical property and that such a sexually dimorphic trait often plays a role in reproductive behavior, the biological role of this eye is unknown. This study examined the effect of this specialized morphology on diurnal activity patterns by comparing males that differed in eye shape due to differences in body size. Males of differing body sizes were produced by manipulating larval nutrition. Body size and both total eye size and the ratio of dorsal to ventral ommatidium width were proportionally scaled. Larger males, however, had a greater number of dorsal ommatidia than is explained by body size alone. The finding that larger males have disproportionately more facets, coupled with proportionately larger facet width, led to the hypothesis that larger males would be more active at lower light levels than smaller males. To test this, flies were subjected to a simulated daily light cycle in a confined space and activity was recorded when a fly interrupted an infrared beam. We found that larger males move significantly earlier in the morning but not later in the afternoon compared to smaller males. As male blow flies often use carrion as a place to find potential mates, these results suggest that it is more important to be early to carrion than it is to be able to stay later.

37.4 SMITH, AE*; WILLIS, MA; Case Western Reserve University; *aes127@case.edu*

Bilateral sensory inputs are not created equal: bilaterality in mechanosensory inputs is more important than olfactory for plume tracking hawkmoths, Manduca sexta

Males of the hawkmoth species *Manduca sexta* are able to track plumes of female pheromone in flight using their olfactory systems, which receive input directly from sensory cells on their antennae. To do this they use two possible odorant comparison strategies: spatial and temporal. If using spatial comparison, unilateral removal of an antenna should greatly diminish their ability to locate an odor source. If using temporal, unilateral antennectomy should have less of an impact, as the moths could still compare odor cues over time using one antenna. To determine which of these underlies plume tracking behavior, we antennectomized moths in three ways: (1) surgical removal of an antenna from adult males prior to flight, (2) surgical removal of the imaginal discs responsible for development of the adult antenna during the last larval stage, (3) surgical restriction of growth of the odor−detecting sensory cells on the antennae in stage 1 pupae while preserving the mechanosensors at the antennal base. In the last treatment group, a donor antenna was attached to the stump on the base of the antenna effectively "re−loading" the large mechanoreceptors at the base prior to flight. Though 97% of control animals find the odor source, only 43% of type 1 antennectomies and 26% of type 2 are able to perform this behavior. With mechanosensation preserved, the type 3 antennectomies perform at a rate of 86%. These results show that, while two antennae are certainly ideal for tracking an odor source, for *M. sexta* one is sufficient. It also reveals the importance of bilateral antennal mechanosensory inputs for flight control. We thank Jen Milligan and Sean Copley for their assistance. AES and MAW were supported by NSF grant IOS−1121498.

2.3 SMITH, AJ*; IMBURGIA, M; DUMONT, ER; Univ. of Mass. at Amherst; *ajsmith@bio.umass.edu*

Tooth Function and the Diversification of Early Mammals

The advent of complex teeth in Mesozoic mammals permitted an increase in taxonomic and dietary diversity, enabling occupation of many different ecological niches. One complex tooth that arose during the Mesozoic, the tribosphenic molar, could simultaneously cut and crush food. The cutting portion of this tooth evolved first, and involved the movement of three cusps from a line into a triangle. This transition is exemplified by two insectivorous mammals, *Morganucodon* (linear) and *Kuehneotherium* (triangular). Here we test whether the difference in dental morphology between *Morganucodon* and *Kuehneotherium* are associated with differences in their ability to fracture insect prey. We gathered measurements from both species and made physical models of the molar tooth rows based on these measurements. We used the models to puncture a gel that mimicked insect cuticle and measured the energy and force required to fracture, maximum force and damage to the gel. Both models required a similar amount of energy to fracture the gel at roughly the same time, but the force at fracture imposed by the *Kuehneotherium* model was higher. The maximum forces produced by the models were similar, but it was reached later and required more energy for *Morganucodon*. Finally, the *Kuehneotherium* model produced more and longer fractures in the gel by distributing forces over a larger area. Taken together, the *Kuehneotherium* model was able to cause more damage to the gel more quickly than the *Morganucodon* model while expending less energy. These results demonstrate that changes in the molar morphology of early mammals had a profound effect on the biomechanics of food processing, and suggest that the evolution of increasingly efficient teeth was fundamental to their taxonomic and trophic diversification.

70.8 SMITH, FW*; BOOTHBY, TC; GOLDSTEIN, B; University of North Carolina at Chapel Hill; *frank.w.smithiii@gmail.com*
The walking heads: Hox gene expression in Hypsibius dujardini and the evolution of the tardigrade body plan
We would like to understand how animal body plans arose. Panarthropods (arthropods, onychophorans, and tardigrades) have modular, segmented bodies, facilitating comparisons between body plans. How the body plan of tardigrades, which consists of a head and four leg−bearing segments, relates to that of other panarthropods, and how the tardigrade body plan evolved, are unclear. To address these issues, we developed *in situ* hybridization methods for tardigrades and investigated the expression patterns of *Hox* genes and several other genes using the tardigrade *Hypsibius dujardini*. Consistent with anterior *Hox* expression patterns in other panarthropods, we found that *labial* is expressed in the developing pharyngeal bulb; *Hox3* is expressed in leg−bearing segments 2 and 3; and *Deformed* is expressed in the posterior of leg−bearing segment 2 through segment 3. Unlike in other panarthropods, *fushi tarazu* and the genital segment marker *Abdominal−B* share anterior expression boundaries in the same segment, leg−bearing segment 4. Consistent with conserved panarthropod antererior and posterior body regions, we found that the head gap gene *orthodenticle* is expressed across the head, while the gap gene *caudal* is expressed in the posterior of leg−bearing segment 4. Our results suggest that the body plan of *H. dujardini* is primarily composed of segments homologous to arthropod head segments and that this species lacks segments homologous to arthropod trunk segments. *Hox* genes that specify trunk segments in arthropods are reconstructed as ancestral for Panarthropoda, but are missing in the *H. dujardini* genome. Our results suggest that there has been a gap mutant−like loss of a region homologous to the arthropod trunk in the tardigrade lineage.

114.4 SMITH, G.D.*; DURSO, A.M.; NEUMAN−LEE, L.A.; FRENCH, S.S.; Utah State University; *gdssmith57@yahoo.com*
The town lizard and the country lizard: The physiological ecology of urbanization in Uta stansburiana
Urbanization is one of the most dramatic and pertinent forms of environmental change facing wildlife. In addition to altering the survival and, ultimately, persistence of wild populations, urbanized landscapes can affect the internal processes of animals. Here we present findings of four years of physiological data on the side−blotched lizard (*Uta stansburiana*), between 2010 and 2014. Circulating corticosterone and stress reactivity were measured, as well as reactive oxygen metabolites and antioxidant barrier in attempt to differentiate stress between animals from three urban and three rural sites in southern Utah. Along with these measures of stress, innate immunity and reproductive investment were quantified in females to determine which crucial processes (immediate reproductive fitness or longer−term self−maintenance) were more important for urban and rural animals. Self−maintenance and reproductive investment contribute directly to population dynamics and demography, so we constructed populations models for these animals as well. Overall we found that the effects of urbanization on the physiology and ecology of side−blotched lizards are variable and dynamic, and the long−term nature of this project has allowed us to explore and relate themes integral to ecoimmunology, life history theory, and conservation biology.

76.3 SMITH, K.E.*; ARONSON, R.B.; THATJE, S.; MCCLINTOCK, J.B.; Florida Institute of Technology, University of Southampton, University of Alabama at Birmingham; *kathryn@fit.edu*
Current population status of king crabs and endemic benthic fauna off the western Antarctic Peninsula
For millions of years king crabs and other durophagous (skeleton−breaking) predators have been fundamentally absent from benthic communities on the Antarctic shelf. In their absence, the resident faunas have evolved in isolation, with limited defenses against durophagy. However, rapidly rising sea−temperatures off the western Antarctic Peninsula (WAP) appear to be facilitating range expansion of bathyal king crabs (Lithodidae) up the continental slope. Expansion of durophagous crabs onto the Antarctic shelf could drastically impact the vulnerable, endemic fauna and restructure benthic food webs. Between 2010 and 2013, we established two 100−km^2 study sites off the WAP. We conducted photographic surveys to investigate the current population status of king crabs and abundant endemic benthic fauna on the slope and shelf environment. At our first study site off Marguerite Bay, we observed lithodids at depths ranging 841−2266 m. We measured a maximum density of more than 5500 individuals per km^{-2}. At our second study site off Anvers Island, approximately 380 km northeast of Marguerite Bay, we observed lithodids at 924−1941 m depth. We measured a maximum density of ~ 2500 individuals per km^{-2}. Here, we examine the current densities of elements of the endemic benthic fauna and compare their depth distributions in relation to populations of lithodids on the slope and shelf environment across the WAP.

45.4 SMITH, KA; University of Washington; *kasm@uw.edu*
Tracking down historical data in the Digital Age
Assessing the effect of global warming on natural systems is critical. The rate of global warming has been increasing in recent years, and a powerful method for determining the effects of global warming on the abundance and distribution of species is to compare present−day data with historical data. The internet has made it possible to download data and information with some searches and clicks, but data prior to 1980 remain buried in stacks and archives of libraries and research institutes. Records of species abundance and distribution prior to 1980 are likely to give the best indication of the effects of climate change. Therefore, these records are equivalent to buried treasure for an ecologist studying climate change. Finding pre−1980 records requires patience, persistence, human interactions, and a willingness to travel. Strategies for obtaining historical data and outcomes of historical studies will be presented.

69.6 SMITH, W. A.*; MACARTHUR, J.; SIWAK, J.; STAWNYCHY, M.; SUBRAMANIAN, S.; Northeastern University; *w.smith@neu.edu*

Ecdysteroid Regulation of Wing Disc Growth in Manduca sexta: Intersection with Insulin Signaling Pathways

Wing disc growth in lepidopteran insects is jointly stimulated by ecdysteroids and insulin−like hormones such as bombyxin. While growth of the discs during the early part of the last larval stage is dependent upon nutrition, in *Manduca sexta* the majority of wing disc growth occurs during the prepupal stage after the insects have stopped feeding. In the present study, we explore the growth of discs removed from larvae just after the cessation of feeding, to better understand the nature of cross−talk between insulin and ecdysteroid signaling at this stage. Discs from wandering fifth instar larvae were cultured for two days in Grace's medium containing 20−hydroxyecdysone, recombinant human insulin, or both hormones. At levels corresponding to peak prepupal levels of circulating ecdysteroids, 20−hydroxyecdysone on its own increased disc content of the ecdysteroid receptor and stimulated limited growth in a manner suggesting the involvement of insulin signaling pathways. Specifically, prolonged exposure to 20−hydroxyecdysone alone stimulated the phosphorylation of Akt/protein kinase B, and of Akt substrates such as glycogen synthase kinase (GSK), as measured using Western blots. Insulin enhanced the phosphorylation of Akt and GSK to a far greater extent than 20−hydroxyecdysone, yet insulin alone did not stimulate growth. The results suggest that, while growth is stimulated most effectively by insulin and ecdysteroids acting together, ecdysteroids are capable of limited activation of insulin signaling independently, by a mechanism that remains to be determined.

P1.68 SMITH, G.D.; HOPKINS, G.R.; HANSEN, T.T*; MOHAMMADI, S.; SKINNER, H.M.; BRODIE, JR., E.D.; FRENCH, S.S.; Utah State University; *hansen_cb_32@yahoo.com*

Effects of temperature on embryonic and larval growth and development in the rough−skinned newt (Taricha granulosa)

Climate change is resulting in abnormal temperature regimes which can have major effects on ectotherms. In response to changing temperatures, wildlife can undergo alterations in their physiology and development in order to survive. Here we show the effects of temperature across embryonic and larval stages on the growth and development of the rough−skinned newt (*Taricha granulosa*). We randomly assigned newt eggs to different temperatures (7, 14, or 21ÚC). After hatching, we randomly placed the newt larvae into three different temperatures. Over four weeks, we measured total length grown and the change in developmental stage. Our results indicate a strong positive correlation over time between temperature and both length and developmental stage. Individuals assigned to cooler embryonic temperatures did not grow as large as ones placed in higher temperatures during their embryonic development, even if they were placed in the same temperature during their larval development. This demonstrates the important carry−over effects of embryonic temperature. While there was an overall positive correlation between temperature and growth and development, larvae appeared to reach an upper limit at the warmest temperatures. Also, while larvae that developed embryonically in the coldest temperatures were unable to grow as large as larvae in the warmer temperatures, they were eventually able to reach the same developmental stage. Our investigation of plasticity and variability of responses to different temperatures along with life−stage carry−over effects, provides a more comprehensive understanding of how organisms respond when posed with temperature changes during development, a reality for most aquatic species.

S4.4 SMITH III, Julian P.S.; Winthrop University, Rock Hill SC; *smithj@winthrop.edu*

When Jaws and Mouth are separate: Functional morphology and evolution of the Kalyptorhynch Proboscis

Flatworms of the Order Kalyptorhynchia are unusual in that the anterior proboscis, used in prey capture, is separate from the mouth opening. In four families and one genus, the proboscis is always armed with hooks or small teeth. The presence/absence of proboscis armature has been used for classification, uniting the diverse Gnathorhynchidae and defining the monotypic Aculeorhynchidae in the suborder Eukalyptorhynchia, and, within the suborder Schizorhynchia, defining the Karkinorhynchidae, Diascorhynchidae, and Nematorhynchidae and defining the genus *Carcharodorynchus* within the family Schizorhynchidae. Previous electron−microscopic studies are consonant with the independent evolution of armed proboscides in the two kalyptorhynch suborders, showing that the proboscis armature is derived from intracellular specializations (Gnathorhynchidae) or from the basal lamina (Karkinorhynchidae, Diascorhynchidae, *Carcharodorhynchus*). Furthermore, analysis of the light−microscopic morphology of the proboscides in the suborder Schizorhynchia suggested that the unarmed proboscis was primitive and the armed proboscides, derived. However, recent molecular phylogenies do not support this simple view, placing the karkinorhynchid suborder Cheliplaninae (possessing an armed proboscis) as the primitive sister group to the remaining Schizorhynchia, and further suggesting that the armed proboscis may have evolved from the unarmed condition multiple times within the remaining Schizorhynchia. Using comparative studies of the proboscis, body−wall musculature, and copulatory organ, I provide a new hypothesis concerning the evolution of the proboscis in the Schizorhynchia. *Funding: Winthrop University Research Council and SC INBRE [National Center for Research Resources (5 P20 RR016461) & the National Institute of General Medical Sciences (8 P20 GM103499) from the NIH*

30.3 SMOLINSKY, AN*; MIDDLETON, KM; PFEIFFER, F; HOLLIDAY, CM; University of Missouri; *ansgh2@mail.missouri.edu*

Material properties of the mandibular symphysis in Alligator mississippiensis

Alligator feeding is characterized by extraordinarily powerful orthal biting and twisting behaviors, which exert high shearing and torsional forces on the skull and mandible. Yet, despite the strength presumably needed to withstand these forces, alligators maintain an unfused mandibular symphysis. The material properties of the symphysis are poorly understood. Here, we used material properties testing machines to load similarly−sized *Alligator mississippiensis* (skull length range 18−27 cm) mandibles. Mandibles joined by the symphysis were potted and loaded in either mediolateral bending (inverted wishboning) or dorsoventral bending. Force−displacement curves were recorded and used to calculate stiffness at 2−, 5−, or 300 mm/min loading speeds. High speed video and post−experimental observation of Cohort 2 revealed that most bending and torsion occurred in the cortical bone lateral to the symphysis rather than in the symphyseal ligaments, to the extent that the ligaments could not be loaded to failure before breaking the dentary. This observation supports finite element models demonstrating that the rostral part of the balancing−side mandible will experience the greatest strains during biting, but begs the question of why such an elaborately reinforced symphysis evolved. Furthermore, forces required to fracture the dentary were two orders of magnitude below the recorded bite forces for similarly−sized individuals. Together, these observations suggest that subadult *A. mississippiensis* employ feedback controls and muscular activity to mitigate the complex strain environment during feeding.

S4.7 SMYTHE, A.B.; Virginia Military Institute; *smytheab@vmi.edu*
Small Worms, Big Teeth: Evolution of Feeding Structures in the Marine Nematode Subclass Enoplia
Members of the subclass Enoplia form one of three primary clades in Nematoda. Enoplia includes Enoplida, primarily aquatic nematodes, and Triplonchida, aquatic and terrestrial nematodes. The presence of presumed ancestral features shared with other animals but no other nematodes have led to the suggestion that Enoplia may represent the earliest nematode lineage. A phylogenetic framework for this group allows exploration of the evolution of feeding structures such as fixed teeth, movable teeth and mandibles, among the primary features used in taxonomy and classification. The taxonomy of Enoplia has been turbulent in recent years, with several families being transferred from Enoplida to Triplonchida and the placement of certain taxa remaining unclear. This study aims to expand taxonomic sampling, clarify relationships, and evaluate hypotheses of homology and evolution of feeding structures within Enoplia. Nearly full−length 18S (SSU) rDNA sequences were determined for members of Enoplia, and phylogenetic trees using maximum likelihood and Bayesian analyses were inferred. Preliminary analyses suggest that fixed teeth and movable mandibles evolved from movable teeth. Several members of Triplonchida (Tobrilina and Tripylina) were shown to be nested within Enoplida, and at least one genus in Enoplida, *Viscosia* (Oncholaimidae), appears to be paraphyletic. Clarifying relationships and expanding knowledge of Enoplia will aid in homology assessment of feeding structures and determination of features needing deeper morphological investigation.

14.5 SODA, KJ*; SLICE, DE; Florida State University, Tallahassee; *k.jamessoda@gmail.com*
Shape Trajectory Analysis Using Procrustes Analysis and VARMA Models
Geometric morphometric (GM) methods have revolutionized how studies into comparative morphology are undertaken. Most GM methods, however, can only be used on specimens whose shapes are fixed, barring direct analyses on specimens' shape trajectories, that is, how the specimen's shape changes through time. Shape trajectories differ from static shape data in that they cannot be represented as single vectors, but rather as a multivariate function from which shape vectors are derived. Here we attempt to represent the shape trajectories of two simulated organisms with radically different styles of movement as vector autoregressive moving average time series models (VARMA). Upon fitting a model to each organism, we then attempt to make statistical comparisons between the two based on the coefficients that compose the model. The advantages and disadvantages of this strategy are discussed. If successful, these methods have numerous applications in evolution, ecology, and comparative biology from comparisons of how different populations differ in locomotor style to describing microevolutionary trends.

72.6 SOCHA, JJ*; TWYMAN, C; YEATON, IJ; Virginia Tech; *jjsocha@vt.edu*
Landing without limbs: body shape during arboreal landings in flying snakes
Nearly all vertebrate gliders land by using their limbs to arrest their glide. Being limbless, flying snakes (genus: *Chrysopelea*) must land by contacting the substrate with the trunk of the body or the tail, potentially leading to injury. A key feature of the gliding system in snakes is dorsoventral flattening from head to vent. This flattening occurs as the snake takes off to enter the air, but it is unclear when the snake returns to its rounded shape, either before, during, or after landing. A flattened shape during landing would increase the surface area of contact, reducing the force of impact and potentially improving the grip for successful landing. However, a flattened shape would also expose the viscera to near−direct contact with the substrate. A rounded shape during landing would better protect the viscera with the ribs, but may increase the total impact force experienced during landing, and reduce grip. To investigate the shape of the snake's body during landing, we recorded landings in short trajectories to a horizontal pole using three high−speed cameras. Data from 28 successful landings of 5 individuals (*C. paradisi*) was analyzed. In all landings, the body was dorsoventrally flattened at the time of impact, maintaining the glide configuration of the body. The remaining body did not swing passively around the landing pole, suggesting that the trunk stiffens actively by muscle activation after landing. In most landings (~70%), when contact occurred the snake underwent further dorsoventral compression, likely an inertial effect accompanied by flexing of the rib cage. This study suggests that flying snakes do not prepare for landing on an arboreal substrate, and absorb impact energy locally in the region of contact. Supported partially by 1351322.

93.7 SOKOLOVA, I.M.*; IVANINA, A.V.; University of North Carolina at Charlotte; *isokolov@uncc.edu*
Mitochondrial mechanisms of hypoxia tolerance in marine bivalves
Estuarine bivalves are among the champions of hypoxia tolerance and are exposed to cyclic oxygen deficiency due to the tidal cycles and/or formation of the benthic "dead zones" in estuaries. Metabolic adaptations such as efficient anaerobic pathways and metabolic rate depression play a key role in hypoxia tolerance of mollusks; however, it remains unknown how mitochondrial functions are preserved during hypoxia and reoxygenation in these organisms. We studied mitochondrial responses to hypoxia in the hard clam *Mercenaria mercenaria* and the bay scallop *Argopecten irradians*. Membrane potential (ΔÈ) and kinetics of substrate oxidation, proton leak and phosphorylation subsystems were measured in clams and scallops exposed to hypoxia (17 h at <1% O_2) followed by a 1 h recovery. In scallops, hypoxia suppressed the capacity of all three mitochondrial subsystems, and mitochondrial condition further deteriorated during reoxygenation, with strong depolarization of mitochondria and decreased capacity for the substrate oxidation and phosphorylation. In contrast, in clams hypoxia increased the Δpsi−dependent capacity of the substrate oxidation subsystem and had weak inhibitory effects on the phosphorylation and proton leak subsystems. During reoxygenation, the substrate oxidation capacity of clam mitochondria further increased and the capacity of the phosphorylation subsystem returned to normal. Upregulation of the substrate oxidation in hypoxia poises clams for a quick recovery upon reoxygenation, while scallops suffer from mitochondrial deterioration limiting their ability to survive hypoxia. Supported by the Charlotte Research Institute and University of North Carolina at Charlotte.

64.6 SOLOMON, J.A.*; DONNELLY, M.; WALTERS, L.J.; University of Central Florida; *joshua.a.solomon@knights.ucf.edu*
Intertidal Oysters &Sea Level Rise: Two years of intertidal oyster growth in Apalachicola Bay, FL.
The Intergovernmental Panel on Climate Change predicts sea level rise up to 56 cm by 2100. Changing sea level may result in changes in competition among intertidal organisms, particularly sessile shellfish. *Crassostrea virginica*, an ecologically and commercially important oyster species in Apalachicola Bay, Florida, forms both intertidal and subtidal reefs. We deployed field experiments investigating potential responses of intertidal oysters to changes in inundation. Experiments occurred at two sites in Apalachicola Bay [East Cove of St. George Island (ASP) and Apalachicola National Estuary Research Reserve (ANERR)]. At each site, five units were deployed supporting stabilized oyster shell incrementally from mean low to high water levels, maximizing the range of inundation. Inundation was used as a proxy for sea level rise. Sites were adjacent to live intertidal oyster reefs growing at an elevation of approximately −0.44m NAVD88. Deployment lasted for one year starting in June 2012 and June 2013. Monitoring included: oyster abundance, orientation and length. After 12 months, mean oyster density peaked at 1018.8 ± 135.8 per m^2 at intermediate elevation at ASP, and 976 ± 137.5 at intermediate elevation at ANERR. Oyster length at both sites peaked at low elevation. Oyster growth angle relative to the benthos varied significantly with elevation ($p = 0.0005$); higher growth angles occurred at lower elevations. These data suggest that changes in mean sea level may result in changes to oyster density and growth patterns, including size and reef structure. Specifically, with increasing vertical shell growth at lower elevation, intertidal oyster reefs may remain intertidal under some sea level rise scenarios.

S8.7 SOMA, KK; Univ. of British Columbia; *ksoma@psych.ubc.ca*
Rapid effects of steroids on the brain and social behavior of songbirds
Endocrinologists have traditionally focused on circulating hormone levels. In the case of steroid hormones, circulating steroids can be locally metabolized within the brain to either more active or less active signalling molecules. Furthermore, the brain can synthesize steroids ("neurosteroids"), such as testosterone and estradiol, de novo from cholesterol or from inactive prohormones in the blood. For such reasons, steroid levels in the brain can be far higher than steroid levels in the blood. Recent data suggest that social interactions rapidly modulate neurosteroid synthesis in songbirds and other species. In addition, steroids have rapid effects on social behavior in songbirds and other species. Taken together, the data suggest that locally−synthesized steroids are more likely to act via non−genomic mechanisms than systemic steroids in the circulation.

83.2 SOMBATSAPHAY, V.*; REITZEL, A.M.; Univ of North Carolina − Charlotte; *vsombats@uncc.edu*
Phylogenetic diversity, developmental expression, and salinity−induced expression of aquaporins in the estuarine anemone Nematostella vectensis
Aquaporins are membrane channel proteins present in eukaryotes and prokaryotes that function to facilitate permeation of small molecules, including water, for regulating cell osmolarity, migration, and metabolism. In bilaterian animals, aquaporins are critical, selective proteins essential for water and ion regulation in specific cells or tissues, particularly the excretory and nervous system. Despite their broad phylogenetic distribution and essential functions in cell physiology, the evolutionary history and functional variation of aquaporins in early diverging animals are poorly understood. Here we will report on the diversity of aquaporins in the cnidarian *Nematostella vectensis*, with comparison to sponge, ctenophore, and placozoan species with reference genomes, and describe expression of these genes during development and in response to osmotic stress. Aquaporins were expressed early in embryogenesis coinciding with germ layer differentiation, and, surprisingly, had distinct spatial expression in the endoderm. In addition, these genes were differentially expressed in response to acute high and low salinity stress during development and in the adult stage, suggesting a role in acclimation to osmotic environment for this euryhaline species. Together our results show discrete developmental expression domains for these water channel proteins and their transcriptional flexibility in response to environmentally−relevant shifts in salinity characteristic of high marsh estuarine habitats.

83.1 SOMBATSAPHAY, V.; REITZEL, A.M.*; Univ. of North Carolina, Charlotte; *areitze2@uncc.edu*
Fine−Scale Tolerance and Sublethal Stress to Salinity Fluctuations in the Life Cycle of an Estuarine Cnidarian
Individuals living in brackish habitats routinely experience dynamic abiotic conditions that include acute and chronic exposure to different salinity environments. For species living in isolated high marsh portions of estuaries, like the anemone *Nematostella vectensis*, salinity can have persistent local variation across a salt marsh but also vary by more than 30 ppt over a single day dependent on rainfall or tidal surge. Because adult *Nematostella* are relatively sessile and offspring are locally retained, these changes in the saline environment may represent a differential lethal stressor dependent on developmental stage or a sublethal stressor that impacts physiological performance. In this study we show that, despite a large tolerance to salinity (> 40 ppt), all developmental stages have a fine scale (1−2 ppt) at the extreme ends of the salinity range where individuals undergo complete mortality. Discrete developmental stages had significant variation in acute exposures suggesting stage−specific sensitivity to salinity stress. We observed sublethal stress, both in extended time for larval settlement as well as reduced growth rates in adults, in salinity conditions where individuals did survive. A long term, common garden experiment where adults were cultured under different salinity conditions additionally showed that reproductive output and offspring survival are impacted by the adult salinity environment. We compare these data with field measurements of salinity fluctuations in *Nematostella*'s habitat and stage−specific variation in other estuarine species.

P1.23 SOMJEE, U*; ALLEN, P/E; MILLER, C/W; Univ. of Florida, Gainesville; *ummat.s@gmail.com*

Reversal in expression of pre− and post−copulatory traits in an insect

Sexual selection had led to the evolution of weapons, traits that function in competition for mates, and testes size to increase competitive chances of fertilization. Environmental factors experienced during development can influence the relative expression of testes and weapons, however relatively few studies examine investment in pre− and post−copulatory traits simultaneously under natural conditions. We examined the influence of rearing environment on the expression of weapon and testes size in a wild population of the heliconia bug, Leptoscelis tricolor, (Hemiptera: Coreidae), across two distinct naturally occurring host plant species. Insects that develop on the host plant Heliconia mariae, produce smaller weapons than those that develop on H. platystachys. However, the reverse pattern is found in testes size, with individuals reared on H. mariae producing larger testes than those reared on H. platystachys. These results reveal a reversal in investment in in pre− and post−copulatory sexual traits in L. tricolor.

P3.113 SOMOVA, E.L.*; HOOTON, K.S.; BLACKSTONE, N.W.; Northern Illinois University; *elbarten@gmail.com*

Effects of Perturbation on Photosystem Redox State in Bleaching Octocorals

Coral reefs are susceptible to climate change through coral bleaching, which is often caused by increases in ocean temperatures and light. Perturbation causes symbiotic algae, *Symbiodinium* spp., that live within the coral to become stressed and lost. Bleaching begins with perturbation of photosynthesis, but the actual site of damage is not clear. Using fluorescent microscopy, the relative chlorophyll fluorescence of individual symbionts can be measured in control and perturbed colonies of *Sarcothelia* sp., *Sympodium* sp., and *Phenganax parrini*. Individual colonies were removed from culture conditions (27 ºC and 110 ¼mol photons m^{-2} s^{-1}) and images of three stolons per colony were obtained. The control colonies were returned to culture conditions while the perturbed colonies were placed in an incubator (30 ºC and 140 ¼mol photons m^{-2} s^{-1}). After the 30 minutes, images of the same three areas of both colonies were again acquired. For each stolon, the fluorescence of the same symbionts were measured in the before and after images. This allowed for changes in the fluorescence of individual symbionts to be tracked over time. Merely measuring colonies significantly increased the fluorescence of some symbionts. Incubation under higher temperature and light levels for 30 minutes consistently increased chlorophyll fluorescence, suggesting greater reduction of photosystem II due to blockage of downstream electron transport. This effect was stronger in colonies of *Sarcothelia* sp. than in colonies of *P. parrini,* which corresponds to reactive oxygen species production by these colonies and to their general susceptibility to perturbation.

P2.171 SONG, B.B.*; HALE, M.E.; Univ. of Chicago; *mhale@uchicago.edu*

The role of fin ray proprioceptive feedback during swimming.

Proprioception, the ability to sense movement and position of the limbs, provides critical sensory feedback for locomotion in many terrestrial vertebrates and insects. Although fish also use paired limbs, the pectoral fins, as primary propulsors, little is known about proprioceptive feedback from the fins or its function. Here we used bluegill sunfish (*Lepomis macrochirus*) to examine proprioception during swimming. The bluegill uses its pectoral fins extensively in locomotion, and electrophysiological recordings have shown that fin ray afferents respond to bending at frequencies typical for steady swimming. In this study, we transected afferent nerves and recorded behavior to examine the role of fin proprioceptive feedback in forward swimming. To assess baseline kinematics, pectoral fin swimming was recorded in a flow tank at range of speeds. Bilateral nerve transections were then performed to remove sensory input from the rays. As transected nerves did not contain motor efferents, transections only removed sensory function. Behavioral trials were repeated after a short recovery period. In contrast to the fin movements of control behaviors, we found marked variability among fin beats within a trial post−transection. In addition, there was a lack of coordination in the timing of fin beats between the left and right sides. Overall, we found a decrease in stroke amplitude and an increase in fin beat frequency. Engagement of the body axis and caudal fin during swimming occurred at lower speeds post−transection than in controls, perhaps compensating for decreased force generation by the pectoral fins. Together these data indicate that proprioception provides important feedback for controlling pectoral fin movements during swimming.

P1.128 SORENSON, G/H*; DESCAMPS, S; GILCHRIST, H/G; JANSSEN, M; WHITE, T; LOVE, O/P; University of Windsor, Windsor, ON, Norwegian Polar Institute, Tromso, NO, Environment Canada, Ottawa, ON, Environment Canada, Ottawa, ON, Carleton University, Ottawa, ON; *sorensog@uwindsor.ca*

Travelling for food: linking foraging patterns with energetic physiology in an Arctic seabird

Polar ecosystems (Arctic/Antarctic) are currently facing some of the most rapidly−emerging environmental stressors worldwide. Ironically, since polar systems tend to exhibit extreme, but highly stable, environments, their associated species may not have the physiological or behavioral flexibility to respond to rapid environmental change. Unfortunately, we know almost nothing about the underlying mechanisms (e.g., physiology, behavior) that govern the relative ability of individuals or populations to respond and succeed to this degree of change. We are combining the measurement of energetic physiology (baseline corticosterone, plasma triglycerides) during multiple stages of reproduction and the tracking of foraging trips using cutting−edge light−weight GPS units in Arctic thick−billed murres (*Uria lomvia*) from a low−Arctic Canadian and high−Arctic Norwegian population. Our goal is to take an integrative approach to examining within−individual, within−population and among−population physiological responses to environmental variation. We will examine relationships between changes in foraging behavior, energetic/stress physiology and colony productivity to determine the interactive effects of environmental stress on individual and population success.

P2.173 SOTO, A*; MCHENRY, M.J.; Univ. of California, Irvine; *alberts2@uci.edu*

Acceleration affects the optimal strategy of prey fish

Game theory offers an analytical framework for understanding how the sensory and motor systems of a prey animal govern its ability to evade a predator. We applied a classic pursuit−evasion game theory model, the homicidal chauffeur', to examine the evasion tactics employed by larval prey zebrafish (*Danio rerio*) when they encounter a predator. We modified this classic model in the interest of replicating our previous findings on the kinematics of prey fish. In particular, we relaxed the simplifying assumption that the predator and prey move at constant speed to predict optimal swimming trajectories with a combination of analytical and numerical modeling. We found that this modification yielded a superior prediction of escape maneuvers than the traditional model. In addition, the optimal escape strategy of a prey fish depends on the acceleration that the animal is capable of generating during an encounter with a predator, a property that is inherent to the mechanics of an escape response.

P1.44 SPAGNA, J.C.*; DORPH, D.; MAYA−MORALES, J.; JIMENEZ, M.L.; William Paterson University, Centro de Investigaciones Biológicas del Noroeste S.C., Centro de Investigaciones Biológicas del Noroeste S.C.; *spagnaj@wpunj.edu*

Whole−continent Molecular Phylogenetics of North American Agelenidae

The family Agelenidae C.L. Koch 1837 is large (70 genera, 1157 species currently described, accounting for about 2.5% of all spider species) with a high level of endemicity in the North America, and California in particular. Spiders from this family have recently been used as models for toxicological and behavioral research. In the Agelenidae, there have been eight genera (*Hololena, Rualena, Calilena, Novalena, Agelenopsis, Barronopsis, Tortolena,* and *Melpomene*) classified in the subfamily Ageleninae, tribe Agelenopsini, endemic to North and Central America. In the past year, an additional genus (*Rothilena*) has been described from Northwestern Mexico. We performed partitioned Bayesian likelihood analysis of molecular sequence data from mitochondrial (CO1 and 16S rDNA) and nuclear (28S rDNA) genes from 25 representative species to develop a phylogenetic hypothesis for these genera. Results support monophyly of a group confined to Western North America extending south into Baja California (*Calilena + Hololena + Novalena + Rualena + Rothilena*). These are sister to a clade including the primarily Gulf Coast, Caribbean and Atlantic Coast genera *Agelenopsis, Barronopsis,* and *Tortolena*. Strong genitalic similarity within the latter group extends to the sole unsequenced genus *Melpomene* from Eastern Mexico and Central America, consistent with a clear biogeographic split between the Atlantic/Gulf Coast genera and those endemic to the Western US and Mexico. Tree morphology indicates an early period of rapid diversification, though large uncertainty in molecular clock estimates confounded our efforts to rigorously evaluate possible causes of this remarkable continent−wide radiation.

P1.24 SPANGLER, A*; COLLIN, R; Smithsonian Tropical Research Institute; *aspangle@gmail.com*

When, Where, and Why: Environmental physiology of egg deposition in an intertidal snail.

Many organisms synchronize reproduction with environmental cycles in order to avoid unfavorable environmental conditions, coordinate timing of reproductive cycles, make use of periodically available resources, and avoid periods of high predation risk. Oviposition and larval hatching commonly follow both annual or seasonal cycles as well as lunar or tidal cycles. Tropical intertidal habitats are well known to undergo drastic physical changes through the daily tidal cycle, but annual cycles are less well−documented. We monitored egg capsule deposition and hatching of the intertidal snail *Nerita scabricosta* in permanent quadrats in 24 tidal pools on the high intertidal of the Pacific coast of Panama. Capsule counts from 2011−2014 show a clear seasonal pattern of reproduction, with oviposition occurring during the rainy season from May−December. The rank oviposition preference among the pools were consistent among years, with some pools showing earlier appearance of capsules, and higher density of capsules compared to other pools. This preference may be related to pool morphology and physical characteristics of the quadrats.

P3.186 SPARKS−HOSKINS, L.C.*; REECE, J.S.; Valdosta State University; *lcsparkshoskins@valdosta.edu*

Evolution of color patterns and disruptive coloration in moray eels (Muraenidae)

Beginning with Darwin and Wallace, biologists have debated the purpose of bright colors and complex color patterns in coral reef fishes. Their explanations have ranged from sexual ornamentation to advertised aggression, species recognition, crypsis, and other types of communication. Support for each of these explanations and many others has been demonstrated for individual species, however, few studies have investigated the ecological and life history correlates of color patterns in a clade of fishes using phylogenetic comparative methods. Here, we investigated 165 out of 200 species of moray eels and placed each species into one of six color pattern categories. We developed a "crowd−sourcing" approach to have undergraduate biology students independently assign species into one of six color pattern categories to assure that there was no researcher−bias in the assignments. We then tested for associations between color patterns and habitat, diet, and sexual system using phylogenetic comparative methods for 46 of those species, and non−phylogenetic methods for all 165 species. We find that the color patterns that are the most disruptive to the outline of the fish's body, such as sharply defined spots or black and white stripping, are significantly more prevalent in species that inhabit shallow waters, consume hard−bodied prey, and have a protogynous sexual system. Species with more cryptic color patterns or uniform coloration tend to inhabit deeper reefs, prey on other fishes, and have a gonochoristic sexual system. This work shows that a variety of factors, including neutral processes, habitat depth, diet and sexual system may affect the evolution of diverse color patterns in coral reef fishes.

84.2 SPEISER, D.I.*; KINGSTON, A; RAMIREZ, M.D.; OAKLEY, T.H.; Univ. of South Carolina, Univ. of Maryland, Baltimore County, Univ. of California, Santa Barbara, Univ. of California, Santa Barbara; *dispeiser@gmail.com*

Characterizing the molecular components of phototransduction in the eyes and aesthetes of chitons (Mollusca: Polyplacophora)

Chitons are marine mollusks protected by eight over−lapping shell plates. In most species, numerous sensory organs − known as aesthetes − are embedded in these shell plates. Aesthetes come in a variety of forms, ranging from non−pigmented sensory cells, to pigmented clusters of cells, to image−forming eyes with lenses made of shell material. Chitons are a promising system for the study of eye evolution because their eyes may be the most recently evolved of any animal. The fossil record of chitons extends back to the Cambrian, but chitons with eyes have only diversified within the last 25 million years. Further, chitons display multiple light−influenced behaviors that are simple, stereotyped, and easily−manipulated in the laboratory. Through transcriptome sequencing, we find that the aesthetes of chitons tend to express molecular components consistent with multiple types of phototransduction. Using immunohistochemistry, we find that the aesthetes, but not the eyes, of the chiton *Acanthopleura granulata* express molecular components of phototransduction (r−opsin, Gq alpha, and the ion channel TRP) that are similar to those expressed by the cephalic eyes of many invertebrates. The eyes of *Acanthopleura granulata*, however, may operate via a separate phototransduction pathway initiated by a distantly−related family of opsins. Finally, we describe how we are using blockers of opsin and ion channel function to study the contribution of different molecular components to the light−influenced behaviors of chitons. We conclude that multiple phototransduction pathways tend to be associated with the aesthetes of chitons and that the eyes of chitons may have evolved from the aesthetes of eyeless ancestors.

68.4 SPENCE, AR*; HOPKINS, GR; BRODIE, JR., ED; FRENCH, SS; Utah State University; *austin.r.spence@gmail.com*

Effects of chronic and acute exposure to ZnO nanoparticles across life−history stages in a caudate amphibian (Taricha granulosa)

Metal nanoparticles can pollute aquatic ecosystems, and have toxic effects on a variety of organisms, especially microbes and invertebrates. To date, little research has been done to investigate the effects of nanoparticles on amphibians, especially caudates. This experiment investigated the effects of zinc oxide (ZnO) nanoparticles on the rough skinned newt, *Taricha granulosa*, at different life−history stages. Chronic and acute toxicity were tested on eggs and larvae. For eggs, chronic exposure caused higher mortality at 10 and 100 mg/L compared to 0, 0.1, and 1 mg/L, with sublethal effects including developmental deformities, decreased time to hatching, and smaller size at hatching. Incubation decreased by 5 days and larvae had a decreased developmental stage when given an acute exposure during late embryonic development. Chronic and acute exposure of larvae both increased mortality up to 75% at both 10 and 100 mg/L, and exhibited sublethal effects, including slower growth and development. These results suggest nanoparticles can have lethal and sublethal effects on amphibians. Assessment of the safety of nanoparticles and their potential effects in aquatic ecosystems needs to be prioritized as these chemicals become more prevalent in the environment.

6.5 SPICA, E; DAVIS, GK*; Bryn Mawr College; *gdavis@brynmawr.edu*

Induction of reproductive fate in the Pea Aphid

The pea aphid, *Acyrthosiphon pisum*, exhibits several environmentally cued, discrete, alternate phenotypes (polyphenisms) during its life cycle. In the case of the reproductive polyphenism, differences in day length determine whether mothers will produce daughters that reproduce either sexually by laying fertilized eggs (oviparous sexual reproduction), or asexually by allowing oocytes to complete embryogenesis within the mother without fertilization (viviparous parthenogenesis). Among other aspects of the polyphenism, we are interested in the process that specifies sexual versus asexual fate during embryonic development. Several lines of evidence implicate juvenile hormone (JH) in this process, namely that titers of JH correlate with day length (Ishikawa et al. 2012) and that topical application of JH can alter reproductive fate (Corbit and Hardie 1985). Together these observations suggest that high titers of JH are responsible for specifying asexual fate. We are exploring this JH hypothesis further by testing whether JH is also *required* for the specification of asexual fate during embryonic development and attempting to discriminate among competing models for the role JH plays in the process. References: Corbit TS, Hardie J. 1985. Juvenile hormone effects on polymorphism in the pea aphid, *Acyrthosiphon pisum*. *Entomologia Experimentalis et Applicata* 38: 131−135; Ishikawa A, Ogawa K, Gotoh H, Walsh TK, Tagu D, Brisson JA, Rispe C, Jaubert−Possamai S, Kanbe T, Tsubota T, Shiotsuki T, Miura T. 2012. Juvenile hormone titre and related gene expression during the change of reproductive modes in the pea aphid. *Insect Mol Biol* 21: 49−60.

P1.103 SPITZER, BJ*; WILCOXEN, TE; SEITZ, J; NUZZO, J; Millikin University, Illinois Raptor Center, Illinois Raptor Center; *bjspitzer@millikin.edu*

Fluctuating asymmetry in relation to feather corticosterone levels in birds of prey admitted to the Illinois Raptor Center.

Raptors, or birds of prey, are birds characterized by precise vision, talons, and powerful beaks that are used to prey upon other animals. Though stress and fluctuating asymmetry have been examined in other avian species, often within the context of sexual selection and honest signals, it has not been closely examined in birds of prey. Corticosterone and its metabolites can be successfully measured from flight feather samples and are thought to be indicative of the stress experienced by birds during molt, when they are first growing the feather. In our study, we recorded structural measurements of paired limbs from each bird admitted to the Illinois Raptor Center and measured corticosterone in the feathers of juvenile and adult red−tailed hawks (*Buteo jamaicensis*), Cooper's hawks (*Accipiter cooperii*), and barred owls (*Strix varia*). We then used an analysis of covariance to determine effects of age and feather corticosterone levels on fluctuating limb symmetry. Because we are also interested in the consequences of asymmetrical growth, we also compared differences in symmetry between birds admitted with and without broken bones. We found a positive correlation between fluctuating asymmetry and corticosterone levels in immature birds but not in adult birds. Birds admitted with broken bones also had more fluctuating asymmetry. These relationships indicate that high levels of stress during development can increase fluctuating asymmetry in immature birds which, in return, may lead to decreased survival

107.5 SPONBERG, S; Georgia Institute of Technology;
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Information−based analysis of centralized vs. decentralized control architectures for rapidly running cockroaches.

Perturbed, transient, and variable movements reveal locomotor dynamics and hence how control is accomplished. Recently a great deal of research has focused on feedback vs. feedforward control strategies. Much less attention has focused on an independent second axis of organization that of centralization vs. decentralization of the control signals. A longstanding hypothesis of locomotor control is that as speed increases, animals should adopt more feedforward, decentralized control strategies that do not require the processing time inherent in acquiring and coordinating centralized, feedback information. Testing the centralization aspect of this hypothesis has been elusive. Using a large dataset of strides from a running cockroach, I tested whether individual muscles represent control of more local (i.e. decentralized), individual limb states or more global variations in whole body dynamics. To do this I quantified the mutual information between muscle activation and three state variables − 1) limb extension 2) center−of−mass vertical acceleration, and 3) global kinematic phase. Mutual information measures how much one signal constrains the possible states another signal adopts. It avoids assumptions of linearity or specific statistical distributions. I discover muscle activation informs global phase more than the individual leg's kinematics or the body's acceleration. A muscle tells us more about what the whole body is doing than it does about the limb that it acts on. This result indicates that even at high speed, variation in neural activity is more centralized. The emerging view is that control is hierarchical with centralized neural feedback operating (when necessary) on top of a feedforward−driven, mechanically decentralized system.

62.1 SPRAYBERRY, J.D.H.; Muhlenberg College;
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Searching for the next meal: modeling the operating range of visual and olfactory signals in bumblebees

Bumblebees, like honeybees, learn from past floral encounters to make future foraging decisions (ex: using spatial memory to return to learned floral patches). Likewise, bumblebees utilize social information while foraging: changing their behavior based upon conspecific scent marks left on inflorescences; and initiating foraging upon receipt of recruitment pheromones released in the nest by returning foragers. However, unlike honeybees, bumblebees have no direct analogue for the waggle dance − i.e. a way for returning workers to provide reliable directions to navigate to a novel resource. While evidence suggests that returning workers may recruit new foragers to the novel floral scent, there is no obvious directional information provided. This means that foragers moving on from a senesced resource or leaving the nest for the first time are, so to speak, flying blind. Presumably the rich array of sensory signals provided by flowers serve as billboards for searching bumblebees. Although recent work is beginning to elucidate how bumblebees integrate visual and olfactory signals in the context of learning, as yet we know very little about how these differing modalities contribute to resource localization. Minimal field evidence bolstered by lab evidence supports the idea that floral scents are attractive to bees. Many studies indicate that visual signals from flowers play a role in foraging behavior. However, these different sensory modalities potentially operate at vastly different scales in the field, which could in turn affect which sensory signals are most relevant during search behavior. This study models the likelihood of encountering an olfactory versus a visual signal in a field environment to shed light on the sensory information available to searching bumblebees.

82.4 SQUARE, T*; JANDZIK, D; MEDEIROS, D.M.; Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, U.S.A., Department of Ecology and Evolutionary Biology, University of Colorado, Boulder; Department of Zoology, Comenius University in Bratislava, Bratislava, Slovakia ;
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A gene expression map of the larval Xenopus laevis head reveals developmental changes underlying the evolution of new skeletal elements in vertebrates

The morphology of the vertebrate head skeleton is highly plastic, with the number, size, shape, and position of its components varying dramatically between groups. While this evolutionary flexibility has been key to vertebrate success, its developmental basis is poorly understood. The larval head skeleton of the frog *Xenopus laevis* possesses a unique combination of ancestral tetrapod features and anuran−specific novelties. We built a detailed gene expression map of the early head mesenchyme in *X. laevis*, focusing on transcription factor families with known functions in vertebrate head skeleton development. While we observed broad conservation of gene expression between *X. laevis* and other gnathostomes, we also found several divergent features that correlate to lineage−specific novelties. We noted a conspicuous change in *dlx1/2* expression in the second pharyngeal arch, presaging the differentiation of the asymmetrical hyoid arch skeleton. In the future mandible we observed a shift in the expression of the joint inhibitor *barx1*, and new expression of the joint marker *gdf5*, suggesting that the anuran−specific infrarostral cartilage evolved by partitioning of Meckel's cartilage with a new paired joint. We posit that changes in the expression of downstream regulators of skeletal differentiation, like *barx1* and *gdf5*, are an important mechanism by which the number and positioning of skeletal elements can be altered during evolution.

P3.58 ST JOHN, PS*; LENDVAI, AZ; DOMALIK, A; BONIER, F; Queen's University, Kingston ON, Virginia Tech, Blacksburg VA, Queen's University, Kingston ON ; *0jpss@queensu.ca*

Variation in anti−predator nest defense behavior within and among individual Tree Swallows (Tachycineta bicolor).

The degree of parental behavior varies not only between species, but also among populations and individuals within species. The causes of variation in parental behavior within species are not fully understood. Additionally, relatively few studies have attempted to quantify within individual variation in parental behavior. Here, we used repeated presentation of a model of a nest predator (black−rat snake) to individual Tree Swallows (*Tachycineta bicolor*), to quantify among and within individual variation in nest defense. We then assessed relationships between intensity of nest defense behavior and measures of body condition and reproductive investment (e.g., clutch size, provisioning rate) to determine factors that might predict individual variation in this parental behavior. Additionally, we look at repeatability of nest defense behavior within individuals to determine if this behavior is part of a stable behavioral phenotype, at least within the period of care of offspring. Our findings have implications for the effectiveness of using a single sample period of parental behavior to describe an individual's behavioral phenotype, in addition to understanding the sources of within−species variation in parental behavior.

96.6 STAATERMAN, E R*; PARIS, C B; KOUGH, A S; University of Miami; *estaaterman@rsmas.miami.edu*

First evidence of fish larvae producing sounds

The acoustic ecology of marine fishes has traditionally focused on adults, while overlooking the early life history stages. Here we document the first acoustic recordings of pre−settlement stage gray snapper larvae *(Lutjanus griseus)*. Through a combination of *in situ* and unprovoked laboratory recordings, we found that *L. griseus* larvae are acoustically active during the night, producing "knock" and "growl" sounds that are spectrally and temporally similar to adults. While the exact function and physiological mechanisms of sound production in fish larvae are unknown, we suggest that these sounds may enable snapper larvae to maintain group cohesion, particularly at night when visual cues are reduced.

31.4 STAGER, M*; POLLOCK, HS; SLY, ND; BENHAM, PM; BRAWN, JD; CHEVIRON, ZA; University of Illinois at Urbana−Champaign; *stager2@illinois.edu*

Climatic indices underlying latitudinal patterns in avian metabolic scope

An organism's ability to adjust metabolic performance in response to current selective pressures has clear implications for fitness and adaptation. At the lower limit, basal metabolic rate is the energy expenditure required for self−maintenance at rest; while at the upper limit, peak metabolic rate is an individual's maximum aerobic performance under conditions of physical exertion. The difference between the two, metabolic scope, is an instantaneous measure of an individual's flexibility to cope with the many energetic demands posed by its environment. Metabolic scope has been shown to linearly increase with increasing absolute latitude across fishes and mammals. This pattern has largely been attributed to underlying latitudinal trends in climatic variability, such that individuals in variable temperate zones are likely to exhibit greater flexibility in their physiological response than do those in the less variable tropics. Alternatively, climatic extremes could drive variation in scope via selective pressure on thermoregulatory performance. To differentiate between these two hypotheses, we characterized patterns in avian metabolic scope using data from the literature and tested for associations with climatic variables using both conventional and phylogenetically informed analyses. We found that climatic extremes (i.e. minimum temperature), not climatic variability, are driving interspecific patterns in avian scope. Moreover, we found a tight correlation between scope and peak metabolic rate, indicating that selection is acting on the upper limits of performance. This represents an important step towards illuminating the mechanisms underlying patterns in avian macrophysiology.

P2.46 STALEY, M*; BONNEAUD, C; GIRADEAU, M; MCGRAW, KJ; HILL, GE; Auburn University, University of Exeter, Arizona State University, Arizona State University; *mms0020@auburn.edu*

The epidemiology of Mycoplasma gallisepticum infections in Arizona house finches (Haemorhous mexicanus)

In 1994, the endemic poultry pathogen *Mycoplasma gallisepticum* (MG) was identified as the causative agent of a novel disease in house finches (*Haemorhous mexicanus*) characterized by swollen eyes. This characteristic eye swelling seen in MG−infected house finches permitted researchers to track the spread and impact of this disease. Following the initial outbreak, MG rapidly spread throughout eastern North American house finch populations, killing an estimated hundreds of millions of house finches. However, MG has only reached western North American populations in the past decade and there may still exist populations, particularly in the southwestern United States, that remain unexposed to this pathogen. Following reports of house finches displaying disease symptoms characteristic of MG infection in Arizona, in August 2011 we trapped house finches at bird feeders in Tempe and Tucson to determine if MG had indeed infected these populations. Upon capture, we noted whether a house finch exhibited swollen eyes and then swabbed the bird's throat, which is the main site of MG localization. We tested these swabs for the presence of MG DNA using a polymerase chain reaction (PCR). We observed house finches with swollen eyes only in Tucson and only finches from Tucson tested positive for MG by PCR. Thus, we confirm MG has indeed reached Arizona, though as of 2011 at least some populations remained unexposed to MG. In 2014, we resampled these locations to assess the continued prevalence of MG in the Tucson area and determine whether Tempe populations are still unexposed to MG.

25.1 STAMPER, S. A.; VAGVOLGYI, B. P.; FORTUNE, E. S. ; COWAN, N. J.*; Johns Hopkins University, New Jersey Institute of Technology; *ncowan@jhu.edu*

Closing the Loop Around Free Behavior During Active Sensing

A central challenge in studying the mechanisms for active sensing is that it necessarily functions as a closed−loop system in which the animal modifies its motor behavior based on sensory feedback to alter ongoing feedback. To address this, we have developed an experimental system that allows us to modify and/or open these feedback loops in a freely behaving animal. We achieve this using refuge tracking behavior in weakly electric knifefish: these fish rapidly swim forward and backward to stay inside a longitudinally moving tube−shaped refuge. While following the refuge, the fish continually perform ancillary movements, the characteristics of which depend on sensory conditions. These "active" movements shape sensory feedback for control (Stamper et al, 2012). Here, we take the next step in analyzing the purpose of these behaviors by actively enhancing or suppressing feedback (aka "reafference") caused by these active movements. In our apparatus, the fish's position is measured at up to 100 frames per second using a custom real−time vision system, allowing us to control the refuge in response to fish movements. Using this system, we can experimentally alter (and even temporarily open) the closed−loop feedback experienced by the animal during refuge tracking, allowing us to examine how changes in sensory feedback caused by active sensing alters ongoing motor programs.

84.6 STANTON , DS; University of Florida / Winthrop University; *stantond2@mailbox.winthrop.edu*

Time Enough at Last: Identification and Analysis of Core Clock Proteins and the Evolution of ARNT and PERIOD in the Lower Bilateria

The circadian rhythm is important to all organisms and plays a key role in physiology. Although much is known about the genetic regulation of the circadian clock in *Drosophila melanogaster* and in *Mus musculus*, less is known about the circadian clock in lower metazoans. This study attempts to fill the information gap between Cnidaria and higher metazoans by characterizing the core circadian clock of *Isodiametra pulchra* (Acoelomorpha). *Isodiametra* are marine worms that are exposed to a wide array of daily environmental changes. *I. pulchra* circadian core−clock mRNA sequences were identified by blasting *Drosophila* and *Mus* protein orthologues for CLOCK, CYCLE/BMAL, ARNT, PERIOD (PER), TIMELESS (TIM1), and TIMEOUT (TIM2) identified in NCBI against an *I. pulchra* transcriptome. Three full−length *I. pulchra* sequences and two incomplete *I. pulchra* sequences were identified. *I. pulchra* protein sequences were aligned with other circadian proteins found in a wide variety of organisms identified through NCBI searches and maximum likelihood trees were constructed. The results reveled that *I. pulchra* has an ARNT orthologue, a TIM2 orthologue, and a PER orthologue. Additionally, I examined the variation in mRNA expression at two time points using sqRT−PCR approach for *I. pulchra* ARNT and *I. pulchra* PER. I found that *I. pulchra* ARNT varied in a circadian fashion where expression was highest one hour before lights on, while *I. pulchra* PER did not vary significantly in expression between the two time points. The *I. pulchra* circadian clock is the most primitive bilaterian clock studied to date. I am grateful to the Ladurner lab (Univ. of Innsbruck) and the Reddien lab (MIT) for sharing the unpublished transcriptomes, and to SCINBRE (NCRR 5 P2O RR016461 and NIGMS 8 P20 GM103499).

P2.36 STANTON, DS*; ROGERS, ME; University of Florida , University of Florida; *stantond2@ufl.edu*

Candidatus Liberibacter asiaticus Infection in the Asian Citrus Psyllid (Hemiptera) − An Ecoimmunological Approach

The Asian Citrus Psyllid (*Diaphorina citri*) is an agricultural pest that has significantly reduced citrus production across many countries including the United States. The *D. citri* transmit a plant pathogenic bacterium (*Candidus* Liberibacter asiaticus) that causes Huanglongbing (HLB) − also known as citrus greening disease. With a multibillion−dollar industry at risk, it is imperative that scientists develop more effective HLB preventative measures. It is evident from years of research that prevention and treatment will take a multifaceted approach. Accordingly, we have begun to investigate ecoimmunological questions that might help to better shape strategies for HLB management by better understanding the interaction between the *Ca.* L. asiaticus and the psyllid's hemocyte population. This preliminary study uses traditional blood smear staining techniques for light microscopy to examine morphological differences between the various types of hemocytes and to better characterize the population found within *D. citri*. Here we investigate the proportions of hemocyte types in a hemocyte population of *Ca.* L. asiaticus infected and uninfected psyllids to better understand the innate immune response against this pathogen. Future studies will use fluorescence microscopy to explore the innate immune response to a *Ca.* L. asiaticus infection and characterize the specific interaction between the bacterium and the hemocytes. An improved knowledge of the interactions between the *Ca.* L. asiaticus and the hemocytes of *D. citri* will led to more targeted preventative measures and that may improve HLB control in the future.

53.1 STARK, A. Y.*; PALECEK, A. ; NIEWIAROWSKI, P. H.; DHINOJWALA, A. ; The University of Akron, Integrated Bioscience , The University of Akron, Polymer Science ; *ays3@zips.uakron.edu*

The Effect of Substrate Structure and Roughness on the Gecko Adhesive System

When tested on smooth, dry substrates in laboratory conditions the gecko can achieve upwards of 20 Newtons of force, which predictions suggest is only attaching about 3% of its adhesive hair−like setae. If all setae came into contact with a substrate at once the gecko would have a safety margin of almost 4000%. Clearly this margin is excessive, but why? When considering geckos in their natural environment we can begin to explore several explanations. For instance, the substrates a gecko moves along are likely not clean, often wet, rough and uneven. Previous work has shown that fouling the adhesive toe pads with dirt and water reduces adhesion and additional work suggests that rough surfaces and wet surfaces can also reduce adhesion. Thus taken together the gecko must have a high safety factor to negotiate the unpredictable substrates and conditions they likely encounter daily. To explore the additive effect of multiple challenges to the gecko adhesive system we tested adhesion on patterned substrates in air and in water. In addition, we tested adhesion on microscopically rough substrates that varied in surface wettability in both air and water. Our results show that first, patterned substrates reduce adhesion in water but not in air. Second, there is a critical size−scale related to the adhesive contact area of the setal tip. This minimum adhesion value is further reduced in water. Taken together our results suggest that when utilizing substrates that are not ideal (wet and rough) the gecko must rely on its impressive "over built" design to maintain adhesion, and in some circumstances even this is not enough.

P2.195 STATLER, RL*; STAAB, KL; McDaniel College; *rachel.statler@gmail.com*

The effects of ornamentation on the feeding mechanisms of goldfish

Goldfish, *Carassius auratus*, are a model system due to popularity and ease of obtaining. However, while there are several functional studies on the feeding mechanisms of the common goldfish, there are no functional studies on those goldfish varieties exhibiting ornamentation. Goldfish, a member of Cypriniformes, use a unique mode of premaxillary protrusion during feeding. Differences in eye and fin configurations, as well as body shape, from the common goldfish are known as ornamentation. This ornamentation may include: lateral protrusions of the eye region ("telescope eye") often filled with lymph ("bubble−eye"), hyperplasia of epithelial tissue on the head (a "hood" or "wen"), and even a complete loss of dorsal fin. We investigated several different varieties of goldfish exhibiting ornamentation (black moor, oranda, lionhead, bubble−eye) to find the effects of this ornamentation on feeding. We document the modifications of the musculoskeletal morphology of the feeding apparatus in ornamental goldfish. Analysis of high−speed video allowed us to test our functional hypotheses. Specifically, we tested whether certain varieties rely more on ram vs. suction feeding modes for prey capture. We expected the wen might inhibit premaxillary protrusion and thus have an effect on suction feeding, while the loss of a dorsal fin would impact swimming (and thus ram feeding), requiring these varieties to rely more on suction. We found that underlying musculoskeletal anatomy varied only slightly despite wide variation in ornamentation but that certain ornamental morphologies affected function in aspects unrelated to skeletal anatomy. This suggests overall conservation of important musculoskeletal traits associated with suction feeding, despite widely varying external appearance.

16.5 STAYTON, CT; Bucknell University; *tstayton@bucknell.edu*
Do functional demands structure the morphological diversification of turtle shells?
Do structures that perform a large number of functions diversify more than those which perform fewer functions? There is currently no theoretical consensus on this question, and little empirical study. Classically, additional functions were thought to impose additional functional constraints and decrease phenotypic diversification. More recent theoretical work suggests that additional functional demands can expand the range of optimal morphologies, facilitating diversification. Turtle shells have proven an excellent system for addressing this question. It has been shown that terrestrial clades show greater levels of morphological diversification than their aquatic relatives, lending support for the classical view. Here, I explore whether this increased diversification can be tied to differences in the functional landscape experience by shells of terrestrial species (which must optimize mechanical strength and righting ability and aquatic species (which additionally must optimize shell hydrodynamics). I assessed the functional performance of theoretical shapes located at evenly−spaced intervals throughout shell morphospace, and constructed performance surfaces for each function. Many−to−one mapping was observed for all functions. Some measures, such as mechanical strength and righting ability, showed similar performance surfaces; others, such as strength and hydrodynamics, were nearly perfectly opposed. Multiple optimization methods were used to predict patterns of variation in both groups. Although the terrestrial turtles generally conformed to expectations, aquatic turtles did not show patterns of variation that were predicted based on their shell functions. Either the assumptions of the optimization methods are violated for aquatic turtles, or additional shell functions, beyond those studied, could influence turtle shell evolution.

92.3 STAYTON, CT*; PULASKI, D; Bucknell University, University of Massachusetts, Amherst; *tstayton@bucknell.edu*
The role of the vertebral column in turtle shell mechanical performance
Although primarily composed of the ribs and novel dermal bones, the turtle carapace (the dorsal portion of the turtle shell) also incorporates elements of the vertebral column. The vertebral column in turtles does not play the same locomotor roles as it does in other species, but there is nonetheless extensive variation in vertebral morphology among turtles. In some species, such as the matamata (*Chelus fimbriatus*) the vertebral column is well−developed, with expanded transverse processes and a large cross−sectional area. In other species, the vertebral column is relatively much smaller. We asked whether the vertebrae might function to increase the strength of the carapace, such that modifications in vertebral structure could be linked to changes in functional performance (even though the variation in vertebral structure might not be driven by selection for mechanical performance). We used CT slices to construct two finite element (FE) models of the same *Kinosternon subrubrum* (Eastern mud turtle) specimen − one with a vertebral column, and one without. The models were scaled to the same surface area (the specimen without the vertebral column was originally slightly smaller) and then each was subjected to a series of 200N loads on the carapace. For each load, both stress (von Mises stresses) and deformation were compared between models. The model without a vertebral column did indeed develop higher stresses for nearly all loads, although the difference in stress never exceeded 12%. Similarly, the two models showed slightly different patterns of deformation, particularly for loads directly over the vertebral column. The turtle vertebral column does contribute to the strength of the shell, raising the possibility of future studies investigating the effects of expanding different parts of the vertebrae for enhancing mechanical performance.

P1.195 STEELE, A.L.*; SATHE, E.A. ; HUSAK, J.F. ; Univ. St. Thomas, St. Paul, MN; *stee3641@stthomas.edu*
Mechanisms of sex−specific growth patterns in the six−lined racerunner
In many animal species, individuals of one sex are larger than the opposite sex within a population. This phenomenon, called sexual size dimorphism, poses many mechanistic mysteries because it can arise from a multitude of factors. The sexes can also differ in relative proportions of body parts, called shape dimorphism, regardless of whether body size does or does not differ. Although the sexes often appear virtually identical during early development, they usually undergo highly divergent growth patterns to achieve different adult sizes and shapes. We conducted a study with wild six−lined racerunners to investigate the mechanisms that cause sexual size and shape dimorphism. Adult six−lined racerunners were captured in the wild, and limb, head, and body measurements were taken. We also measured sprint−speed performance to determine if sex differences in morphology manifested in sex differences in performance. Although the sexes did not differ in overall body size, univariate and multivariate analyses showed that males have larger heads and longer limbs relative to their body size than females. This shows that male and female six−lined racerunners exhibit patterns of sexual shape dimorphism, but not sexual size dimorphism. We also found that despite a sex difference in limb morphology, there was no sex difference in sprint speed. This suggests that limb divergence does not result in performance dimorphism, perhaps due to the larger head size of males.

11.7 STEFFENSON, M.M.*; AZZINNARI, J.S.; BROWN, C.A.; FORMANOWICZ, D.R.; Adams State University , West Texas A&M University, Tennessee Technological University, University of Texas at Arlington; *mmsteffenson@adams.edu*
Environmental disturbance and its effects on life−history variation in the scorpion Vaejovis cashi
Life history traits exemplify alternative strategies of organisms used to maximize fitness. Environmental disturbances can cause an organism to change these strategies, resulting in trade−offs. *Vaejovis cashi*, a scorpion species in the Chiricahua Mountains of Arizona, was recently affected by the Horseshoe 2 Fire in 2011. These scorpions acquire their reproductive energy the year prior to giving birth and so individuals collected the year after the fire acquired their energy reserves for reproduction the year of the fire. Gravid females were collected from three regions of the affected area and were curated until they gave birth and their offspring dispersed. The females and offspring were weighed and measured to determine if any life history trade−offs between litter size, offspring mass and size, or female size occurred. By comparing the data from these individuals to data collected the previous year, it was determined that female size was significantly different in all sites, and there was a trend of trade−offs that differed between them. The trend of the least affected site was that litter size and total litter mass was reduced after the fire. In the moderately affected site, there was an increase in litter size and total litter mass, indicating that the offspring were smaller but there were enough of them to exceed the total litter mass of unaffected years. Data here indicate that female scorpions may have changed their life−history strategies in order to maximize their fitness when faced with uncertain environmental conditions.

15.6 STEINWORTH, B*; LAYDEN, MJ; CHOCK, T; ROETTINGER, E; MARTINDALE, MQ; Whitney Laboratory, Univ. of Florida, Lehigh University, Univ. de Nice Sophia − Antipolis; *bsteinworth@whitney.ufl.edu*

Multiple gene regulatory pathways involve Mek signaling in embryonic ectoderm of the sea anemone Nematostella vectensis

To better understand gene regulatory networks controlling neurogenesis in the sea anemone *Nematostella vectensis*, we manipulated levels of the gene *NvashA*, a transcription factor involved in development of a subset of the embryonic nervous system. We assessed expression of potential target genes during the late blastula stage, when *NvashA* is first expressed. Because *NvashA* is downregulated by treatment with Mek inhibitor UO126, we chose transcription factors that showed altered expression level in response to UO126 treatment in a custom genome−wide microarray. Of more than fifty UO126−regulated transcription factors identified by microarray, twenty−three are expressed in a spatial pattern similar to *NvashA*. *NvashA* is expressed in single cells spread throughout the embryonic ectoderm during the late blastula and early gastrula stages, a pattern common to genes involved in neural development. Of these twenty−four candidates, we identified downstream targets of *NvashA* using quantitative PCR and *in situ* hybridization following altered levels of *NvashA*. Interaction with *NvashA* indicates a possible role in gene networks controlling neurogenesis. Nine of the twenty−four transcription factors are unaffected by altered *NvashA* expression levels. These transcription factors may act upstream of *NvashA*, may be involved in processes other than neurogenesis, or may regulate *NvashA*−independent neurogenesis. Future work investigating the effects of manipulating levels of these identified UO126 targets will further illuminate neurogenesis regulatory networks.

70.3 STEPHENSON, T/Q*; DUBUC, T/Q; MARTINDALE, M/Q; Whitney Marine Lab; *tbs5@ufl.edu*

Hox Genes are Involved in Patterning the Oral Aboral Axis in Nematostella vectensis

Hox genes are a set of transcription factors important for axial specification during development in bilaterally symmetrical animals (the Bilateria). The presence of Hox genes in the phylum Cnidaria, an outgroup of Bilateria, suggests that the origin of the Hox code and its function in axial patterning may predate Bilaterian evolution. To investigate the role of early Hox genes in axial patterning, we examined Hox gene expression during early development in the model sea anemone, *Nematostella vectensis*. Using quantitative PCR and *in situ* hybridization, we have determined that axially distinct Hox expression begins earlier in development than previously reported in cnidarians. At blastula stages, the anterior Hox gene Ax6 is expressed in the animal (oral) hemisphere and the maternally loaded posterior Hox gene Ax1 becomes spatially restricted to the vegetal (aboral) hemisphere. We functionally tested the role of Hox gene expression through mRNA overexpression and morpholino knockdown in early developing embryos. Overexpression and knockdown of the anterior Hox genes Ax6 and Ax6a resulted in hypertrophy or abnormal gastrulation and endomesoderm formation, respectively. Knockdown of Ax1 resulted in the absence of the apical tuft and metamorphosis. Our data also suggest the presence of reciprocal interactions between anterior and posterior Hox genes. We are currently investigating the role of signaling pathways that may be under Hox gene control, and generating stable transgenic animals to further identify the role of Hox genes in axial specification. These data demonstrate that Cnidarian Hox genes play an important role prior to gastrulation in the development of the oral−aboral axis and may provide insight into the earliest roles for Hox gene patterning in the bilaterian radiation.

P3.180 STERCULA, J.M.*; PATTON, M.S.; SELZNICK, L.A.; JOHNSON, M.A.; Trinity University; *jstercul@trinity.edu*

The role of myoblast fusion in the evolution of muscle fiber size in Anolis lizards

Interspecific variation in muscle fiber size may result from several mechanisms. For example, muscle fibers may increase in size if a muscle is used more frequently, or with more force; this is known as a "training effect." Alternatively, a species may exhibit larger muscle fibers in adulthood if during embryonic development, a larger number of myoblasts (single−cell precursors to muscle fibers) fuse in the formation of multi−nucleated fibers. Previous work has shown that *Anolis* lizard species vary dramatically in the size of the fibers that compose two muscles: the ceratohyoid (CH), which controls extension of the dewlap (a colorful throat fan used in social displays), and in the retractor penis magnus (RPM), which controls movement of the copulatory organs. In this study, we tested the hypothesis that variation in the CH and RPM fiber sizes results from the fusion of varying numbers of myoblasts. We measured the cross−sectional area of CH and RPM fibers in adult males from 9 species, and because each myoblast contains a single nucleus, we counted the number of nuclei in cross−sections of a fiber as a proxy for the number of myoblasts that fused to form that fiber during development. We found that within 6 of the 9 species, RPM cell size increased in correlation with the number of myonuclei, but CH cell size only increased with the number of nuclei within 4 species. Further, using phylogenetically−informed analyses, our results showed that the evolution of larger RPM fibers is associated with the fusion of larger numbers of myoblasts, suggesting that this is one mechanism of the evolution of larger muscles in anoles. However, this pattern was not seen in the evolution of larger CH fibers, indicating that other mechanisms of muscle growth also occur in this group.

41.5 STEWART, W.J.*; HIGHAM, T.E.; Univ. of California, Riverside; *wstewart@whitney.ufl.edu*

Gecko clinging strength before and after death

Many geckos adhere to surfaces with remarkable strength using toe pads on the bottom of their digits. A single toe pad, consisting of thousands of microscopic and adhesive setae, is capable of supporting a gecko s entire body weight. While the micro−mechanics of these setae are well−studied, our understanding of gecko adhesion at the whole−animal level is limited. It remains unclear whether geckos control the clinging strength of their toe pads, or whether the magnitude of adhesion is passively determined. Considering that a complex tendon system connects the toe pads with limb muscles, we tested the hypothesis that geckos use muscle activity to actively control pad position and the resultant loading of setae. This was achieved with experiments that compared the clinging ability of Tokay geckos (*Gekko gecko*) before and immediately after death. Using a novel device that applied repeatable and steady−increasing pulling forces to the foot in shear, we found that death, surprisingly, did not affect the dynamic adhesive force or motion of a gecko foot when pulled along a vertical surface. Adhesive force was similarly high and variable when the animal was alive (mean±SD = 5.4±1.7 N) and within 30 min after death (5.4±2.1 N). However, kinematic analyses revealed that live geckos are able to control the degree of toe pad engagement and can rapidly stop strong adhesion by hyperextending the toes. These findings suggest that living processes, such as muscle activity, are not required for strong adhesion by geckos.

82.3 STEWART, TA; Univ. of Chicago; *tomstewart@uchicago.edu*
Tinkering and the origin of a new fin skeleton
Phenotypes can evolve by leaps. One mode of saltation is the translocation of tissues or organs from one part of the body to another. Adipose fins (appendages found on many teleost fishes between the dorsal and caudal fin) have repeatedly evolved skeleton in this way lepidotrichia having been coopted into this territory at least four times independently providing a powerful system to explore this phenomenon. To understand the origin of this skeleton, I describe the morphology and development of lepidotrichia in the adipose fin of the redtail catfish, *Phractocephalus hemioliopterus*. Specimens (n=54) ranged in size from 20 to 90 cm standard length and came from wild populations and public aquariums. Adipose fins were x−rayed in lateral aspect. Radiographs were digitized, and adipose fin area and the amount of skeleton in the fin were quantified. The development of lepidotrichia in these fins differs in several ways from what has been described in other fin systems. These lepidotrichia begin to differentiate at the distal tip of the fin, while other lepidotrichia begin to differentiate proximally. These lepidotrichia appear to grow both proximally and distally, while other lepidotrichia are thought to grow only distally. Finally, these lepidotrichia can begin differentiating at multiple sites within the fin, while other fin skeleton begins differentiating at a single location. Adipose fin lepidotrichia are also uniquely variable: rays are wavy, irregular in their thickness, and exhibit no regular pattern of segmentation or branching. The skeleton of *P. hemioliopterus* adipose fins is, thus, among the most variable of all vertebrate appendages. These results imply a lack of canalization, highlight how diverse developmental programs can underlie similar morphologies, and suggest that the identity of serial homologs can be affected by developmental context.

S11.6 STILLMAN, Jonathon H; SF State Univ. and Univ. California, Berkeley; *stillmaj@sfsu.edu*
Transcriptomic responses to warming across the pancrustacea
Mechanisms of the cellular stress response (CSR) are generally conserved, and thus thermal stress typically induces similar suites of genes (e.g., hsps) across a wide range of organisms. However, physiological changes associated with thermal acclimation that lead to shifts in the temperature at which the CSR is induced have the potential to be more varied across taxa, especially as they may be related to differences in eurythermality, thermal optima, respiratory physiology and capacity to avoid oxidative stress. We examined transcriptomic differences associated with acclimation to temperatures at and below the CSR induction in pancrustacean taxa including the water flea *Daphnia pulex* (Branchiopoda), a caddisfly *Dicosmoecus gilvipes* (Hexapoda), three stoneflies *Pteronarcys princeps, Hesperoperla pacifica* and *Calineuria californica* (Hexapoda), two porcelain crabs *Petrolisthes cinctipes* and *Petrolisthes manimaculis* (Decapoda), and the red king crab *Paralithodes camtschaticus* (Decapoda). Our analyses seek to identify genes that are differentially expressed with the same general thermal dependence to make some inferences about fundamental characteristics of pancrustacea, and genes that have lineage specific responses to temperature to look for physiological diversification across the pancrustacea. Specifically, we will test the hypotheses that (1) at critical temperatures a similar suite of CSR genes will be differentially expressed across taxa, but that (2) the genes differentially expressed at temperatures just below those required for induction of the CSR will differ among taxa in a manner related to the evolutionary history or respiratory strategy of each taxon (e.g., whether they are from lineages that are terrestrial or aquatic, or from lineages that are eurythermal vs. stenothermal).

67.4 STINSON, C.M.*; DEBAN, S.M.; Univ. of South Florida, Tampa; *cstinson@mail.usf.edu*
Functional Trade−offs in Aquatic Feeding of Salamandrid Salamanders
When feeding aquatically, salamanders often rely on suction to capture prey; however, in terrestrial habitats jaw prehension and tongue protraction are more common. During suction feeding rapid depression of the hyobranchial apparatus expands the buccal cavity, drawing water and prey into the mouth. Salamandrids exhibit a wide range of hyobranchial apparatus morphologies, regarding robustness and ossification, and utilize a variety of feeding modes in different habitats. Because of morphological differences of the hyobranchial apparatus among species, as well as opposing functions of the tongue skeleton in hyobranchial depression versus tongue projection, we hypothesized that performance trade−offs occur during feeding. We predicted the presence of a robust hyobranchial apparatus, as in *Paramesotriton labiatus* may result in increased performance during aquatic feeding. High−speed imaging and kinematic analyses determined that *P. labiatus* and *Notophthalmus viridescens* suction fed aquatically, but differ in prey capture mode while feeding terrestrially. Kinematic analyses also revealed that feeding performance differs among species in terms of maximal hyobranchial depression and velocity of maximal hyobranchial depression. Generally, we found support for functional trade−offs during feeding of salamandrid salamanders.

12.1 STOCKER, M. R.*; NESBITT, S. J.; CRISWELL, K. E.; PARKER, W. G.; BROWN, M. A.; ROWE, T.; Virginia Tech, Univ. of Chicago, Petrified Forest N.P., UT Austin; *stockerm@vt.edu*
Iterative evolution of archosauromorph body plans through the Mesozoic: Cranial convergence on pachycephalosaurids by a new Triassic archosauriform
Crown archosaurs and their relatives (=archosauromorphs) possess disparate cranial morphologies and body plans, which are unmatched by other contemporary vertebrates in the Mesozoic. General body plans of Triassic archosauromorphs (e.g. azendohsaurids, shuvosaurids, aetosaurs) were repeated by other archosaurs (e.g. early sauropodomorphs, ornithomimids, ankylosaurs) later in the Mesozoic. Here we present a case of convergence between a new archosauriform from the Late Triassic of Texas and Cretaceous pachycephalosaurid dinosaurs. Like pachycephalosaurids, this specimen preserves a thickened skull roof with obliterated cranial sutures, an expanded posterior skull margin, and large orbits. CT data reveal large, laterally expanded olfactory bulbs and a complete left osseous labyrinth. The anterior semicircular canal has the largest diameter of the three, indicating increased sensitivity to changes in pitch. Our cladistic analysis of Archosauromorpha recovers this taxon as an archosauriform based on the presence of an antorbital fenestra and associated fossa in the lacrimal and an ossified laterosphenoid. The similarity between this taxon and pachycephalosaurids over 100 million years later illustrates the early exploration of cranial morphospace. Distinctive ecomorphological modifications of Jurassic and Cretaceous dinosaurs increasingly are represented in Triassic archosauromorphs, implying that faunal and ecological shifts interpreted to occur among dinosaurs later in the Mesozoic possibly occurred much earlier during the Triassic archosauromorph radiation.

19.3 STOFFER, B*; UETZ, G W; University of Cincinnati; *stoffebm@mail.uc.edu*

Experience matters: The effects of the social environment on mate choice plasticity in a wolf spider

Females may be able to assess the availability or quality of males in the population prior to choosing a mate and adjust their preferences. For example, if males are abundant, of high quality, or the sex ratio is male−biased, females may become more selective. We tested whether female *Schizocosa ocreata*, the brush−legged wolf spider, demonstrated mate choice plasticity by using video and/or vibratory playback to simulate conditions in their social environment. First, we manipulated the perceived availability of males in order to tease apart whether the number of males simultaneously encountered or the encounter rate best predicted female selectivity. Instead, the total number of males that females saw as juveniles best predicted female selectivity for tuft size (a secondary sexual character). Second, females were presented with males of varying quality (small tufts, average tufts, or large tufts) in order to test the effects of visual imprinting. Females imprinted upon males of a particular quality, even demonstrating preferences towards low−quality males with small tufts if they saw only these males as juveniles. Finally, we tested whether females would demonstrate stronger preferences towards unimodal signals (vibratory or visual) depending on different sensory experiences with courting male signals (vibratory only, visual only, or both). Females were more receptive towards the unimodal signal that they experienced as juveniles. However, all females preferred multimodal signals, regardless of previous sensory experience. Thus, an adult's mating decision can clearly be impacted by a variety of conditions in the individual's social environment.

88.1 STOVER, KK*; BRAINERD, EL; ROBERTS, TJ; Brown University; *stokris@gmail.com*

Supersize me: Extreme body mass in domestic turkeys influences locomotor mechanics.

As a result of selective breeding, domestic poultry grow very rapidly and reach elevated body masses. The turkey, *Meleagris gallopavo,* has been bred to massive proportions, with some broad−breasted white (BBW) strains reaching over 24 kg at adulthood, while wild turkeys reach only 8 kg on average. It is reasonable to predict that this dramatic increase in body mass should affect locomotor biomechanics, and indeed, a prior study noted large lateral oscillations during walking in domestic turkeys. This "waddle" has been attributed to the need for domestic turkeys to bring their heavier bodies squarely over the stance foot for balance. The goal of this study is to understand how the lateral oscillations affect the ground reaction forces and gait kinematics of domestic turkeys. Five wild and five BBW turkeys locomoted down a trackway with a force plate positioned midway. The domestic turkeys' average speed was very slow, 0.48 m s^{-1} compared to the wild turkeys, 1.93 m s^{-1}. BBW's average peak vertical force was 1.04 times body mass, much lower than even their domestic poultry counterpart, the broiler chicken. Mediolateral forces were significantly higher in the BBWs at any given speed ($P< 0.001$), while fore−aft forces were significantly lower than wild turkeys ($P= 0.012$). Normalized step width was larger in both wild and BBW males compared to females ($P=0.013$, $P=0.030$, respectively), however step length was not different. These results indicate that artificial selection for increased body mass results in locomotor changes that are apparent in the ground reaction force signature and influence fundamental mechanics, such as the motion of the center of mass.

21.7 STOWERS, AK*; LENTINK, D; Stanford University; *astowers@stanford.edu*

Passive wing morphing as a consequence of centrifugal acceleration in flapping wings

Birds, bats and insects are able to maneuver in cluttered environments that are practically impossible for flying robots to navigate. In these situations, animals are able to morph their wings in complex manners to avoid collision or damage. From dynamic analysis and robotic experiments, we predict that the combination of flapping wings and a wrist joint may aid in the wing's recovery from obstacle impact. During flapping flight, centrifugal accelerations drive wings to unfold to their full wingspan without requiring use of muscles and tendons. This enables wingspan recovery using minimal effort. We demonstrate this effect in a 40 cm wingspan robot flapping in the range of 5−17 Hz. The robot has two flapping wings and is constructed with an unactuated joint at the wrist allowing the wings to passively adjust sweep angle in response to disturbances. Experiments show that following impacts, or after release from being held shut, the flapping wing will passively unfold within one to two flaps. A model based off the inertial properties of the wing during flapping predicts this unfolding is caused by centrifugal acceleration of the hand wing. For the wing amplitudes and fold ratios of bird, bat and insect wings, our model predicts that their wings can recover passively from impact in approximately one half to one full wingbeat.

P3.122 STRADER, M/E*; MATZ, M/V; the University of Texas at Austin; *stradermarie@gmail.com*

Coral larval fluorescence as an indicator of dispersal potential

In broadcast spawning reef−building corals, the length of the larval competency period and the rate of lipid depletion both contribute to a larva's ability to disperse to new environments. Coral larvae also expend their limited energy reserves to produce costly GFP−like fluorescent proteins (FPs), however the biological function of FPs in this stage is unknown. Fluorescence has been suspected to play a role in dispersal potential since a previous study showed that fluorescent color morphs settle at different proportions after early exposure to settlement cue, suggesting red morphs are primed for long−distance dispersal. To further investigate the possible link between fluorescence and dispersal potential we measured larval fluorescence, settlement competency, lipid content and global gene expression throughout thirteen days post−fertilization in *Acropora millepora*. Expression of FP genes is tightly regulated throughout larval development, but the best correlations with larval competency were observed not at the transcript abundance level but at the protein level (assessed by fluorescence intensity). There are also differences in expression between the different colored FPs (red, green and cyan) through time, suggesting that each may play a unique functional role during the larval stage. Global gene expression changes through time were subject to weighted gene co−expression network analysis to elucidate molecular pathways that are co−regulated with changes in FPs, giving insight into the possible biological function of coral FPs through this critically important life−history stage.

P1.87 STRASBURG, ML*; MARTIN III, AL; Saginaw Valley State University; *mlstrasb@svsu.edu*

The Effects of Hypoxia in the Crayfish, Orconectes rusticus

Many different aquatic species exhibit changes in behavior when exposed to hypoxic waters. Crayfish are a highly diverse species that are found in a variety of waters both hypoxic and normoxic. Crayfish experience adverse physiological effects in hypoxic waters, but it is unknown if crayfish exhibit a preference to areas with higher oxygen concentrations. The purpose of this study was to analyze the responses of the crayfish, *Orconectes rusticus*, when exposed to varying levels of oxygen. Each animal was placed in a y−maze (working section: 30.5 x 61 x 30.5cm, arms: 30.5 x 43 x 30.5cm) with each arm containing water of different oxygen concentrations, ranging from 1 to 6 mg O_2/l. A current of 10 cm/sec was streamed through each arm of the y−maze. After each set of initial trials, data was analyzed based on initial arm choice, time spent in each arm, and time spent at the furthest upstream position. When the results showed significant preference, a new scenario was designed with a narrower margin of difference between oxygen levels. In contrast, when results illustrated no preference, the crayfish were presented with a wider margin of difference, for subsequent trials. This allowed us to determine if *Orconectes rusticus* exhibits an oxygen preference, thus demonstrating its potential habitat selection based on a range of oxygen levels.

P1.60 STRATHMANN, R R*; OYARZUN, F X; BRANTE, A; Univ. of Washington, Univ. de Concepcion, Univ. de Concepcion de la Santisima; *rrstrath@u.washington.edu*

Regulation of Particle Capture by Swimming Veligers and Trochophores; Differences in Metatrochal Behavior

In molluscan and annelid larvae that feed with opposed ciliary bands, a preoral prototrochal band of long cilia creates a current for both swimming and feeding. A postoral metatrochal band of shorter cilia beats toward the prototroch and aids capture of food particles. The larvae regulate particle capture while swimming in water with non−nutritious particles or with satiating concentrations of food. Larvae of a gastropod reduced but did not stop capture of algal cells while swimming with the velum extended. In observations thus far, arrests of the metatrochs were less obvious in mollusc larvae than in annelid larvae (Polygordiidae, Serpulidae, Capitellidae). The molluscs' metatrochs arrested while cilia were in several positions of the beat cycle, whereas metatrochs of the annelids arrested with cilia aligned. Continued observations are testing the hypothesis that metatrochal behavior is similar within molluscs and annelids but different in the two phyla. If the opposed band feeding mechanism originated separately but only once in each phylum, then consistent differences between phyla in metatrochal behavior would be expected. If the opposed band mechanism arose several times within each phylum, consistent differences would not be expected.

P1.75 STREETS, A.M.*; BIERMAN, H.S.; SOARES, D.; CARR, C.E.; Univ. of Maryland, College Park, New Jersey Inst. of Technology; *astreets@umd.edu*

Evolution of the Cochlear Nuclei Circuitry in the Alligator

Animals evolved nervous systems that can detect specific physical features of their environment. Localization of sound in space is important in vertebrates, who use the information for communication and predator detection, and thus they have evolved nuclei in the auditory brainstem that encode cues for localization well. The circuitry and connections of these nuclei have been well studied in mammals and birds. Crocodilians are a particularly interesting group to study because they have not changed morphologically in millions of years, and are a sister group to birds. Further, crocodilians, including the *Alligator mississippiensis*, live in acoustically challenging environments and have well developed vocalization repertoires. This project examines the projections of the auditory nerve to the primary auditory brainstem nuclei. We used anatomical techniques including immunohistochemistry and neuronal tract tracing to map out the pathway of the auditory nerve. Since these nuclei have been shown to be present in all archosaurs, results provide insights into the evolution of sound localization. Any differences or similarities in connectivity will shed light on the ancestral condition of the group.

37.1 STROTHER, J.A.*; NERN, A.; ROGERS, E.; REISER, M.B.; Janelia Farm Research Campus, HHMI; *james.a.strother@gmail.com*

Visualizing fly vision: using calcium imaging of neuron populations to unravel motion vision in fruit flies

Visual perception of object motion is critical to countless animal behaviors. Flies exhibit a rich repertoire of visually mediated behaviors and have emerged as a powerful model system for examining the neural computations underlying motion vision. Using genetically−encoded fluorescent calcium indicators and two−photon microscopy, we recorded the population−level activity of neurons in the neuropil responsible for motion vision, the medulla, in *Drosophila melanogaster*. We found that the individual layers of the medulla respond selectively and characteristically to either light increments or decrements across a wide range of visual stimuli. In order to identify the origin and scope of this selectivity, we then recorded the activity of specific upstream and downstream neurons in response to the same stimuli. Our results provide direct evidence that motion vision in flies is computed in two parallel and largely independent pathways, one that is selective for light increments and one that is selective for light decrements.

P1.94 STURGILL, M.L.*; VIAR, S.J.; JACOBS, M.W.; McDaniel College; *mls007@mcdaniel.edu*

Conspecific Predation Increases Hiding Behavior in Dragonfly Larvae

Populations of dragonfly larvae are subject to conspecific predation and heterospecific predation. These predatory larvae have acute perception to motion, usually remaining immobile until potential prey is detected. Likewise, changes in activity level and hiding behavior are common predator avoidance behaviors. We measured larval behavior in the presence of caged conspecific predators, caged heterospecific predators, or in the absence of predators (control) in the field using floating behavioral arenas, with two rock refuges present in each arena. Time spent hiding and activity level per trial were measured for each individual by recording larval position every ten minutes over a two−hour period. Activity level did not vary among the treatments, but we observed a significantly higher percentage of hiding in conspecific treatments compared to heterospecific and control treatments. Dragonfly larvae have excellent vision; thus hiding may be a more effective method than immobility in the face of conspecific predation. If dragonfly larvae are still able to forage effectively near hiding places, then hiding may also be less costly than an overall reduction in activity level.

P2.178 SUI, J*; MERZ, R.A.; Swarthmore College ; *justinsui93@gmail.com*

Hooking and Sheeting: strategies used by Haminoea vesicula to maintain stability on different substrates

Many marine gastropods face the challenge of adhering to substrates under adverse flow conditions. Some species live on both solid and sedimentary substrates, although how these substrate generalists resist detachment from materials with fundamentally different mechanical properties is not well studied. We used field observations and flow tank experiments to compare the capabilities and tactics of Haminoea vesicula, an opisthobranch gastropod, when exposed to destabilizing flow on its native sand and eelgrass. Velocities of outgoing and incoming spring tides in the tidal creeks and over and within eelgrass beds where H. vesicula live at False Bay, San Juan Island, WA ranged from 1 to 30 cm/s. In a flow tank, snails' response to current depended on substrate and orientation. On eelgrass, snails moving into flow maintained their position at velocities exceeding 40 cm/s, but were more vulnerable when facing away from or sideways to flow (falling off at mean velocities of 25 and 32 cm/s respectively). In the latter orientation, snails often rotated into flow by hooking onto the leading edge of eelgrass with the anterior edge of their cephalic shield. In this position, snails resisted flows exceeding 40 cm/s. Snails crawling on sediment and exposed to turbulent flow drew sediment−encrusted mucus sheets dorsally, completely ensheathing their bodies. "Sheeting" significantly increased snails' effective weight and ability to resist flow. On sand, snails ensheathed in sediment were least stable in the sideways orientation compared to those facing into or away from flow (mean velocities of 13 vs. 20 and 23 cm/s). Experiments on sandpaper indicated that snails were destabilized on sediment due to failure of adhesion of the sedimentary layers beneath them rather than their attachment to the sand.

P1.6 SULLIVAN, EM*; HANEY, RA; GARB, JE; University of Massachusetts Lowell; *erin_sullivan@student.uml.edu*

An investigation of cold−stunning in Kemp's ridley sea turtles using high−throughput gene expression profiling

The Kemp's ridley (*Lepidochelys kempii*) turtle is the smallest and most endangered of all sea turtle species. Each year, juvenile Kemp's ridleys strand in Cape Cod, MA (USA) due to mass cold−stun events. Many of these animals are triaged and rehabilitated at the New England Aquarium (Quincy, MA), providing an opportunity for comparative investigations between cold−stunned and rehabilitated turtles. Utilizing blood cells as a source of RNA, we are examining gene expression levels for turtles while in a hypothermic state. Within 12−18 weeks thereafter, the same analysis is being conducted for turtles in a convalescent condition. RNA−seq allows for *de novo* assembly of a transcriptome in the absence of a sequenced *L. kempii* genome. This reference transcriptome allows for gene expression comparisons and the identification of genes that are relevant to the clinical treatment of these animals, such as cold tolerance thresholds or predictors of susceptibility to pathogens. Investigating gene expression in endangered sea turtles may lead to better accuracy in clinical treatments, informing the conservation of this vulnerable species.

S2.10 SUSKI, Cory/D*; COOKE, Steven/J; University of Illinois, Carleton University; *suski@illinois.edu*

Linking landscape−scale disturbances to stress and condition of resident fishes: implications for restoration and conservation

Human activities that alter land use, such as urbanization and increased agriculture, can negatively impact habitat for resident organisms. More importantly, habitat choices have physiological consequences for organisms, and sub−optimal habitats can lead to increased energy expenditure or chronic stress that can cause negative outcomes for individuals populations. Fish have been well studied in terms of habitat use and selection with much research on physiology and environmental relations in a laboratory context. Less common are efforts to explore physiological and energetic consequences of habitat selection in the wild. The use of sub−lethal physiological tools can provide novel insights into how both land use and habitat types impact individual fish. With the imperiled and threatened status of many freshwater fishes, there is a critical need to define relationships between land use, habitat quality and physiological performance for resident fishes to aid with restoration and habitat analyses. The objective of this study was to relate variation in land use at the watershed scale to the physiological properties of resident fishes. For this, we used both an extensive, as well as an intensive, approach, coupling field observations, standardized stress sampling, and physiological sampling across a range of land uses. Results demonstrate the value of natural areas in facilitating the physiological condition of resident fishes. Results are further discussed in the context of habitat restoration.

104.2 SUSTAITA, D*; GATESY, SM; ROBERTS, TJ; Brown University; *diego_sustaita@brown.edu*
Reconciling variation in moment arms and measurement techniques of Emu toe joints
Moment arms are integral to understanding how muscle forces power limb movements. Two common approaches for measuring moment arms are the tendon excursion (TE; the distance a tendon moves past a joint, as a function of joint angle) and the geometric method (GM; the linear distance between the tendon and the center of joint rotation). Although TE has the advantage of circumventing the difficulty of identifying the joint center, it may not adequately account for complex joint geometries. For instance, if the path of a tendon in a toe is altered during flexion−extension in ways that increase travel length without actually contributing to the phalangeal in−lever, then TE and GM may not measure the same thing. We used TE and GM to measure (in 3D from CT) the moment arms of the combined M. flexor hallucis and digitorum longus tendon at the tarsometatarso−phalangeal (TMTP) joints of an Emu foot. The TE−derived moment arms were similar across all toes, despite the apparent variation in TMTP joint condyle diameters. Conversely, the GM−derived moment arms reflected differences in condyle size. Although both methods agreed for the middle toe, TE produced considerably larger moment arm estimates than did GM for the inner and outer toes. The oblique orientations of the TMTP condyles of the side toes, coupled with the effects of cartilaginous pulleys at the bases of the proximal phalanges, dynamically change the positions of the flexor tendon branches relative to the joints. As a result, tendon excursion may be increased proximal to the TMTP joints, without any ostensible effect on the moment arms measured just distal to them. We further discuss this phenomenon, and explore the potential functional implications of the apparent similarity in TE, and discrepancies in GM, moment arms across toes.

S6.10 SWADDLE, J P*; KIGHT, C R; College of William and Mary; *jpswad@wm.edu*
Noise pollution and understanding song in anthropogenic environments
Vocal responses to anthropogenic noise have been documented in a growing number of songbird species. It is important to understand whether these song adjustments are primarily proximate changes reflecting developmental plasticity and/or behavioral flexibility, or longer−term ultimate consequences of selection on vocal performance. Few studies have investigated these differences. Furthermore, human noise pollution is often accompanied by structural changes to the habitat, including the introduction of noisy roadways and the removal of native vegetation. To date, no studies have simultaneously investigated the impact of both acoustic and structural disturbance on the same species. The relevance of each of these variables must be quantified if we wish to refine our understanding of the ways in which human activities influence avian communication via noise pollution. We report a study of breeding eastern bluebirds (*Sialia sialis*) that quantifies both among− and within−male song adjustments in response to ambient noise, and also investigated whether anthropogenic habitat modifications explained variations in song parameters. We found that males in noisier sites produced both higher−pitched and louder songs than birds in quieter areas. Likewise, individual males demonstrated immediate adjustments to noise disturbance, increasing their song amplitude between periods of quiet and loud ambient noise. Both spectral and temporal aspects of a male's song were related to whether his habitat was more natural' or anthropogenic.' These results indicate that male song adjustments may represent simultaneous and flexible responses to multiple human habitat modifications. We suggest that human habitats provide an ideal setting in which to perform natural experiments' on animal behavior and cognition.

P2.138 SWANSON, E.M.*; LARDNER, C.K.; MILLS, I.; BAKEN, E.; SNELL−ROOD, E.C.; Univ. of Minnesota, Twin Cities, Univ. of Minnesota, Twin Cities; College of William and Mary; *eliswanson@gmail.com*
Evolution of hormonal pleiotropy and life−history trade−offs in butterflies
Trade−offs between the future well−being of an organism and investment in offspring represent a hallmark of biological diversity. Despite a long history of interest in life history trade−offs, most related research has focused either on the evolutionary reasons to expect certain trade−offs, or the physiological mechanisms that mediate individual life history traits over ontogeny. Recently, researchers have suggested that hormones may mediate the life history trade−offs themselves, and that the pleiotropic nature of hormones may have consequences for the rate of evolution of individual life history traits. Specifically, it is unclear whether the fact that individual hormones play an important role in mediating multiple life history traits simultaneously represents an adaptation to certain consistent evolutionary patterns in life history traits, a limitation on the rate of independent evolution of life history traits, or an unavoidable result of a limited number of available physiological mechanisms. We are testing these hypotheses here by comparing statistical relationships between endocrine and life history traits within species to those among species in a comparative phylogenetic context to understand how the role of endocrine variation within species translates to relationships among species. We are also currently using quantitative RT−PCR to measure a variety of molecular signals, including endocrine traits and transcription factors, to further test these hypotheses.

P3.190 SWEETSER, PW*; HILTON, EJ; College of William and Mary, Virginia Institute of Marine Science; *peter.william.sweetser@gmail.com*
Osteology of the Crescent Gunnel, Pholis laeta, as a baseline for an analysis of the phylogenetic relationships among species of the family Pholidae (Cottiformes: Zoarcoidei)
The gunnels, of the family Pholidae, form a group of 15 species of generally small, elongated, laterally compressed, blenny−like fishes. They are found throughout the intertidal and coastal zones in the North Pacific and North Atlantic oceans. They are currently recognized in three genera: *Pholis* (11 species), *Apodichthys* (3 species), and *Rhodymenichthys* (1 species). These fishes are unique in possessing haemonephropophyses, which are structurally similar to haemal arches and spines, but are found throughout the abdominal region (i.e., from the third centrum posterior to the caudal region of the vertebral column). Previous comparative and phylogenetic studies of this family have suffered from a lack of sufficiently detailed fundamental morphological data. In this study, we provide a complete description of the osteology of *P. laeta*, a member of the family found in the North Pacific from the Yellow Sea to Washington State, USA, based on cleared and stained specimens and x−rays. In addition to staining and x−rays of *P. laeta*, anatomical comparisons were made to other species of the family. We discovered new morphological characters, including significant taxonomic variation in the insertion pattern of anal−fin pterygiophores between haemal spines. In a preliminary systematic analysis, the family was well supported as a monophyletic group, and the three genera were each recovered as monophyletic as well, although the phylogenetic resolution within the genera was poorly resolved.

78.2 SWENARTON, M.K.*; JOHNSON, E.G.; AKINS, J.L.; University of North Florida, Reef Environmental Education Foundation; *mk.swenarton@unf.edu*

Population biology differences in lionfish (Pterois volitans/P. miles) from northeastern and southeastern Florida

The invasive Indo−Pacific lionfish (*Pterois volitans* and *P. miles*) is currently established in the Western Atlantic, Caribbean Sea, and Gulf of Mexico. As managers formulate plans to mitigate the harmful impacts of this invasive species throughout its' range, the collection of regional life history information, which is sparse to date, is pertinent to predicting the response of lionfish populations to management initiatives. In order to elucidate potential life history differences that exist throughout their invaded range, lionfish were collected from a previously unstudied region, the southern South Atlantic Bight (n=3969), and the Florida Keys (n=792) throughout 2013 and 2014 in coordination with multiple lionfish derby events. Population structure was analyzed by fitting a statistical length−based model to the observed total length frequencies in each region. Increased variation in the fish length−at−ages from Florida Keys indicate lionfish juveniles are recruiting over a broad time scale and the reproductive season may be prolonged in that region, relative to their northern conspecifics. Ongoing analysis will quantify differences in growth, age, time of spawning, and size at maturity by region. Our present and future findings will provide urgently needed information on life history parameters for this species, aiding resource managers seeking to more effectively control the species by accurately predicting the effect of removal initiatives on the population.

P1.28 SWORE, J*; KOHN, A; SWALLA, B; MOROZ, L; University of Washington, Friday Harbor Labs, University of Florida,, University of Washington, Friday Harbor Laboratories, University of Florida, Whitney Laboratories; *jjswore@uw.edu*

Origins of Ionotropic Glutamate Receptors: insights from the basal metazoan Pleurobrachia bachei

Ctenophores are predatory gelatinous zooplankton which swim by beating eight rows composed of fused cilia. The recent publication of two ctenophore genomes, Pleurobrachia bachei and Mnemiopsis leidyi, has brought to the forefront molecular evidence that suggests ctenophores branched off from other animals near the base of the metazoan. Genomic data also uncovered the unusual characteristics of the ctenophore P. bachei nervous system. The evidence available suggests that ctenophores use a single canonical neurotransmitter, glutamate, to control their complex predatory behavior. Ctenophores exhibit an expansion of ionotropic glutamate receptors (iGluRs) that have undergone various molecular modifications after gene duplication. Phylogenetic studies show that these receptors are not associated with the common clades of AMPA, Kainate, NMDA and other phyla's iGluRs from other other phyla. These receptors exhibit variable expression in ctenophore adults and embryos. Limited data suggests that glutamate is functional in the animal. However it is unclear in which cells glutamate is signaling. We are continuing to use a molecular and genomics approaches to ask how ctenophores have evolved variability in their iGluRs. We have identified three conserved domains in the P. bachei iGluRs, but only one conserved motif among other animal phyla. We also explore expression patterns of these iGluRs within P. bachei with parallel Phalloidin and Antibody staining of tyrosylated tubulin immunofluorescence to aid in identification of iGluR expression patterns within the muscles and neurons of P. bachei. Our findings suggest that Ctenophores use iGluRs in both neurotransmission and signaling muscle fibers. This new data will contribute to understanding the evolution of animal nervous systems

P3.66 SYLVIA, K.E.*; DEMAS, G.E.; Indiana University, Bloomington; *ksylvia@indiana.edu*

Effects of a Neonatal Immune Challenge on Reproductive Development and Associated Behaviors in Siberian Hamsters (Phodopus sungorus)

Early life environmental stressors have the potential to disrupt development in ways that could severely impact fitness. However, the mechanisms by which the stressors affect reproductive physiology and behavior are not well understood. The timing of an environmental stressor is critical in determining the effect on an organism's life, and treatment with lipopolysaccharide (LPS), a cell wall component of gram−negative bacteria, is commonly employed to induce an immune response. Despite what is known about the effects of sickness on reproduction, the precise physiological mechanisms have not yet been determined. The goal of this study was to investigate the effects of a neonatal immune challenge on subsequent adult reproductive physiology and associated behaviors, and the possible neuroendocrine mechanisms mediating these effects. Hamsters were housed in a 16:8 light:dark photoperiod and received LPS or saline injections on pnd 3 and 5, as there is heightened sensitivity of the GnRH pulse generator at these time points. Body mass and food intake were tracked throughout the study. Vaginal patency (females) was recorded and estimated testis volume (males) was calculated to track onset of reproductive maturity. Animals were placed in staged mating pairs with reproductively mature individuals of the opposite sex at pnd75, during which a series of behaviors were scored. Animals treated with LPS showed changes in food intake, body weight, and reproductive organ mass, as well as timing of reproductive maturity. Reproductive behaviors and other associated social behaviors were affected by LPS injections. Collectively, the results of this study will contribute to a greater understanding of how the neuroendocrine and immune systems interact during development.

P2.24 SZEJNER−SIGAL, A*; WILLIAMS, C.M.; MORGAN, T.J.; HAHN, D.A.; Univ. of Florida, Univ. of California, Berkeley, Kansas State Univ. ; *aszejner@ufl.edu*

Does artificial selection for cold hardiness also drive growth rates in the fly Drosophila melanogaster?

Temperature can directly affect ectotherm life cycles, especially development. Ectotherms at high altitudes/latitudes experience cold temperatures and short growing seasons, and must develop quickly given seasonal time constraints. Ectotherms living at high altitudes/latitudes often have high metabolic rates relative to related organisms from lower altitudes/latitudes, a pattern termed metabolic cold adaptation. Because high metabolic rates are often positively correlated with high growth rates, the need to develop quickly in seasonally constrained habitats, a pattern termed countergradient variation, is often considered to be the major selective factor driving the metabolic cold adaptation. However, selection for high metabolic rates in seasonally constrained habitats is likely multifarious and driven by factors beyond growth rates and development time. In previous work we have shown that artificial selection for fast recovery from chill coma, a trait that should also be under selection at high altitudes/latitudes, also drives the evolution of higher metabolic rates across lines of the fly *Drosophila melanogaster*. Here we test whether selected lines with faster recovery from chill coma and higher metabolic rates also have faster development times and higher growth rates by rearing flies from egg to adult at four different temperatures (15, 20, 25, and 29^{o}C). Our work suggests that to understand the evolution of altitudinal/latitudinal patterns in life history traits such as growth rates and development times, one must also consider how selection on other traits, like hardiness to short−term cold exposures that are also frequent at high altitudes/latitudes, may facilitate or constrain life history evolution.

99.4 TAFT, NK; University of Wisconsin−Parkside; *taft@uwp.edu*
Variation in stiffness of the lepidotrichia among the paired and median fins of yellow perch
Actinopterygii are named for the bony fin rays (lepidotrichia) that define the shape and function of their fins. Despite this, little is known about how these properties vary among the fins within individuals. I used three−point bending tests to measure the stiffness of the fin rays among fins of yellow perch, *Perca flavescens*. Yellow perch are benthopelagic; they swim in the water column, but also use their pelvic fins to rest and interact with the substrate. I tested every other fin ray from the pectoral, pelvic, soft dorsal, anal fins from multiple individuals. Each fin ray was tested at three locations, one−third (proximal), one−half (middle), and two−thirds (distal) the distance from the proximal end of each ray. Bending tests were conducted at a rate of 4mm/ minute to a maximum displacement of 0.8mm. The absolute maximum forces required to displace the rays ranged from 0.01 to 3.25 N. I calculated stiffness by dividing maximum force (N) by the displacement at which maximum force occurred (mm). All fin rays tested were most stiff proximally and least stiff distally. The paired fins exhibited the most extreme trends in stiffness; the pelvic fins were significantly more stiff than those of all other fins and the pectoral rays were much less stiff. The dorsal and anal fins were not significantly different from one another, and were intermediate in stiffness between the pelvic and pectoral fins. The rays at the edges of all fins were stiffer than those in the center. There was also a trend for rays near the leading edge to be slightly more stiff than those of the trailing edge. This contrast in stiffness between the paired and median informs our understanding of how the material properties of individual fin rays affect whole−fin function.

P2.169 TAKYI−MICAH, M*; SANTHANAKRISHNAN, A; Oklahoma State University; *askrish@okstate.edu*
Currents Induced by Cassiopea Jellyfish: Effects of Bell Size and Interactions with Background Flow
Patchy aggregations of *Cassiopea* medusae, commonly referred to as the "upside−down" jellyfish, are seen in sheltered marine environments such as mangrove forests and coral reefs in shallow regions saturated with sunlight. They exhibit a sessile, non−swimming lifestyle, and are oriented such that their bells are attached to the substrate and oral arms directed toward the free surface. Pulsations of their bells drive flow toward and away from the body, assisting in filter feeding and for exchange of inorganic and organic matter across the water column. While several studies have examined the basic functional morphology and fluid interaction in individual *Cassiopea*, the effects of body size and background flow on currents generated by these medusae are unclear. We investigate the effects of body size and background flow on currents generated using three experimental approaches. Bell pulsation kinematics was quantified from digitized videos. Fluorescein dye introduced underneath the substrate via gravity feed was used to investigate release of porewater via bell motion. Quantitative flow visualization studies of *Cassiopea* currents were conducted using 2D high−speed particle image velocimetry (PIV). The medusae were introduced in a low−speed recirculating water tunnel to replicate the background flows observed in their natural environment. The results of the study suggest an inverse dependence of bell diameter on pulsing frequencies and peak induced jet velocities. Vertical mixing of medusa−induced jets were observed in the presence of background flow. The implications of the study findings on organism−induced mixing in nearly quiescent flow habitats will be presented.

73.7 TAN, M.*; STOUT, C.C.; LEMMON, A.R.; LEMMON, E.M.; ARMBRUSTER, J.W.; Auburn University, Florida State University, Florida State University; *miltontan@auburn.edu*
Phylogeny of Paedomorphic Fishes of Cypriniformes Using Anchored Phylogenomics
The phylogenetic relationships of certain paedomorphic members of the Cypriniformes (specifically the genera *Paedocypris*, *Danionella*, *Sundadanio*) have been challenging to infer. These three paedomorphic genera all have a miniature body size and share the loss of numerous bones; morphological study suggests that these paedomorphic taxa form a single clade. On the other hand, multiple molecular studies have presented conflicting relationships with high support; molecular phylogenetic studies that included mitochondrial sequences unite *Paedocypris* and *Sundadanio* as sister genera, while a study that included only nuclear loci place these three genera in disparate parts of the phylogeny. To address this difficult phylogenetic problem, we utilized Anchored Phylogenomics sequence capture to enrich 393 loci in these fishes and other Cypriniformes for a phylogenomic−scale study. Our analysis revealed that *Paedocypris*, *Danionella*, and *Sundadanio* do not form a clade, and thus paedomorphism evolved multiple times within the Cypriniformes.

P3.64 TAN, X; SUKHARAN, D*; BASTIAANS, E; ZUK, M; Univ. of Minnesota, Twin Cities; *ejbastiaans@gmail.com*
Effect of immune challenge at varied life history stages on male courtship song in a cricket
Male crickets attract females by singing a species−specific song. A different song, called courtship song, is used at close range, and may indicate a male's individual characteristics in addition to his species identity. Earlier work found that female crickets preferred longer courtship songs with longer trills and shorter intervals between pulses. At the same time, males with longer trills seem to pay a price via a less vigorous immune response and lower sperm viability. This supports observations from other studies that there is a tradeoff between immunity and reproductive effort. Because older crickets may be more likely than younger crickets to invest more energy into attracting mates than on sustaining themselves, we expect that the older crickets would sing songs with longer trills and shorter intervals as compared to younger crickets. Our research centers on the study of the Pacific Field Cricket, *Teleogryllus oceanicus*, and how its courtship song changes when immune challenged at different life stages. Using these results, we can then evaluate how the crickets' resource allocation strategies vary during development to maximize individual fitness, the two major factors of which are reproduction and individual survival.

P3.153 TANG, HK*; KLAASSEN VAN OORSCHOT, B; TOBALSKE, B; Mount Holyoke College, University of Montana; *tang24h@mtholyoke.edu*

Emarginate Primary Feathers: Form and Morphing in a Comparative Framework

Slotted primary feathers are thought to minimize lift−induced drag during translational bird flight. However, recent research has revealed that instead of increasing efficiency during translational flight, such feathers may have a more prominent effect during take−off by maximizing force production. These feathers have a characteristic notch which allow them to separate vertically. Here we address the evolutionary patterns associated with the development of these feathers. We developed a technique for scoring emargination, and we mapped this onto a phylogeny of extant birds to improve understanding of the evolution of these traits. We tested the hypothesis that emargination scales positively with increasing body mass and explored functional aspects of these slotted feathers. We examined the degree of feather emargination in 45 species and show that an intermediate amount of notching may be ancestral. However, notable differences exist, such as the lack of feather emargination within birds of the Laridae family and extreme emargination in the pelican a species whose clade typically exhibits very little notching. We also quantified the aerodynamic forces acting on the feathers and the subsequent three−dimensional feather deformation (i.e. bending and spanwise twist). Feather bending reorients lift force towards the body and over the center of mass, which may increase passive stability. Funded by the following grants: NSF GRFP DGE 809127 and DGE‘313190.

17.6 TARRANT, AM*; BAUMGARTNER, MF; HANSEN, BH; ALTIN, D; NORDTUG, T; OLSEN, AJ; Woods Hole Oceanographic Institution, SINTEF, BioTrix, SINTEF, NTNU; *atarrant@whoi.edu*

Metabolic shifts associated with progression through the last juvenile stage in the copepod Calanus finmarchicus

Calanus finmarchicus is a highly abundant copepod that acts as an important primary consumer in North Atlantic ecosystems. In this species, the last juvenile stage (fifth copepodid, C5) is of particular interest because individuals may either delay maturation and enter a dormant period or molt directly into adults. We seek to understand the physiological changes associated with progression of the copepods along each of these two paths, and in this study, we characterize the direct path toward the terminal molt. We sampled lab−reared *C. finmarchicus* copepods daily throughout the C5 stage and assessed molt stage progression, gonad development and lipid storage. We conducted Illumina−based RNA−seq to identify a large pool of differentially expressed genes during early and late stages of the C5 molt cycle. We monitored the population daily throughout the C5 stage to assess molt stage progression, gonad development, lipid storage and expression of specific genes. We found that copepods varied considerably in molt stage duration and that progression through the stage was associated with substantial accumulation of lipids within the oil sac. Among the genes exhibiting dynamic expression profiles, many were associated with energetic storage and metabolism. In particular, genes comprising the pentose phosphate and glycolysis pathways, as well as genes necessary for triglyceride and wax ester storage were usually upregulated early in the molt cycle. These gene expression profiles are consistent with widespread metabolic changes coupled with accumulation of lipids and progression through the molt cycle.

P1.37 TASSIA, MG*; CANNON, JT; KONIKOFF, C; PERRY, L; KAUR, P; DUNN, K; SHENKAR, N; HALANYCH, KM; SWALLA, BJ; University of Washington, Seattle and Friday Harbor Laboratories, WA, Auburn University, AL and Friday Harbor Laboratories, WA, University of Washington, Seattle, University of Washington, Seattle; *mtassia@uw.edu*

Hemichordata Global Diversity and Evolution

Phylum Hemichordata has about 130 described species; however, recent studies of hemichordate phylogeny and taxonomy suggest the species number has been largely underestimated. One issue is that species are described by experts, and historically few taxonomists have studied this group of marine invertebrates. Despite this previous lack of coverage, hemichordates have been rediscovered and researched for the past 20 years, and are critical to understanding the evolution of the chordates. We provide an overview of our current knowledge of hemichordates, focusing on their global biodiversity, geographic distribution, and taxonomy. Using information available in the World Register of Marine Species and the published literature, we assembled a list of described, extant species. The majority (83%) of these species are enteropneusts, and more taxonomic descriptions are forthcoming. Family Ptychoderidae currently contains the most species, closely followed by the Harrimaniidae. Hemichordates are found throughout the world's oceans, with the highest reported numbers in the Northern Pacific and Atlantic provinces. Pterobranchs, the colonial Class of Hemichordata, are abundant in Antarctica, but have also been found at lower latitudes. We consider this a baseline report and expect, as new marine habitats are characterized and explored, new species of Hemichordata will continue to be discovered and characterized. Molecular phylogenetics, combined with taxonomy, has allowed documentation of new species, as both tornaria larvae and adults can be studied morphologically and sequenced.

P2.201 TAYLOR, C.T*; GARCIA, E.; PODEROSO, C.; WILSON, M. ; DICKSON, K.A.; California State University, Fullerton ; *chytaylor@csu.fullerton.edu*

Density, distribution and development of putative chorionase−containing cells in the California grunion, Leuresthes tenuis

The California grunion is an unusual fish because adults spawn on beaches during spring high tides and embryos develop within the sand until triggered to hatch by wave action during a subsequent spring high tide. Because hatching occurs quickly and the chorion is strong to protect the embryo within the sand, specializations for rapid chorion breakdown are expected in this species. Cells located laterally along the body are observed in embryos within, or after manual removal from, the chorion, but not after embryos are stimulated to hatch. It has been proposed that these cells contain the chorionase enzyme(s) required for hatching. This study characterized the density, distribution, and development of the putative chorionase−containing cells in California grunion embryos. Grunion gametes were stripped from adults collected while spawning in summer 2013 and 2014, fertilized, and maintained in laboratory incubators set at 20^{o}C. Embryos and hatched larvae were examined by light and electron microscopy. Putative chorionase−containing cells appeared as early as five days post−fertilization (dpf). Cell density did not change significantly from 5 dpf to 12 dpf. The cells, within the one−cell−thick outer epithelium, are filled with protein and can release their contents into the space between the embryo and chorion. The cells are in a distinct pattern along the length of the embryo, starting anterior−dorsally near the head and continuing down the length of the body at the lateral midline. Assuming they contain chorionase, the placement of these cells at high densities along most of the body and rapid release of their contents would facilitate rapid chorion digestion and hatching.

81.1 TAYLOR−BURT, KR*; MIARA, M; BIEWENER, AA; Harvard U; *karitaylorburt@fas.harvard.edu*

In situ force−length properties of the pigeon pectoralis in relation to in vivo length changes during level flight

The avian pectoralis produces most of the power for flight and is well suited to studies of how muscle properties affect flight performance. Previous work has linked kinematics to *in vitro* estimates of power output and examined *in vivo* pectoralis force production and length change. This study is the first to relate *in situ* force−length properties of the pigeon pectoralis to its *in vivo* force−length flight patterns. Muscle activation (via electromyography) and length changes (via sonomicrometry) were recorded *in vivo* during level flight. Active and passive force−length curves were determined *in situ* by quantifying fascicle length with sonomicrometry and force with a load cell at the muscle's insertion on the humerus. *In vivo* fascicle strains ranged from ~90 to 120% l_o (length at peak active force, P_o). Based on past studies, we estimate that maximum *in vivo* pectoralis force occurs at ~110% l_o, on the descending limb of the muscle's active force−length curve. The estimated total force (active+passive) at 110% l_o is 97% P_o. Passive force develops at 97% l_o, increasing steeply up to 30% P_o at the largest strains (120% l_o). Our results indicate that the pectoralis produces force to power level flight on both the ascending and descending limbs of its force−length curve and passive force is substantial at the upstroke−downstroke transition. Although *in vivo* active force production is maximal on the descending limb of the muscle's force−length curve, total force is similar to P_o at these lengths. Thus, passive force compensates for reduced active force and could provide elastic energy storage in the muscle's aponeurosis and central tendon to assist in wing deceleration at the end of upstroke and wing acceleration as the muscle develops active force early in downstroke.

32.7 TEETS, N.M.*; HANDLER, A.M.; HAHN, D.A.; Univ. of Florida, USDA ARS; *n.teets@ufl.edu*

Testing the role of oxidative stress in sexual selection with transgenic overexpression of antioxidant defense systems in the Caribbean fruit fly, Anastrepha suspensa

Oxidative stress mediates sexual selection in many animals by linking cellular stress to condition−dependent sexual signals. While the relationship between oxidative stress and ornamental carotenoid pigments is well established, carotenoids and related pigments play a lesser role in cellular redox status than endogenous antioxidants. Previous work has shown that environmental treatments boosting the enzyme activity of superoxide dismutase (SOD) are also associated with greater sexual competitiveness in the Caribbean fruit fly, *Anastrepha suspensa*, a lek mating species with intense male−male competition and sexual selection. Here, we test the link between antioxidants and sexual selection by transgenic overexpression of SOD in *A. suspensa*. Using piggyBac−mediated germline transformation, we generated several lines that overexpress either the cytosolic or mitochondrial isoform of SOD. Our transgene contains a single copy of the native SOD driven by a heat shock promoter, all contained within loxP sites to allow recombinase−mediated cassette exchange. Transgene expression varied across genotypes, with our best lines exhibiting 4−fold increases in SOD mRNA levels and a doubling of enzyme activity. There was strong correlation between mRNA levels and SOD activity across lines, allowing for precise control of SOD activity levels. We are now conducting experiments to test whether elevated SOD activity attenuates ROS−mediated oxidative damage and improves mating competitiveness of males. These lines also provide a valuable genetic resource for testing the roles of ROS and antioxidants in aging and stress and may inform strategies for enhancing the quality of males released for Sterile Insect Technique.

P2.64 TEETS, N.M.*; DENLINGER, D.L.; Univ. of Florida, Ohio State Univ.; *n.teets@ufl.edu*

Quantitative phosphoproteomics reveals signaling events associated with rapid cold hardening in a temperate flesh fly

Rapid cold hardening (RCH) is a type of adaptive plasticity in which brief chilling allows insects to significantly enhance their cold tolerance within minutes to hours. RCH is an essential adaptation for dealing with sudden cold snaps and diurnal temperature fluctuations, but the underlying mechanisms are poorly understood. Whereas many stress responses are transcriptionally regulated, the temperatures (around 0°C) and time scales (less than 30 min in some cases) at which RCH occurs are not conducive to the synthesis of new gene products. Rather, protein phosphorylation and other posttranslational signaling events are thought to be the main drivers of RCH, but the identity of these signaling pathways is largely unknown. Here, we used quantitative phosphoproteomics to profile changes in protein phosphorylation that accompany RCH in the flesh fly, *Sarcophaga bullata*. Brains and fat body were dissected from adult *S. bullata*, held at either control (25°C) or RCH conditions (2 h at 0°C), then analyzed for global changes in protein phosphorylation using 2D electrophoresis with Pro−Q Diamond staining, which only stains phosphoproteins. Protein spots that exhibited differential phosphorylation were cored and sequenced with LC/MS/MS. RCH caused substantial changes in protein phosphorylation, as we detected 84 proteins that were differentially phosphorylated in the brain and 65 in the fat body. Functional groups that were differentially phosphorylated in both tissue types included heat shock proteins, cytoskeletal genes, and genes involved in metabolism and ATP synthesis. Our results identify a number of candidate signaling events associated with RCH, and future targeted studies will assess the functional significance of these phosphorylation events.

43.2 TELEMECO, R.S.; University of Washington; *telemeco@uw.edu*

An integrative taxonomic analysis of the southern and panamint alligator lizard complex: Combining morphological, ecological, and molecular evidence

Describing standing biodiversity and its evolutionary origins are major goals of modern biology. While molecular genetic tools provide immense power to explore phylogenetic relationships, these tools are not without limitations. By integrating multiple datasets, we can better resolve phylogenetic history, delineate species boundaries, and increase our understanding of how lineages have ecologically diverged. I used such an integrative approach to test predictions from competing phylogenetic hypotheses for southern and Panamint alligator lizards (*Elgaria multicarinata* and *E. panamintina*, respectively). Recent mtDNA evidence contradicts the traditional taxonomy of these lizards, calling the species status of *E. panamintina* into doubt, and suggesting that *E. multicarinata* might be composed of 2−4 cryptic species. First, I examined male genital morphology for evidence of reproductive isolation among putative clades. Next, I examined head morphology to assess potential ecological divergence. Finally, I further explored ecological divergence using species distribution modeling. My results support components of both the traditional and mitochondrial DNA phylogenies. All of my data support the species status of *E. panamintina*, and I suggest that the aberrant mtDNA phylogeny results from incomplete lineage sorting after peripatric speciation. In addition, My results support the existence of two divergent cryptic clades within *E. multicarinata*, as predicted by the mtDNA phylogeny. By integrating morphometric analyses and species distribution modeling with prior molecular data, I obtained phylogenetic inferences that were impossible with any available dataset in isolation.

P2.72 TELEMECO, R.S.*; SMITH, C.; ANGILLETTA, M.J.; VANDENBROOKS, J.M.; University of Washington, Arizona State University, Midwestern University; *telemeco@uw.edu*

Hypoxia reduces the lethal thermal limit of lizard embryos: Empirical support for the oxygen−limited thermal tolerance hypothesis

Although temperature defines a major axis of the fundamental niche, the proximate mechanisms that set the limits of thermal tolerance remain uncertain. Classically, high temperatures were thought to become lethal by disrupting the folding of proteins or the integrity of cell membranes. However, animals frequently die at temperatures far below those predicted to cause these cellular structures to fail. More recently, an alternative hypothesis based on oxygen limitation has been proposed: lethal thermal limits occur when cardiac and respiratory systems cannot sufficiently supply oxygen to the body. Oxygen deficiency presumably induces positive feedbacks that rapidly lead to systemic failure and hence death. Currently, support for this hypothesis is equivocal; studies examining a diverse group of aquatic ectotherms support the hypothesis, but studies examining terrestrial insects do not. Here, we present the first test of the oxygen limitation hypothesis in a terrestrial vertebrate. We compared the upper lethal limits of temperature among developing lizard embryos (*Sceloporus tristichus*) across a range of oxygen concentrations, spanning hypoxia to hyperoxia (10% − 30%). Eggs were incubated under a naturalistic diel cycle in which the maximal temperature of the cycle increased by 1.0°C each day. Heart rates of embryos were monitored daily to determine the point of death. Consistent with the hypothesis that oxygen limitation sets the lethal temperature, embryos exposed to normoxia and hyperoxia survived to higher temperatures than did embryos exposed to hypoxia. Our results suggest that critical high temperatures become lethal in *S. tristichus* embryos because tissues require more oxygen at high temperatures than developing respiratory and cardiac systems can deliver.

P3.22 TEZAK, B.M*; WYNEKEN, J; Florida Atlantic University; *btezak@fau.edu*

Using an Immunohistochemical Approach to Identify the Sex of Marine Turtles

Marine turtles exhibit temperature dependent sex determination (TSD). During critical periods of embryonic development, the nest's thermal environment directs whether an embryo will develop as a male or a female. Nests that incubate at warmer sand temperatures tend to produce female−biased sex ratios. The rapid increase of global temperature highlights the need for a clear assessment of effects on sea turtle sex ratios. However, identifying hatchling sex ratios at rookeries remain as coarse estimates because the mechanisms that trigger male vs. female development are understood only in part. We rely mainly upon laparoscopic procedures to verify hatchling sex; however, in some species, morphological sex can be ambiguous even at the histological level. Recent studies using immunohistochemical techniques identified that red−eared slider (*Trachemys scripta*) embryos over−expressed a cold−induced RNA binding protein in the ovary when compared to developing testes. We developed a variation of this technique and successfully identified the sexes of loggerhead sea turtle (*Caretta caretta*) hatchlings, a species that can also be identified reliably using standard histological and laparoscopic methods. We then tested the technique with a more challenging species, the leatherback turtle (*Dermochelys coriacea*), species that retains many neotenic features. The morphology of leatherback hatchling gonads remains difficult to interpret, particularly when dead−in−nest hatchlings and embryos are the source tissues. Our purpose is to introduce the modified procedure and its efficacy. This new technique has the potential to greatly enhance our ability to investigate verify hatchling sex ratios and identify baseline sex ratios, fundamental steps in assessing global climate change on sea turtle populations.

P1.63 THABET, AA; MAAS, AE*; ALATALO, P; SABER, SA; LAWSON, GL; TARRANT, AM; Woods Hole Ocg. Inst. and Al−Azhar Univ., Assiut, Egypt., Woods Hole Ocg. Inst. and Bermuda Inst. Ocean Sci., Woods Hole Ocg. Inst., Al−Azhar Univ., Cairo, Egypt, Woods Hole Ocg. Inst.; *amaas@whoi.edu*

Development of the thecosome pteropod Limacina retroversa

Thecosome pteropods are specialized pelagic mollusks that produce calcium carbonate shells of aragonite. Because pteropods may serve as sentinel species in regards to the effects of ocean acidification (OA) and other stressors, it is important to have a baseline understanding of their distribution, developmental timing and life history so that changes due to anthropogenic forcing can be recognized. Relatively little is known regarding the morphology and timing of progression through early developmental stages in the genus *Limacina*. In this study, we characterized the generation time, developmental timing and early shell formation in *Limacina retroversa*, an abundant and ecologically important thecosome species in the North Atlantic. Wild−caught adult *L. retroversa* typically laid gelatinous ribbons containing 10 − >100 eggs within 2 days of capture. When reared at 8°C, embryos advanced to the 16−cell stage by 11 hours post spawning (HPS) and to a mixture of blastula and early gastrula stages by 16 HPS. Free−swimming trochophore larvae hatched from the egg capsule after 3 days, and shelled veliger larvae were observed after 6−7 days. Calcein staining enabled visualization of early calcification within the round shell gland of trochophore larvae and assessments of incremental growth in juvenile pteropods. Eggs laid in captivity reached reproductive maturity after ~3 months, and adults continued laying eggs for the rest of their lives (approximately 6 months). This study provides a baseline and framework for future studies of the effects of environmental conditions on *Limacina* development.

P3.207 THALATHOTI, SP*; GOLDINA, A; Elizabethtown College; *thalathotis@etown.edu*

Individual recognition in crayfish Orconectes obscurus

Individual recognition is important for maintaining stable social hierarchies and minimizing aggression intensity. While status recognition facilitates discrimination based on individual behavior that resulted from prior winning or losing experience, it does not assume individual discrimination. In crustaceans, evidence for individual recognition is scarce. The goal of our study was to assess whether crayfish *Orconectes obscurus* can recognize individuals based on previous experience with the individual, and not social status. We examined the ability of *O. obscurus* to distinguish between previously known opponents and unknown opponents of the same status. After a one week isolation period, two individuals were placed in a tank and allowed to establish dominance in a familiarization trial. Once dominance was established, the opponents were isolated for another week. At the end of this isolation period each individual was paired with 3 opponents; 1) known opponent from the familiarization trial, 2) an unknown opponent of the same status as known opponent, and 3) naïve individual. Order of opponent presentation was randomized. We compared average fight durations and aggression levels in familiarization trials to subsequent fights. While fight duration between known and unknown opponents did not differ significantly, aggression intensity reflected extent of previous experience with opponents. Dominants exhibited less aggression towards known subordinates than towards unknown subordinates or naïve individuals. Subordinate individuals exhibited least aggression towards known dominants, while aggression towards unknown opponents varied. Our preliminary data suggest that *O. obscurus* can distinguish between individuals of different status, but can also distinguish between individuals based on previous social experience.

54.3 THAWLEY, CJ*; ROBBINS, TR; FREIDENFELDS, NA; LANGKILDE, T; Penn State University, University of Connecticut; *cjt171@psu.edu*

Attracting unwanted attention: the costs and benefits of adaptation to an invasive predator

As global change accelerates, species often must adapt quickly or face extirpation or extinction. While adaptive responses may improve fitness under novel selective pressures, they may also maladapt organisms to original environmental conditions, including native predators. Invasive fire ants (*Solenopsis invicta*) are novel venomous predators of Eastern Fence Lizards (*Sceloporus undulatus*). Lizards from fire ant−invaded sites flee and twitch in response to potentially lethal fire ant attacks at higher frequencies than lizards from sites uninvaded by fire ants. While we found evidence that this behavior is adaptive in the presence of fire ants, these changes appear maladaptive in the presence of native predators, as lizards from fire ant invaded sites suffered higher mortality in the absence of fire ants. A behavioral shift from reliance on crypsis to increased responsiveness could attract visual predators and reduce probability of survival when attacked. We found that behavioral responses to fire ants are generalized to native ants, suggesting that lizards adapted to fire ant presence may break crypsis often and potentially attract predators. This response to fire ants did not, however, carry−over to affect reactions to a perceived avian predator. We also found support for the costs of this behavioral adaptation in the field: fence lizards from populations exposed to fire ants had significantly higher injury rates than fire ant naïve lizards. Our results suggest a generalized anti−ant behavior may improve survival in the presence of fire ants but reduce fitness in the absence of this invader, potentially due to increased predation by native visual predators. These results inform our understanding of both the consequences and limitations of rapid adaptation.

P1.19 THOMAS, A.T.*; REECE, J.S.; Valdosta State University; *ashithomas@valdosta.edu*

Evolution of diadromy in Anguilliformes

Anguilliform fishes, also known as "True eels" are diadromous. While most stay in marine water throughout their whole migration loop, some transition from saltwater to freshwater (anadromy) and some migrate from freshwater to saltwater (catadromy). In order to understand the evolution of diadromy we searched for published anguilliform phylogenies, compiled them into one tree, and mapped the diadromous trait across the 258 species (or other higher taxonomic groups) represented by the new supertree. The intent of the research was to understand where the ability to cross salinity barriers in migration might have come from; whether the trait had a single origin, or if it evolved in several places along the ancestry of eels. We investigated the pattern and timing of the evolution of diadromy and report on independent evolution of catadromy and diadromy, rates of transition between states for time−calibrated branches of the supertree, and ecological and geographic correlates of different diadromous character states.

80.4 THOMAS, D.R.*; WALKER, G.R.; CHADWELL, B.A.; BUTCHER, M.T.; Youngstown State University, Northeastern Ohio University of Medicine; *drthomas03@student.ysu.edu*

Ontogeny of myosin heavy chain expression and prehensile tail function in the gray short−tailed opossum (Monodelphis domestica)

Monodelphis domestica is a terrestrial opossum that uses its semiprehensile tail for nest construction. The employment of this behavior is observed by age 5−7 months, when they are considered adults by their sexual maturity. Our previous study of myosin heavy chain (MHC) isoforms in the m. flexor caudae longus of adults uniquely identified pure MHC−2A fibers and more oxidative fibers in the proximal tail compared with a faster distal tail. These findings lead to hypotheses about developmental changes in MHC isoform content with tail use, specifically (i) juveniles should express fast developmental isoforms, in addition to having a large composition of fast MHC−2B throughout the tail, and (ii) at ages 3−5 months the developmental isoforms will transition into adult MHC−1 and 2A fibers, while MHC−2B will shift to the 2X isoform, each corresponding with the onset of nest construction behavior. To test these hypotheses, caudal muscle was harvested post−mortem from individuals ranging in age from 1−7 months, and MHC expression was quantified by RT−PCR, SDS−PAGE, and gel densitometry. To further evaluate how MHC isoform transitions correlate with nest construction, video data of tail use from individuals in different age groups (3 months to adulthood) was also collected and will be analysed for frequencies of tail behaviors. Preliminary data from protein gel analysis indicate that there is a shift from a fast MHC isoform content in the juveniles to a slower composition in the adults. With the complete results of this study we will understand adult MHC expression as it relates to development of tail prehensility in didelphids and more generally, how frequency of use of an appendage influences muscle fiber type properties.

P1.111 THOMAS, J.R.*; WOODLEY, S.K.; Duquesne University; *thomasj6@duq.edu*

Examining the effects of testosterone on wound healing in a terrestrial amphibian (Desmognathus ochrophaeus)

Across taxa, immunity is a complex process that both affects and can be affected by the endocrine system. For example, glucocorticoids have a number of immune−effects such as delaying the healing process. Another relationship occurs between the immune system and the neuroendocrine reproductive−axis, with testosterone (T) often suppressing immune function. One hypothesis for the immunosuppressive effects of T on immunity is the immunocompetence handicap hypothesis (ICHH), which suggests that T drives the development of secondary sexual characteristics at the cost of immunosuppression. We tested the effects of T on wound healing in Allegheny Mountain dusky salamanders, a species with androgen−dependent glands used by males in pheromone delivery during mating. Wound healing is a biologically relevant measure of innate immunity that consists of inflammation, growth, and tissue remodeling. Subjects were assigned to one of four treatment groups: castration + testosterone propionate (TP) implant, castration + blank implant, sham surgery + blank implant, or intact. After healing from surgery, all animals received a dermal biopsy that was monitored over the course of 30 days. We predicted that removal of T via castration would enhance healing compared to subjects in which T was present. Overall, healing did not differ among treatments. This suggests that T has neither enhancing nor inhibitory effects on wound healing.

8.7 THOMETZ, N.M.*; KENDALL, T.L.; RICHTER, B.; WILLIAMS, T.M.; University of California Santa Cruz; *nthometz@ucsc.edu*

Physiological Capacity for Diving in the Critically Endangered Hawaiian Monk Seal

Despite being critically endangered, relatively little is known about the physiological capacities of the Hawaiian monk seal (*Monachus schauinslandi*). Utilizing data from both wild and captive monk seals we quantified blood, muscle, lung, and total O_2 storage capacity as well as diving and swimming metabolic rates for this species. Blood volume (BV; n=1), hemogolobin and hematocrit (Hb, Hct; n=2) were measured in captive male monk seals. BV was determined to be 87.49 ml kg^{-1}, while Hb and Hct values were 17.29±0.20 g dL^{-1} and 49.16±0.58%, respectively. Average muscle myoglobin (Mb) was quantified by analyzing major locomotor muscles (*longissimus dorsi*) sampled from sub−adult (n=2) and adult (n=3) wild monk seals. Average [Mb] was determined to be 5.21±0.19 gÉ00g^{-1} muscle. Diving lung volume was estimated from values of closely related phocid species. Calculated blood, muscle, and lung O_2 stores for adult monk seals were 17.27 ml kg^{-1}, 23.03 ml kg^{-1}, and 4.26 ml kg^{-1}, respectively, making total O_2 storage capacity 44.57 ml kg^{-1}. Diving and swimming metabolic rates were measured in one captive adult male seal using open−flow respirometry. The average submerged swimming metabolic rate was 7.74±1.56 ml O_2 min^{-1} kg^{-1}. By dividing total O_2 stores by O_2 demand, the cADL of an adult monk seal was estimated to be between 5.8−13.9 minutes, depending upon activity level underwater. Considered living fossils' due to their distinct evolutionary history, our study suggests that Hawaiian monk seals are also physiologically unique among pinnipeds, exhibiting characteristics similar to both phocid and otariid species.

P3.140 THOMPSON, J.T.*; LAVALVA, S.; LOIACONO, M.; Franklin and Marshall College; *joseph.thompson@fandm.edu*

The kinematics and motor control of a biological plunger

The mantle and funnel play familiar roles in providing power for and controlling the pulsed jet that squids use for swimming and maneuvering, but movements of the head toward and away from the mantle (i.e. acting like the plunger for the mantle "syringe") may also be important modulators of the pulsed jet and the subsequent refilling of the mantle cavity. We investigated the morphology and the *in vivo* operating range and activation of the muscles that control head retraction and extension in Atlantic longfin squid (*Doryteuthis pealeii*). These muscles include the posterior (PNR) and anterior nuchal retractors (ANR), and the head retractor (HR) muscle. The ANR and HR are muscular hydrostatic organs composed of longitudinal, transverse, and circumferential muscle fibers, whereas the PNR is composed only of longitudinal fibers. Sonomicrometry records of 45 squid revealed that head retraction and extension precede mantle contraction and expansion significantly during jetting. The head experiences an impressive range of longitudinal strains during escape jets, with mean maximum extensions and retractions of +0.26 ± 0.29 and −0.64 ± 0.22, respectively. In addition, the muscles actuate the head at impressive strain rates, with mean maximum extension and retraction strain rates at 15&degC of 1.61 ± 1.14 and −5.74 ± 3.8 muscle lengths s^{-1}, respectively. Synchronized sonomicrometry and electromyography experiments in 17 squid revealed that longitudinal fibers are activated during head retraction in all three muscles, that transverse fibers in the HR and ANR are active during head extension, and that circumferential fibers in the HR are active both during extension and brief periods when head position is isometric. We also discovered two populations of longitudinal fibers in the HR and PNR that differ in the timing of their activation during head retraction. Funded by NSF grant IOS−0950827.

P1.52 THOMPSON, E.S.*; IYENGAR, E.V.; Muhlenberg College; *iyengar@muhlenberg.edu*

Feeding preference and possible competition between the terrestrial slugs Ariolimax columbianus and Arion rufus

Within the last 100 years, the arrival in the Pacific Northwest of the invasive European slug *Arion rufus* has introduced a potential competitor for the iconic banana slug *Ariolimax columbianus*, the second largest terrestrial slug in the world. We conducted transect studies in three habitats (cedar forest, Doug fir forest, and grasslands) on San Juan Island, WA, to examine the relative demographics of these slugs and note possible food sources. Utilizing those data, we conducted feeding preference studies across leaves from 16 local plant species, incorporating slugs from the two species from different source habitats, different size classes, and both the black and brown morphs of *Arion rufus*, which tend to specialize in different habitats. We used ImageJ to measure the area eaten from each leaf and calculated feeding rates. The feeding preferences of *Ariolimax columbianus* were consistent across size classes and source populations, and the two color morphs and various source populations of *Arion rufus* were also largely consistent within this species. While both species are generalists, they demonstrated feeding preferences that frequently overlapped, indicating that *Arion rufus* may compete with *Ariolimax columbianus* for food resources.

P3.92 TIERNEY, A J; POWERS, C*; ROY, M; HANZLIK, K; HATHAWAY, R; Colgate University; *atierney@colgate.edu*

Effects of ambient fluoxetine on behavior and growth in the crayfish Orconectes rusticus.

Recent studies have documented the widespread occurrence of human pharmaceuticals in aquatic ecosystems. These chemicals or active metabolites may persist in the environment for months or years and have been shown to have adverse effects in numerous aquatic species. Our studies examined the effects of chronic low−level exposure to fluoxetine on behavior and growth following molting in the crayfish *Orconectes rusticus*. Fluoxetine, a widely prescribed antidepressant, is a serotonin reuptake inhibitor which alters levels of serotonin in synapses. Upon collection, male Form II crayfish (N = 75) were weighed and measured (carapace and chela length) and placed individually in water containing 0, 2, 20, 200, or 500 µg/L of fluoxetine. Prior to and following a two−week long exposure to fluoxetine, crayfish were tested in an open field arena to assess locomotion, exploration, and sheltering behavior. Animals were then held in their assigned dose of drug until each completed the molt to Form I; two weeks after molting each was again weighed and measured. In the open field tests, crayfish exposed to fluoxetine displayed significant increases in locomotion and decreases in sheltering behavior at concentrations at and above 2 µg/L. Timing of the molt was not affected by fluoxetine, but weight gain following the molt to Form I was significantly greater in animals exposed to fluoxetine at 500 µg/L and a similar tendency occurred at lower concentrations. In crayfish, serotonin acts both as a hormone and a neurotransmitter and we consider our results in the light of serotonin's effects on molting, growth, and behavior in crustaceans.

P2.179 TIETBOHL, MD*; WAINWRIGHT, DK; PAIG−TRAN, EWM; SUMMERS, AP; CROFTS, SB; FARINA, SD; Wake Forest University, Harvard University, California State University Fullerton , University of Washington, University of Washington , Cornell University; *tietmd11@wfu.edu*

What's underneath? Performance, morphological, and structural differences in the adhesive disc of Pacific Northwest fishes

Several clades of percomorph fishes have ventral adhesive organs modified from the pelvic fins that facilitate attachment to a variety of substrates. We examined the adhesive organs of the Northern clingfish (*Gobiesox maeandricus*), Pacific spiny lumpsucker (*Eumicrotremus orbis*), and tide pool snailfish (*Liparis florae*). We also tested the adhesive ability of the marbled snailfish (*Liparis dennyi*) on surfaces of different roughness. Previous research has shown that clingfish can stick to a variety of substrates, and our data suggest Liparid suction discs may have even stronger adhesive abilities, which falls in line with existing data. We used scanning electron microscopy and cleared and stained individuals to look for differences in morphology that might explain performance differences. *E. orbis* and *L. florae* have much larger papillae (9.31 ± 1.55 ¼m, 9.96 ± 1.21 ¼m) than *G. maeandricus* (0.76 ± 0.26 ¼m), and a more rigid support to their disc. Large papillae may increase friction, which prevents the disc from slipping, and rigid pelvic spines resist bending of the disc roof. We also used high speed video to determine the mechanism of detachment for *E. orbis* and *L. florae*. Clingfish detach by abducting a specialized fourth lepidotrich. Both *E. orbis* and *L. florae* appear to use abduction of their pelvic fins and operculum to brace themselves as they pull back the anterior edge of their disc, causing failure and allowing the disc to be peeled back posteriorly, similar to the removal of a commercial suction disc. Both methods allow for quick detachment from the substrate which could facilitate escape from predators or pursuit of prey.

24.5 TITIALII, K*; PARKS, A; CUNDIFF, JA; CRESPI, EJ; Washington State University; *kayla.titialii@email.wsu.edu*

A ROLE FOR LEPTIN IN MEDIATING NUTRITION−DEPENDENT REGENERATION RATE IN XENOPUS LAEVIS

While much is known about the cellular and molecular mechanisms of limb regeneration, relatively little is known about how the nutritional state of the animal regulates regeneration. We tested the hypothesis that regeneration rate is positively regulated by food intake in *Xenopus laevis* tadpoles, and the peptide hormone leptin mediates nutrition−dependent limb regeneration rate in developing tadpoles. First, we exposed tadpoles to one of three diets after limb amputation: food restricted, control, and high food. This experiment showed that after 18 d, the food−restricted tadpoles had reduced regeneration area than that of the controls, but the high−food tadpoles did not increase regeneration despite greater body growth. In a second experiment, we injected (ip) tadpoles with recombinant Xenopus leptin or saline at the time of amputation, then exposed them to either food−restricted or control diets for 15 d. Compared to the control diet group, regeneration rates were slower in the food−restricted group, and the development of the uncut limbs was also slower. The area regenerated was enhanced by the leptin treatment in the food−restricted group, but not in the control diet group. Our findings demonstrate that regeneration rate is affected by food intake, but when food is abundant, excess resources are routed toward overall growth. Furthermore, *X. laevis* tadpoles simultaneously allocate resources to both regeneration and other developmental processes. Given that leptin mRNA expression is positively correlated with nutritional state at this stage of development, the ability of leptin to enhance regeneration in low food conditions suggests that this hormone is a nutritional modulator of limb regeneration.

P2.47 TITUS, L*; BENNETT, S; ZYLBERBERG, M; Ohio Northern University, California Academy of Sciences, University of California San Francisco; *l−titus@onu.edu*

Occurrence of Avian Malaria in the California Tioga

Plasmodium and *Haemoproteous*, two genera of parasitic protozoans, are ubiquitous among birds and can have important fitness consequences for their hosts, impacting host ecology. To fully understand the impacts of these parasites on the ecology of migratory birds, it is important to know whether migratory species become infected at their nesting grounds or wintering grounds. Migratory mountain white−crowned sparrows (*Zonotrichia leucophrys oriantha*) that nest at Tioga Pass, CA, are known to carry both *Haemoproteus* and *Plasmodium* species parasites; however, it is unknown where they acquire these infections. To determine whether birds nesting at Tioga Pass could have become infected with avian malaria on their nesting grounds, we screened 192 *Culicidae* mosquitos collected in July 2006 for the presence of *Haemoproteus* and *Plasmodium*, which these mosquitoes are known to vector. Mosquitoes were captured by CO2 traps set in thirteen different microhabitats (classified by the presence or absence of water and the type of foliage present) and were visually categorized into 37 morphospecies. Cytochrome c oxidase subunits I and II were sequenced and compared to previously published data to taxonomically identify morphospecies. In addition, we examined how vector density varies by microhabitat type. Our data suggest that the mosquitoes of the Tioga Pass are not infected with these parasites and, therefore, the mountain white crowned sparrows are more likely to be infected with these parasites either at their wintering grounds or during migration.

P3.179 TOLCHIN, S*; MEYER, N.P.; Clark University; *stolchin@clarku.edu*

Role of Notch/Delta signaling in neural development of the annelid Capitella teleta

Notch signaling is vital for neural development in both vertebrate and insect models, but not much is known about this process in annelids. Here we use the model organism *Capitella teleta*, a marine annelid within Spiralia, to explore Notch function. We hypothesized that Notch signaling in annelids functions similarly to the known vertebrate model, where activated Notch blocks progression of neural stem cells towards cell cycle exit and differentiation. We used pharmacological treatments (DAPT, LY411575) to block Notch signaling and test this hypothesis. DAPT treatments caused a decrease in neural, foregut, and mesodermal tissues. In situ hybridization (ISH) of DAPT treated animals for *Cte−ash1*, a proneural homolog, showed an increase in expression throughout mesodermal and foregut tissue while ISH for *Cte−syt1*, a pan−neuronal marker, showed very little difference among treatments. These surprising results suggest that Notch signaling may not play a crucial role in annelid neural development, a finding that would be very different from vertebrates and insects. Preliminary ISH data for *Cte−elav1*, an earlier pan−neuronal marker, and *Cte−ash1* after LY411575 treatment should further clarify the function of Notch signaling in this organism. We are also currently cloning the full length *notch* gene for future knockdown and misexpression experiments. Together, these methods will allow us to rigorously test and observe the function of Notch during annelid development.

59.1 TORSON, A. T.; YOCUM, G. D.; RINEHART, J. P.; KEMP, W. P.; BOWSHER, J. B.*; North Dakota State University, USDA ARS; *julia.bowsher@ndsu.edu*

The genetic profile of increased longevity during chilling in the solitary bee Megachile rotundata

The physiological responses to long−term, ecologically relevant temperature stress are poorly understood. In insects, long−term low temperature exposure can lead to chill injury. However, periodically increasing temperatures during chilling has been shown to increase survival. The transcriptomic response for this increase in survival have never been characterized. Here we present the first transcriptome−level analysis of increased longevity under fluctuating temperatures during chilling. Overwintering post−diapause quiescent alfalfa leafcutting bees, *Megachile rotundata*, were exposed to a constant temperature of 6°C or 6°C with a daily fluctuation to 20°C. RNA−seq was performed at two different time points, before and after mortality rates began to diverge between temperature treatments. Expression analysis identified differentially regulated transcripts functioning in ion homeostasis, metabolic pathways, and oxidative stress response. The exact timing of these gene expression changes was determined by measuring expression of selected transcripts at two−week intervals. Taken together, these results provide genetic support for the hypotheses that fluctuating temperatures protect against chill injury by reducing oxidative stress and returning ion concentrations and metabolic functions to favorable levels. In addition to these established mechanisms, we identified additional mechanisms, immune response and neurogenesis, that are associated with increased longevity during chilling in *M. rotundata*.

P1.53 TRACKENBERG, SN*; PERNET, B; ALLEN, JD; College of William and Mary, California State University, Long Beach; *sntrackenberg@email.wm.edu*

How do changes in offspring provisioning influence larval and juvenile development in seastars?

Organisms have a limited amount of resources available to produce offspring, leading to a tradeoff between the size and number of offspring they can produce. In the extreme, differences in per−offspring maternal investment can lead to disparate modes of development, even among closely related species. Echinoid echinoderms have long been used as a model system to investigate the consequences of changes in maternal investment for offspring development, but responses in echinoids may not apply to other taxa. To expand the taxonomic coverage of the effects of changes in maternal investment, we tested how experimental reductions in egg size affected larval and juvenile development in the seastar, *Pisaster ochraceus*. We manipulated maternal investment by killing one of the blastomeres of two−cell stage embryos with a laser, to effectively halve the amount of maternal investment in the egg. In control embryos (whole), no cells were killed and the initial investment was retained. The larvae from whole and half sized embryos were reared to metamorphosis in beakers with 20 embryos of a single treatment per beaker (N = 5). We measured time to metamorphosis, spine length at metamorphosis, and disk area at metamorphosis. Whole embryos developed into juveniles with three percent larger disk area and 10 percent more spines than half sized embryos. Whole embryos also reached metamorphosis on average 14 percent earlier than half sized embryos. These results were in the same direction as our predictions based on the effects of egg size manipulation in echinoids, but effect sizes were smaller than anticipated. We are currently tracking juveniles post−metamorphosis to test for latent effects of changes in maternal investment.

S3.9 TRACY, CR*; MCWHORTER, TJ; GIENGER, CM; STARCK, JM; MEDLEY, P; MANOLIS, SC; WEBB, GJW; CHRISTIAN, KA; California State University Fullerton, University of Adelaide, Austin Peay State University, University of Munich, Environmental Research Institute of the Supervising Scientist, Wildlife Management International, Charles Darwin University; *ctracy@fullerton.edu*

Alligators and crocodiles have high paracellular nutrient absorption, but differ in digestive morphology and physiology

Animals from the Crocodilidae and Alligatoridae respond differently to similar diets. We investigated the digestive morphology and physiology of young *Alligator mississippiensis* and *Crocodylus porosus* to understand these differences. Allometry of gut length differed; alligators have a steeper increase in intestine mass with body size and crocodiles have a steeper increase in intestine length with body size. Both species showed decreasing intestinal surface area magnification (SAM) from the proximal to distal ends. Although alligators had overall larger SAM, their shorter gut meant that total surface area was not significantly different. Alligators had significantly higher maltase activity, but lower aminopeptidase activity than crocodiles; sucrase activity was barely detectable in both species. These differences in enzyme activity may help explain different responses to captive diets. Both species had high absorption of 3−O methyl d−glucose (absorbed by mediated transport), and also had surprisingly high uptake of l−glucose (absorbed paracellularly), with fractional absorptions as high as those previously seen only in small birds and bats. Absorption rate analysis suggested paracellular uptake was a high proportion of total nutrient uptake in both species. Most paracellular studies to date have been on adults, and we measured juveniles so it is unclear whether paracellular absorption is consistently high within crocodilians or if high values are specific to juveniles.

75.6 TRAN, C.*; PEREZ, S.F.; PRINGLE, J.R.; Stanford University School of Medicine, College of San Mateo; *cawa@stanford.edu*

Induction of larval settlement in the sea anemone Aiptasia in the laboratory

Recapitulating the full sexual life cycle of *Aiptasia* in the laboratory is critical for the further development of this important model system for coral biology. This should allow development of classical and molecular genetic analyses, including germ−line transformation with gene−disruption and gene−tagging constructs. We have been attempting both to improve the efficiency and predictability of laboratory spawning and to achieve the settlement and metamorphosis of the larvae thus produced. This has led to field studies at sites in Florida that have large natural populations of *Aiptasia* to identify natural cues and surfaces that induce settlement and metamorphosis of the larvae. Anemones were found on mollusc shells, rocks, and crustose coralline algae, and larger populations dominate mangrove roots in the Florida Keys. Glass microscope slides and ceramic tiles were deployed at these sites to collect microbial biofilms over time. Settlement assays were then conducted on natural substrata, biofilmed slides and tiles that had been in the field for 2 months, and individual bacterial strains isolated from these surfaces. The small (~100 µm diameter), translucent *Aiptasia* larvae were stained with neutral red to improve visualization of larvae and potential recruits on dark surfaces. Larvae from 5−14 d old were able to attach to biofilmed surfaces as early as 8 h after initial exposure and to settle by 24 h. To our knowledge, this is the first documented observation of successful settlement of *Aiptasia* larvae in the laboratory. To date, a single settled larva has been observed to undergo metamorphosis. We are currently attempting both to identify the exact cues associated with the surfaces that induce settlement and to obtain consistent metamorphosis.

P2.71 TREIDEL, LA*; BOWDEN, RM; Illinois St. Univ.; *latreid@ilstu.edu*

Effects of season and incubation temperature fluctuation frequency on oxidative stress in hatchling red−eared sliders (Trachemys scripta)

Maternally derived yolk antioxidants promote cell differentiation and immune function, while protecting offspring from oxidative stress during embryonic and early postnatal periods in oviparous species. The role of yolk antioxidants in reptiles is presently unknown, but given their life−history, antioxidants may play crucial and unique roles in reptilian development. We performed two experiments to independently determine how season and temperature fluctuation frequency during incubation impact oxidative stress in the red eared slider turtle (*Trachemys scripta*). To investigate seasonal effects of egg production on oxidative stress, clutches collected either early or late in the 2013 nesting season were randomly and evenly assigned to a constant temperature (29.5°C) or daily sinusoidal fluctuating temperature incubation (28.7+3°C) treatment, which has a constant temperature equivalent of 29.4°C. To assess the effect of temperature fluctuation frequency on oxidative stress, eggs from early season clutches were incubated in one of three fluctuating incubation regimes; 28.7+3°C sinusoidal fluctuations every 12 (Hyper), 24 (Normal), or 48 hours (Hypo). After hatching all individuals from both experiments were sacrificed and liver and brain tissues were harvested. Lipid peroxidation and total antioxidant capacity (TAC) of tissues were then spectrophotometrically determined. We report that regardless of season and incubation conditions, both lipid peroxidation and TAC were significantly related to clutch identity. Furthermore, while antioxidant systems appear to sufficiently protect individuals from oxidative damage during embryonic development, TAC was negatively affected by season and low frequency (Hypo) temperature fluctuations.

25.6 TRIBLEHORN, JD; College of Charleston, South Carolina; *triblehornj@cofc.edu*

Comparative study of cercal system sensory processing across three cockroach species that vary in their wind−mediated behavioral responses.

The wind−sensitive insect cercal sensory system is involved in important behaviors including predator detection and initiating terrestrial escape responses as well as flight maintenance. However, not all insects possessing a cercal system exhibit these behaviors. In cockroaches (Blatteria), wind evokes strong terrestrial escape responses in *Periplaneta americana*, but only weak escape responses in *Blaberus craniifer*, and no escape responses in *Gromphadorhina portentosa*. Both *P. americana* and *B. craniifer* possess pink flight muscles correlated with flight ability while *G. portentosa* lacks wings. These different behavioral combinations could correlate with differences in sensory processing of wind information by the cercal system. Using extracellular recordings, we investigated whether such differences existed by characterizing the responses from the filiform afferent and wind−sensitive interneuron (WSI) populations to different wind velocities. We also compared these responses to examine information transfer at the first synapse. Our main results were: 1) wind elicited the weakest afferent and WSI responses in *G. portentosa*, which also possessed the smallest cerci with the least filiform hair receptors; 2) *B. craniifer* afferent and WSI responses were similar to or greater than responses in *P. americana* even though *B. craniifer* possessed smaller cerci with less filiform hair receptors than *P. americana*; 3) the greater filiform afferent responses in *B. craniifer*, including a larger amplitude second positive peak compared to the other two species, suggest more synchronous activity between filiform afferents in this species; 4) the transfer of information at the first synapse appears to be similar in both *P. americana* and *G. portentosa*, but different in *B. craniifer*.

102.8 TRINGALI, A*; BOUGHTON, R; BOWMAN, R.K.; WINDSOR, R; Archbold Biological Station; *angela.tringali@gmail.com*

Reducing plumage reflectance causes changes in dominance and corticosterone

Ornamental traits remain honest indicators of fitness if there is a direct cost to producing or maintaining the trait or if a tradeoff between ornamentation and other physiological processes exists. In addition to regulating physiology, hormones control behavior; thus phenotype, physiology and behavior are linked by hormone levels. In birds, plumage color is often an honest indicator of social status, and hormones are known to influence plumage color, providing a mechanism by which dominance signals and behaviors may be linked. Previous work on Florida scrub−jays (*Aphelocoma coerulescens*) demonstrated that experimental reductions of plumage reflectance induced a decrease in social dominance, but the mechanism underlying this effect is unknown. Here, we test the hypothesis that the decrease in dominance is due to changes in levels of corticosterone or testosterone and present data supporting the role of corticosterone mediating the effect of plumage manipulation on behavior.

P2.56 TRUONG, L. Z.*; LINKEM, C. N.; ORTIZ, B. B.; DITSCHE, P.; Wellesley College, Univ. of Hawaii, Manoa, Univ. of Washington, Univ. of Washington; *ltruong@wellesley.edu*

Northern Clingfish (Gobiesox maeandricus) − Substrate characteristics, changing water levels and wave forces.

Diurnal exposure to air during fluctuating tides, and forces imposed by crashing waves, make the intertidal zone, the habitat of Northern clingfish, unusually stressful. To cope with environmental pressures, clingfish utilize both behavioral and morphological adaptations. Modified pelvic and pectoral fins form a suction cup, which enables the fish to attach to challenging surfaces that can be extremely rough or fouled. In this study we are interested in (1) the characteristics of the intertidal rocks that make up the clingfish habitat, (2) the impact of the changing water level on distribution, and (3) the wave forces in their environment. Clingfish distribution along an intertidal transect was recorded between June 30−July30, 2014. Each collection day we overturned every rock in the transect, noted in which quadrat fish were found and determined characteristics such as rock size and roughness. Water height in relation to the mean lower low water (MLLW) was determined for the transect. Since the tides fluctuate each day, we calculated the daily time under water (DTUW) for each fish assuming it stayed in the area in which it was captured. We deployed dynamometers at 3 locations on San Juan Island to measure the maximum wave velocities. Clingfish prefer large rocks (15cm), with a huge range of surface roughness. Clingfish were found exclusively in areas that had at least 80% DTUW, this corresponds to a low intertidal region where wave forces are expected to be high. However, the maximal flow velocities measured did not exceed 4m/s in the summer. We expect higher velocities, and potentially different distribution of clingfishes in the stormier winter.

12.6 TSAI, H.P.*; MIDDLETON, K.M.; HOLLIDAY, C.M.; University of Missouri; *hptkr7@mail.missouri.edu*

More than one way to be a giant: convergence and disparity in saurischian dinosaur hip joints during body size evolution

Reconstructing joint anatomy and function is critical to understanding locomotor behavior, ecology, and evolution of vertebrates. Saurischian dinosaurs evolved a wide diversity of hip joint morphology and locomotor postures, as well as seven orders of magnitude in body size. Sauropods and theropods independently, iteratively evolved large body size, and used large volumes of soft tissues to maintain hip joint articulation. This study tested the relationships among hip joint morphological characters, body mass, and locomotor postures of saurischians. Femora and pelves of 120 taxa were digitized using 3D imaging techniques. Discrete and continuous characters were analyzed using phylogenetically corrected correlation to reveal trends in body size evolution. Theropods and sauropods decreased bony hip joint congruence by reducing supraacetabular ossifications and medially deflecting the femoral head, such that contact between the thick femoral chondroepiphysis and acetabular pads maintains articulation. However, both characters preceded phylogenetic body size increases, suggesting changes in soft tissue morphology occurred in small bodied basal taxa. Moreover, sauropods used thick femoral cartilage for maintaining joint congruence, whereas theropods relied on acetabular soft tissues such as ligaments and articular pads. Differential distribution of fibro− and hyaline cartilages suggests that the sauropod hip joint is built to sustain heavy compressive loads, whereas those of theropods experienced both compression and shear forces. These data indicate that the archosaur hip joint underwent divergent transformations in soft tissue morphology reflective of body size, locomotor posture, and joint loading.

P2.68 TSAI, CA*; YAHN, JM; KARASOV, WH; Univ. of Wisconsin, Madison; *ytsai8@wisc.edu*

Warmer temperature increases toxicokinetic elimination of PCB and PBDE in larvae

A major feature of climate change is global temperature increase, which can affect toxicant exposure to wildlife in various ways. In this study, *Lithobates pipiens* tadpoles were exposed to two kinds of Great Lake pollutants at two temperatures, 18°C and 27°C, to examine the effects of temperature on toxicant elimination rates. The tadpoles were raised on a control diet to an asymptotic size and then fed diets containing a mixure of polychlorinated biphenyl congeners (PCB; 100 ng/g wet food) or polybrominated diphenyl ether congeners (PBDE; 1000 ng/g wet food) for two weeks. The tadpoles were then allowed to depurate for two weeks. Tadpoles were weighed, staged and collected for tissue residue analysis at the beginning and the end of depuration. Previous studies have established that both PCB and PBDE elimination rates in *L. pipiens* follow first order, single compartment kinetics, therefore allowing us to obtain rate constants with two sample time points. Temperature significantly affected the size of the animals, and the rate constants (k_e) were corrected accordingly. PCB elimination rates were significantly higher at 27°C (k_e = 0. 197) than at 18°C (k_e = 0.058), with a Q_{10} value of 3.9, and PBDE elimination rates were also significantly higher at 27°C (k_e = 0.170) than at 18°C (k_e = 0.020), with a Q_{10} value of 10.9. The Q_{10} values of both compounds exceed the typical value of 2−3, indicating that warming temperatures, which are expected in climate change scenarios, may increase toxicant elimination much more than expected. How this will affect tissue residue levels will depend also on how temperature affects toxicant absorption. Funding provided by Sea Grant College Program, NOAA (Grant no. NA10OAR4170070, Project R/HCE−14).

75.1 TSOUNIS, G*; EDMUNDS, PJ; LASKER, H; California State University Northridge; *georgios.tsounis@csun.edu*

Octocoral success in degrading reefs: A case study in St John, US Virgin Islands

Global declines in cover of reef building scleractinian corals on tropical reefs have occurred over the last few decades, and these losses have been caused by a diversity of anthropogenic effects including global climate change. In response, there are large research efforts to study the patterns and causes of the changes and to develop mitigation measures. However, these efforts are usually focused on scleractinian corals, while the impacts on other taxa, such as non reef building octocorals in the Caribbean, are less well understood. Since octocorals can provide significant 3−dimensional habitat, they can be considered ecosystem engineers that affect biodiversity. In light of their potential importance, we compared trajectories of change in scleractinian and octocoral communities on two reefs in St. John, US Virgin Islands, that have been studied for 27 years. Patterns of changing abundance of these two groups differed noticeably, where in one case scleractinians suffered a dramatic decline, while octocorals often resisted stressors like hurricanes better. Furthermore, it appears that octocorals recover faster from stressors. Our results show that octocorals can maintain habitat structure where scleractinians suffer losses, and this raises the question of their role in future reef ecosystems. It is likely that despite general reef degradation in the Caribbean, octocorals might be able to maintain ecosystem services that rely on 3−dimensional structure, including functioning as nurseries for coastal fishes and enhancing biodiversity.

106.6 TULENKO, FJ*; AUGUSTUS, GJ; SIMS, SE; DAVIS, MC; Kennesaw State University; *mdavi144@kennesaw.edu*

Expression of 5' HoxD Cluster Genes in the American Paddlefish Polyodon spathula

How an autopod with morphologically distinct digits evolved during the fin to limb transition is one of the fundamental questions of comparative vertebrate anatomy. Recently published data for *Hox* family transcription factors provide new insights into this question, revealing that 1) certain enhancers regulating autopod *HoxD* expression are primitive to tetrapods; and 2) an inverted, collinear late−phase of 5' *HoxD* expression, once thought specific to tetrapods, is present in more basal taxa including paddlefish (an actinopterygian) and catshark (a chondrichthyan). Notably, any comparison of gene expression between paddlefish and other gnathostomes is complicated by a whole genome duplication (est. 42MYA) endemic to the paddlefish lineage. Here we present new *in−situ* hybridization results for 5' *HoxD* members in paddlefish, revealing variation in late phase expression not described previously. Additionally, we use 3'UTR probes specific to alpha and beta paralogues of *HoxD13* to test if both are expressed during paired fin development, and whether their relative position and timing of onset differ. Finally, we characterize the expression of *Evx2* and *LNP*, two non−Hox genes that reside at the 5' end of the *HoxD* cluster. In tetrapods, homologues of *Evx2* and *LNP* are expressed during autopod development and are regulated by the same enhancers that govern the transcription of 5' *HoxD* genes. We hypothesize that a similar expression profile between 5' *HoxD* genes and their non−*Hox* neighbors in paddlefish would be consistent with shared enhancers, as in tetrapods. Our new data will be discussed in the context of the emerging viewpoint that the evolutionary origin of the autopod involved minor modifications of ancient patterns of gene expression and their underlying regulatory landscape.

67.6 TURINGAN, R.G.*; SLOAN, T.J.; KERFOOT, J.R.; Florida Institute of Technology, Union University; *turingan@fit.edu*

Variable response of feeding kinematics to environmental temperature in teleost fishes

It has been hypothesized that below an optimal temperature, a 10 °C increase in temperature induces a twofold increase in the rate of muscular contraction. This doubling of physiological rate can translate into a doubling of performance of functional systems driven by physiological rate processes. However, previous research revealed that feeding kinematics in fishes has no or little response to temperature. We investigated the effects of temperature on feeding kinematics in teleost fishes to elucidate the sources of variation in organismal response to temperature change. Two sets of experiments were conducted. In one, we compared the thermal sensitivity (Q_{10}) of kinematic velocities among different sizes of an invasive teleost. In the other, we compared the thermal sensitivity of kinematic velocities between the northern and the southern populations of an invasive fish. In addition, we compared the thermal sensitivity of the expansive and compressive phases of the feeding repertoire in these invasive fishes. Results revealed that thermal response of kinematic velocities are confounded by (1) body size or life−history stage of fish, (2) geographic location of fish, and (3) phases of the feeding event. It is conceivable that teleost fishes have the ability to mitigate the consequential effect of temperature change on muscle shortening velocity, thus, are able to perform equally well under fluctuating environmental conditions.

P2.189 TURINGAN, R.G; PANG, Y*; SLOAN, T; HENSELMAN, J; FAVATA, C; Florida Institution of Technology; *pangyuchen1001@gmail.com*

Latitudinal Variation in Temperature Response of Feeding Performance in Bluegill Sunfish Lepomis macrochirus

The ability of an individual to perform a certain task (e.g., prey capture) driven by a temperature−dependent process is constrained by the reduction in biological rates as a consequence of decrease in environmental temperature. Environmental temperature has a profound influence on the fish's ability to successfully accomplish relevant tasks such as swimming, feeding, mating, and escaping from predators. The expression of temperature−induced changes in fish−muscle physiology varies according to different temporal scales (e.g., seasonal or developmental) and levels of organization. Seasonal temperature change may induce modifications of muscle properties, allowing fish to acclimate to the new ambient temperature and drive plastic responses that mitigate temperature effects on whole−organismal performance. In an attempt to advance our understanding of how acclimation contributes to the mitigation of temperature−induced effects on performance, this study was designed to compare the prey−capture performance of bluegill sunfish, *Lepomis microchirus*, adapted to two contrasting ecosystems: western Massachusetts and central Florida. Overlapping size class of fish in both allopatric populations were filmed in a common experimental room at Florida Institute of Technology using high−speed video while feeding on pieces of earthworm, *Lumbricus*, at 20C, 24C, 28C, and 30C to compare prey−capture kinematics among temperatures and between populations. In the initial phase of prey−capture, kinematics is independent of temperature, whereas, the kinematics of the compressive phase of the feeding event is more variable and appeared to be temperature dependent. The disparate effects of temperature on different components of feeding are extremely interesting and warrant further investigations.

61.6 TURNER, R.L.; Florida Institute of Technology, Melbourne, FL; *rturner@fit.edu*

Approaches to Teaching Marine Microbiology

Teaching undergraduate marine biology majors about marine microbes can be a disappointing experience because their interests too often focus on marine megafauna. Furthermore, textbooks on marine biology minimally support the subject. Marine microbes comprise one−third of my semester course taught to seniors. Although my lectures are organized phylogenetically (viruses, eubacteria, archaeons, stramenopiles [except brown algae], haptophytes, alveolates, filose amoebae, choanoflagellates, ascomycotes), major themes on the biology and ecology of marine microbes help to unify the subject: the origin of life in the seas, metabolic diversity, effectors of global climate change and extinctions, marine diseases, among others. Relevance to student interests is maintained by tying marine microbes to food chains and diseases of megafauna, fisheries, and aquaculture organisms. Scientific importance of marine microbes is emphasized by use of recent primary and review papers as required readings to supplement the textbook. PowerPoint−based lectures are sprinkled with frames titled "Marine Biology in the News", which report recent developments about marine microbes from Sigma Xi SmartBrief and other current science news sources. Lectures also are laced with "amazing facts" on largest, smallest, most abundant, firsts, weirdest, etc. The roles of marine microbes in the sea are emphasized again in later lectures on macroalgae, marine vascular plants, metazoan plankton, and marine tetrapods. Over the years, complaints about coverage of marine microbes on end−course evaluations have greatly decreased, and attendance has remained high. Production of a few career marine microbiologists among alumni adds to my reward.

P2.59 TURNER, CR*; STILLMAN, JH; SFSU, Romberg Tiburon Center; *cturner@mail.sfsu.edu*

Effects of ocean acidification and warming on the growth of juvenile porcelain crabs

Sea surface pH is projected to decline 0.3 units from current conditions by the year 2010 (ocean acidification, OA). In the same timespan, global surface temperature is expected to increase up to 5°C (ocean warming, OW). Intertidal zone organisms, which are adapted to variable and extreme environments, may already be living at their tolerance limits, and OA and OW may be physiologically stressful. Few studies have examined the integrated effects of growth on juvenile organisms under such conditions, as juvenile growth has been shown to be negatively impacted by both OA and OW. Previous research on adult *Petrolisthes cinctipes* showed that OA and OW conditions resulted in metabolic depression and increased thermal tolerance. However, it was unclear how ATP energy was allocated under OA and OW conditions. We asked: is ATP energy expenditure affected in growth processes of juvenile *P. cinctipes* while experiencing future OA and OW conditions? We hypothesized that ATP energy supply to growth processes would decrease, and therefore, juvenile *P. cinctipes* growth rates would slow under OA and OW conditions. To simulate year 2100 conditions, we have conducted a multi−stressor experiment to assess growth in response to OA and OW. Juvenile *P. cinctipes* were exposed for 35 days to four hours of either future OA (pH 7.3) or ambient (pH 8.0) conditions while immersed, and five hours of either a temperature spike to 25°C or ambient temperature (14°C) while emersed. Initial mortality data may indicate an increase in temperature may exacerbate mortality under acidic conditions. In addition, growth may be hindered in OA conditions, and may be exacerbated in combination with OW. These results may suggest that ATP energy may be diverted from growth to compensate for the physiological processes needed for survival in OA and OW conditions.

P3.198 TUTTLE, V.; MANSOUR, M.; GOVINDAVARI, J.P.*; SMITH, R.; CONRAD, J.L.; NYIT College of Osteopathic Medicine, Jungle Bob's Reptile World; *jack.conrad@gmail.com*

Evolution of non−integumentary soft−tissue anatomy within Squamata (Reptilia)

Numerous phylogenetic studies have addressed squamate (lizard and snake) diversity over the 30 years, typically focusing on osteological data or molecular data. Non−integumentary soft−tissue (NIST) characters are rarely used in these analyses, despite an abundance of descriptive publications. Using published data and new specimen dissections, we constructed a phylogenetic data matrix of 331 NIST characters. Our matrix includes characters addressing skeletal muscle, brain/nervous system, and tongue morphology, among others. We analyzed these data to determine what signal, if any, is provided by these under−used character systems. Although there was limited overlap in character scoring between some groups of taxa, we included 60 squamate species representing 41 "families" (including all of the major squamate clades) in our analysis, and the outgroup *Sphenodon punctatus*. Our analyses recovered many of the clades traditionally recognized in morphological studies (e.g., Varanoidea). As with recent genetics−based analyses, dibamids are found to be basal within the tree. Unexpected results were also recovered. Macrostomatan snakes were recovered as closely related to teiids based on cranial musculature, hemipenial characters, foretongue division, and spermatozoan microstructure. *Xantusia* was recovered as a proximal gekkotan outgroup based on eyeball morphology, gross and microscopic tongue morphology, and inner ear microstructure. These and other unexpected results may be more important for understanding ecology/behavior−based convergence than true relationships. Even so, these NIST character systems offer informative data regarding squamate evolution and diversity.

32.4 TWEETEN, K.A.*; DANIELSON, K; St. Catherine University; *katweeten@stkate.edu*

Analysis of Extracellular Matrix Molecules in Lumbriculus Cocoons and Embryos

Extracellular matrix interactions with cells affect signal transduction, cell migration, differentiation, and tissue organization. The components of the extracellular matrix and their functions during embryonic development in annelids are not well−characterized. With access during the summer months to cocoon−producing *Lumbriculus*, we used immunological and histological techniques to look for glycosaminoglycans and extracellular matrix proteins in cocoons and embryos. Ponceau S staining of sectioned cocoons showed that the cocoon membrane was proteinaceous. Several proteins ranging in size from 21,000 to 91,000 daltons were also detected in the matrix (jelly) that surrounds embryos within cocoons. The jelly was comprised of sulfated mucopolysaccharides, based on safranin O, alcian blue, and dimethylmethylene blue staining. Incubation of cocoons for 1 to 16 hours with enzymes that degrade glucan sulfate, chondroitin sulfate, and dermatan sulfate showed no differences in alcian blue staining between control and enzyme−treated sections. These results, together with the inability of hyaluronic acid−binding protein to interact with the jelly, suggested the matrix surrounding *Lumbriculus* embryos is a distinct glycan. In adult worms, epidermal cells in the segments containing reproductive structures stained with safranin O and alcian blue and were elongated compared to epidermal cells in segments without reproductive structures. It is likely that the elongated cells were involved in production and secretion of the jelly during cocoon formation. Immunohistochemistry revealed the presence of laminin and fibronectin in embryos at late stages of development. Future research will explore the relationships between the temporal expression of these extracellular matrix molecules and specific events occurring during embryonic development.

P1.41 TWIGG, R.S.*; KOCOT, K.M.; BRANNOCK, P.M.; MAHON, A.R.; HALANYCH, K.M.; Auburn University, Auburn, AL, Auburn University, Auburn, AL; University of Queensland, Brisbane, Australia, Central Michigan University, Mount Pleasant, MI; *rst0004@auburn.edu*

Phylogenetic Identification and Species Diversity of Antarctic Octopods

The Antarctic is home to a vast number of species adapted to survive the harsh environment and potentially travel over great distances. Octopods are a facet of this ecosystem in need of further study. Moreover, the Antarctic is undergoing rapid climate change, and thus understanding organismal ranges is important to assess future changes. We are also interested in Antarctic octopod biogeography from an evolutionary perspective. During the 2013 cruises on the *R/V Nathaniel B. Palmer* and *R/V Laurence M. Gould*, octopod samples were collected along the western portion of Antarctica from the Ross Sea to the Peninsula. Distinguishing octopod species morphologically can be difficult because of limited external characteristics, and thus we are augmenting morphological assessments with data from the COI mitochondrial gene for barcoding. Most of individuals sampled were *Adelieledone polymorpha*, *Pareledone aequipapillae*, or *P. turqueti*. Results showed *P. turqueti* was present throughout sampled regions, while both *A. polymorpha* and *P. aequipapillae* were found predominantly in the Wrights Gulf and the Ross Sea regions. Presumably, all three species have similar reproductive habits as octopods brood their young, suggesting other factors account for differences in distributions. This study expands knowledge of regional biogeographic patterns, and will contribute to a preliminary understanding of octopus species diversity in Antarctic waters.

25.4 TYRRELL, LP*; BUTLER, SR; YORZINSKI, JL; FERNÁNDEZ−JURICIC, E; Purdue University; *ltyrrell@purdue.edu*

A novel system for eye−tracking in small birds.

Animals use vision to gather information about their environment, and then use that information to make behavioral decisions that affect fitness. They will often move their heads or eyes to inspect areas of interest with their centers of acute vision, such as foveae, to gather high−resolution information about potential mates and predation risks. But, few studies to date accurately determine where laterally eyed animals direct their visual attention and how they use their eyes to gather information. Therefore, we developed an eye−tracking system that can simultaneously track the gaze of two eyes. This is particularly useful for studying animals with laterally placed eyes (most vertebrates) where the two eyes are viewing different images. This system can also accommodate comparative studies using animals of varying size, including small animals that are not frequently used in eye−tracking studies due to constraints of existing eye−tracking systems. We conducted an experiment to test the accuracy of the system and to define eye movement patterns in European starlings (*Sturnus vulgaris*). We were able to accurately track the gaze of starlings with less than 5º of error. Starlings primarily moved their eyes along an axis 17.8º (± 2.9º) off horizontal, such that they look forward and down, as well as up and back. This axis could aid the ground foraging starling in finding food on the ground and in detecting aerial predators approaching from behind. Starlings exhibited a spectrum of yoked and non−yoked eye movements, including the ability to fully converge their eyes forward, but could not simultaneously diverge their eyes to the extent predicted by the movements of a single eye. Therefore, starlings have a more limited ability to reduce the blind area behind the head than previously thought.

P2.58 UELAND, W.R.*; BERNER, N.J.; Sewanee: University of the South; *nberner@sewanee.edu*

Correlation of tafazzin (TAZ) gene expression with cardiolipin composition in the Eastern red spotted newt (Notophthalmus viridescens viridescens)

Adult Eastern red spotted newts remain active in winter. Our previous research shows that acclimation to winter conditions includes an increase their metabolic rate and in the activity of membrane−bound metabolic enzymes, an adjustment of overall membrane fatty acid composition toward more polyunsaturation, and modified fatty acid content of cardiolipin (CL). Of particular interest here are the higher skeletal muscle cytochrome c oxidase (CCO) activity and the change in CL structure in winter newts. The skeletal muscle of winter newts presents a predominant CL with a lower mass ratio (1447.97 *m/z*) in comparison to summer newts (1449.99 *m/z*). Cardiolipin plays a role in maintaining mitochondrial membrane shape, and is thought to facilitate structural changes necessary for CCO activity. After biosynthesis, CL is modified into an active form by the phospholipid transacylase called tafazzin, which is encoded by the *TAZ* gene. Our experiment was conducted to test the hypothesis that *TAZ* gene expression levels change with season (increase in winter), which would correlate with CL fatty acid makeup and changes in CCO activity, providing a possible mechanism for acclimation of these characteristics. Newts were collected in winter and summer, euthanized, and skeletal muscle and liver tissue was stored in RNAlater™. RNA was isolated from approximately 0.04 g tissue. The RNA samples were diluted to similar concentrations for conversion to cDNA. Quantitative real time PCR was run to compare *TAZ* gene expression in winter and summer newts. Preliminary data from 8 summer and 10 winter newt liver tissue samples show a significant ($p = 0.017$) increase in *TAZ* expression in winter. We expect *TAZ* levels to be up−regulated in winter newt skeletal muscle tissue as well.

110.6 UY, FMK*; ZORRILLA, N; University of Miami; *floriamk@bio.miami.edu*

The role of visual stimuli and social interactions in influencing brain plasticity in newly−established colonies of a primitively eusocial wasp

Plasticity in brain development has evolved in many independent taxa, suggesting advantages for the ability to preferentially invest in specific neural structures in a changing environment. However, the explicit role of changes in ecological factors and environmental stimuli in neural developmental plasticity remains poorly understood. Using the wasp *Mischocyttarus mexicanus* where females form solitary or group nests, we investigated the influence of social interactions and visual stimuli in the development of the brain's Mushroom Bodies (MB), the neuropils associated with learning and memory. We compared MB development in solitary foundresses and groups foundresses. We also experimentally manipulated whether wasps were reared in a visually complex environment, or in the laboratory under deprived light conditions and constrained from foraging for both solitary and group conditions. In contrast to previous studies, we found no association between level of social interaction (i.e., solitary vs. group) and volume of the lip, the MB substructure that receives olfactory information from interactions. Lack of differences between group and solitary foundresses in the field and laboratory, and between reproductives and auxiliaries in MB development may be related to behavioral and reproductive plasticity, and to frequent nest−switching in this species. In contrast, collar and basal ring volume, the MB substructures known to receive optical input, were positively associated with exposure to complex visual stimuli. Our results indicate that visual stimuli influence the differential development of brain structures that receive visual input suggesting that plasticity in brain architecture is influenced by changes in visually complex environments.

S4.6 UYENO, TA*; CLARK, AJ; Valdosta State University, College of Charleston; *tauyeno@valdosta.edu*

Muscle articulations: an assessment of multifunctional jaw joints made of soft tissue

This study surveys animals that use soft tissues rather than rigid links to build jaw joints. Rigid biting elements are useful; having hard surfaces to use on substrates or other organisms can directly impact survival and reproduction. Typically, biting surfaces are connected through rigid jaw links that transmit the bite reaction forces. As such, jaws must incorporate joints that resist compression resulting from bites. Most jaw joints are "sliding joints", in which jaw links come into direct contact and the shape of the siding contact surfaces dictates possible link motion. There are, however, organisms that have biting elements on jaws that are made of flexible muscle and connective tissues. If arranged as a muscular hydrostat, in which multiple muscle fiber orientations may co−contract to provide turgid skeletal support, the multifunctional joint may a) provide the force to move the biting elements, b) create pivots and c) transmit bite reaction forces. Such flexible joints, termed "muscle articulations", may be important to a number of "soft" invertebrates. In this survey, we review muscle articulation function of the joints found between inarticulate brachiopod valves, cephalopod beaks, kalyptorhynch flatworm hooks, and errant polychaete jaws. We also present a novel interpretation of the hagfish knotting/feeding behavior as a putative muscle articulation. Hagfish toothplates, and their flexible support structures, were analyzed using dissections, X−ray microCT using PTAH (contrast agent), and histology. Videos of hagfish feeding show that coordinated jaw plate/body movements provide the leverage needed for strong "bites", even despite the lack of an element opposing the toothplate.

29.2 UYENO, D; Florida Museum of Natural History, University of Florida; *daisuke.uyeno@gmail.com*

Are most fish parasitic copepods undescribed? Great diversity of pennellids (Copepoda: Siphonostomatoida) revealed during survey of gobies in the western Pacific

Parasitic copepods have evolved a diversity of highly modified body types to suite their varied lifestyles. Reduction and loss of appendages and simplification of the general body are hallmarks of adaptation to parasitic life. The Pennellidae (Siphonostomatoida), comprising more than 130 species in 20 genera, is one of the most highly modified families. Following mating females penetrate into the host's tissue and transform their body without molting. Pennelids are mesoparasites of marine fishes and whales, and species that infest commercial fishes have been most studied. Gobioidei (Actinopterygii: Perciformes) is one of the most diverse groups of marine to freshwater fishes, comprising more than 2100 species. Since many gobies are less than 150 mm in length, they have limited value to fisheries. Consequently their parasites have remained understudied, and only three species of pennellids, *Cardiodectes rotundicaudatus* Izawa, 1970, *Haemobaphes diceraus* C. B. Wilson, 1917 and *Serpentisaccus magnificus* Blasiola, 1979, have been documented from gobies. During recent field surveys using SCUBA diving, twelve species of pennellids were found on gobies collected in the coastal waters of Japan, Philippines, New Caledonia, Australia and Papua New Guinea; eleven of these were undescribed. This shows that parasitic copepods are greatly underdescribed and their diversity will only be understood when all fishes are surveyed.

24.4 VALLE, S*; CARPENTIER, E; VU, B; DEVICHE, P; Arizona State University, Universite de Poitiers; *shelley.valle@asu.edu*

Food restriction negatively affects multiple levels of the reproductive axis in male House Finches (Haemorhous mexicanus)

Nutrition influences reproductive functions across vertebrates, but the effects of food availability on the functioning of the hypothalamic−pituitary−gonadal (HPG) axis and the mechanisms mediating these effects in wild birds remain unclear. We investigated the influence of mild chronic food restriction on the HPG axis of photostimulated House Finches (*Haemorhous mexicanus*). Food−restricted birds had underdeveloped testes with smaller seminiferous tubules than control (*ad libitum* fed) birds. Baseline plasma testosterone (T) increased in response to photostimulation in control but not in food−restricted birds. However, food availability did not affect the plasma T increase resulting from a gonadotropin−releasing hormone (GnRH) or a luteinizing hormone (LH) challenge. Thus, decreased testis size and low plasma T secretion during food restriction did not result from decreased sensitivity of the pituitary gland to GnRH or of the testes to LH. The number of hypothalamic GnRH−I immunoreactive cells was higher in food−restricted than control finches, suggesting accumulation from non−release. Food availability did not influence plasma CORT, indicating that the observed HPG axis inhibition did not follow increased activity of the hypothalamic−pituitary−adrenal axis. This study is among the first to examine multilevel functional changes in the HPG axis in response to food restriction in a wild bird. The results indicate that food availability affects both hypothalamic and gonadal function and further investigations are needed to clarify the mechanisms by which nutritional signals mediate these effects. Supported by National Science Foundation Award 1026620 to P.D.

S10.8 VAN ALSTYNE, K.L.; Western Washington University; *kathy.vanalstyne@wwu.edu*

HARMFUL NATURAL PRODUCTS PRODUCED BY GREEN TIDE SEAWEEDS AND THEIR POTENTIAL EFFECTS ON OTHER ORGANISMS

Large accumulations of green seaweeds are occurring with increasing frequency on shores worldwide. These blooms, known as "green tides", have a number of impacts on planktonic and benthic organisms in habitats where the blooms occur. Although the best−known impacts involve smothering or shading other organisms, blooms can alter the environment by affecting seawater chemistry. In addition to altering the pH and changing CO2 and oxygen concentrations in the surrounding seawater via respiration and photosynthesis, the algae comprising the blooms produce natural products that can be consumed by herbivores or released into the surrounding air or water. Some of the best studied compounds produced by green tide seaweeds include the sulfur compound dimethylsulfoniopropionate (DMSP), the neurotransmitter dopamine, and a variety of reactive oxygen species (ROS). These compounds and their breakdown products have ecological, physiological, and environmental effects, which can include deterring feeding by herbivores; acting as allelopathic agents and toxins towards potential competitors, fouling organisms, and other species in the environment; and, potentially acting as intra− or interspecific signaling molecules. Here, I will examine factors affecting the production and release of these natural products as well as their known and potential impacts on other organisms in the environment in order to assess whether these deleterious effects are incidental or have adaptive value.

P3.78 VAN DER WALT, M*; NEUMAN−LEE, LA; SMITH, GD; FRENCH, SS; Utah State University; *Marilize268@gmail.com*

Group housing and stress in side−blotched lizards

While reptiles are commonly considered solitary animals, they can have complex social interactions in nature. This has been confirmed by observed adverse behavioral changes in reptiles housed individually when in captivity. However, few studies have examined the true physiological consequences of this practice. In this study, we tested how being housed with and without conspecifics caused physiological changes, including circulating corticosterone and reproductive hormone concentrations, and bactericidal ability in male and female side−blotched lizards (*Uta stansburiana*). While there were no significant physiological changes in females, we found that males housed alone had significantly higher corticosterone concentrations, and that males housed with a female had higher testosterone levels. In addition, males housed in pairs had relatively reduced immune function when compared to individually housed males. The difference among sexes may be due to the stronger territoriality males exhibit when compared to females. Our results suggest that individually housing male reptiles might be stressful, and that males group−housed with female conspecifics maintain higher levels of testosterone indicative of better reproductive function. This group housing is not without cost, however, as animals with elevated testosterone also show reduced immune ability. As both scenarios may be adverse or beneficial to an animal, research and animal husbandry facilities must take these physiological changes into consideration when determining housing regimes for reptiles.

P2.183 VAN HEMMEN, A.R.*; DITSCHE, P.; University of Washington, Seattle, University of Washington; *abby.vanhemmen@gmail.com*

Stuck on You: The Attachment Forces of Metridium farcimen

To cope with the forces of wave activity, organisms living in the intertidal have developed a variety of mechanisms to stay in place. *Metridium farcimen* (white−plumed sea anemone) can withstand wave action by strongly attaching to solid substrates. However, not much is known about the attachment forces this animal utilizes to hold onto the substrate. *M. farcimen* attach to a substrate by secreting an adhesive glue from the basal foot. Limpets, another intertidal invertebrate, attach to substrate using glue and the additional force of suction. In this study, we explore the possibility of suction and glue working in unison to attach *M. farcimen* to substrate. Since no suction can occur on surfaces with holes, our experiments were performed using acrylic glass substrates with and without holes. Specimens attached to the substrate were placed in a small water tank where they were connected to the sensor of a mechanical testing machine. The machine recorded the force required to remove the anemone from the substrate. The pull−off forces and the area of each anemone's basal foot were used to calculate tenacity. Specimens attached to solid substrates with a tenacity of 9.36 kPa ± 5.35 (mean ± s.d.). This is comparably less than other intertidal species such as limpets or clingfish. On holed substrates tenacity was 5.48 kPa ± 2.31 (mean ± s.d.). These data imply that suction is a component of *M. farcimen* attachment, but glue plays the dominant role. Attachment site selection behaviors were also examined. When given the option of attaching to acrylic glass substrates with and without holes, *M. farcimen* showed no preference for either substrate. We conclude that suction contributes to attachment in *M. farcimen*, but does not seem to influence attachment site selection under normal conditions.

S12.3 VAN WASSENBERGH, S.; Ghent University, Belgium; *sam.vanwassenbergh@ugent.be*

Computational fluid dynamics of suction feeding

Suction feeders generate a flow of water that draws the prey into the mouth. This process involves extremely unsteady flow, outside as well as inside of the mouth cavity. Especially for flow patterns inside the mouth cavity and related dynamics and energetics (e.g. the forces, muscle work, and power requirements) for expanding the mouth cavity, our current knowledge is largely based on modelling studies. Computational fluid dynamics (CFD) is a mathematical modelling technique that allows a more complete and accurate assessment of suction feeding hydrodynamics compared to previous modeling approaches. It simulates fluid flows by numerically solving the motion equations for a fluid volume divided into a mesh containing a large number of small volume elements. Using CFD software that allows the surface mesh of the head of the animal to be programmed to deform as observed in vivo, the three−dimensional flow patterns as well as the instantaneous hydrodynamic forces exerted at the surface of the head can be calculated, hence enabling inverse dynamic analyses. In this presentation, examples of new technical advances and biomechanical insights based on dynamic−mesh CFD models will be given. This will include how Chinese giant salamanders generate suction by separating their long and wide jaws, how the quickly rotating and widening snout of seahorses is employed to capture prey, and how the outflow of water through the opercular slits in fish can be modelled.

92.6 VANCE, J.T.*; HUMBERT, J.S.; College of Charleston, Univ. of Maryland; *vancejt@cofc.edu*

Optomotor response to simulated yaw rotations during tethered flight in honey bees, Apis mellifera

Insects are capable of rapid sensorimotor responses to mitigate severe flight perturbations. Although the visual system of honey bees has been well−studied in the context of flight navigation, it is unclear how vision is used over short timescales for reactive flight control. In this study, we investigated the latency and bandwidth of the compound eye visual system in tethered honey bees (*Apis mellifera*) by simulating egomotion about the yaw−axis using a custom LED arena. Six simple 90−degree rotations of the visual field, ranging from 250°s^{-1} to 1500°s^{-1}, were presented in random order. Two complex oscillating visual patterns, constructed using the sum of sine waves generated at logarithmically−spaced frequencies of prime multiples, were presented to evaluate the optomotor response between 0.65 and 30 hz. High−speed videography recorded wing and head kinematics in the horizontal plane. Bees responded to the 90−degree rotations using asymmetric stroke amplitude, presumably to generate a yaw moment opposing the perceived rotation, and head rotation in the direction of the moving visual field. The optomotor latency of wing and head kinematics was 47 msec on average, and did not differ across rotation velocity. The amplitude of the wing and head kinematics response was inversely related to rotation velocity. During the sum of sines visual perturbation, bees exhibited wing kinematics frequency response beyond 20 hz with increasing phase lag, however head kinematics response declined above 10 hz. Although the bandwidth of head kinematics may be limited by the available power of the neck musculature, the resulting reduction in gaze stabilization at high frequencies could be mitigated by reducing the effect of head phase lag, associated with optomotor latency, on optic flow.

66.4 VANDENBROOKS, J.M.*; BARTHOLOMEW, N.R.; BURDETT, J.; QUINLAN, M.; CALL, G.B.; Midwestern University; *jvandenbrooks@midwestern.edu*

Carbon dioxide anesthesia impacts climbing and flight behavior in Drosophila melanogaster

Laboratories that research *Drosophila melanogaster* use carbon dioxide (CO_2) on a daily basis to anesthetize flies for sorting and other work. However, CO_2 has potential effects on a variety of physiological and behavioral mechanisms including respiratory and muscle physiology, and climbing and flight behavior. We have examined the effect of multiple levels of CO_2 and varying exposure times on the subsequent recovery of motor function tested with both climbing and flight assays. We have found that with as little as five minutes exposure to 100% CO_2 *D. melanogaster* exhibit motor deficits up to 16 hours after exposure. Any exposure length above five minutes produces behavioral effects on climbing that last for over 24 hours. Overall, there is a positive correlation between CO_2 exposure length and recovery time. When given just one hour to recover after any length of exposure, climbing is reduced by 70−90% and flight by 40−60% as compared to control flies. This effect is not due to anoxia alone, but a CO_2−specific mechanism as shown by a reduced impact of exposing *D. melanogaster* to just anoxia (100% nitrogen). Additionally, we have shown that exposure to as low as 65% CO_2 (balanced with 20% oxygen and 15% nitrogen) affects the motor capability of *D. melanogaster*. Exposure of *D. melanogaster* to flow rates similar to that would be used in CO_2−exposure pads in most laboratories reduces climbing ability by 35−75% depending on the flow rate. These results point to a strong impact of CO_2 anesthesia on subsequent experimental tests in the lab indicating the importance of monitoring CO_2 exposure levels, flow rate and length of exposure for any physiological or behavioral study.

P1.196 VANMAURIK, L.N.*; WORTHAM, J.L.; Univ. of South Florida, Univ. of Tampa; *Lvanmaurik@mail.usf.edu*

Clarification of setae morphology and terminology in decapod crustaceans using Macrobrachium (Caridea) and Libinia (Brachyura)

Like many other invertebrates, crustaceans have setae which are articulated outgrowths of the exoskeleton. Setae have a multitude of functions including tactile response, chemosensory reception, mechanical action, decoration and protection, and the removal of fouling debris. There is much confusion in the literature regarding the proper usage of terminology when describing the morphology of setal types and structures. Scanning electron microscopy (SEM) examination of pereopods and grooming appendages using several species in two distinct crustacean groups provide excellent examples for the clarification of common setal types as well as the identification of novel setae types and structures. Documentation and description of these novel setae provide an opportunity to clarify the proper use of terminology. Using two species of caridean shrimp (*Macrobrachium* spp.) and four species of brachyuran crabs (such as *Libinia* spp.), five novel setae types were identified. In addition, description of common setae types such as simple, spiniform, serrate, and pappose setae along with structures such as denticules, setules, annuli, and spines are offered. The aim of this study is to clarify the setal terminology of crustaceans in hopes that future authors will employ universal language to avoid further confusion and erroneous classifications and descriptions.

P3.46 VARGA, K.T.; University of Illinois at Chicago; *varga@sxu.edu*
Phosphatidylserine is Important for Clathrin−Mediated Endocytosis
Phosphatidylserine is important for clathrin−mediated endocytosis Author Block: *K.Varga, L−W. Gong; Department of Biological Sciences, Laboratory of Integrative Neuroscience, UIC, Chicago, IL Phosphatidylserine (PS) is the most abundant negatively charged phospholipid species found within eukaryotic membranes. Its biological importance is displayed through its unique biochemical properties, most notably through its direct binding to proteins bearing C2 domains. Interestingly, PS is highly relevant to vesicle exocytosis at synapses via its interaction with vesicular protein Synaptotagmin 1 (syt 1) C2 domains. Concurrently, endocytosis occurs at synapses to maintain synaptic integrity. However, it remains unclear whether PS plays a role during synaptic vesicle endocytosis. In the present study, clathrin−mediated endocytosis (CME) of single vesicles was monitored using cell−attached capacitance measurements in the mouse adrenal chromaffin cell. In this approach, a sinusoidal voltage is superimposed to the holding potential and a two−phase lock−in amplifier is used to analyze the current output signal. From here, the two outputs of the amplifier provide direct changes of both membrane conductance and membrane capacitance. Supplementation of PS, was compared to supplementation of two other neutrally charged lipid species: phosphatidylethylalomine (PE) or phosphatidylcholine (PC). These additions were carried out in chromaffin cells in culture prior to cell−attached electrophysiology. Our results showed that: (1) Negatively charged PS but not neutrally charged PC or PE, significantly decreased the fission−pore duration during the last stage of vesicle retrieval; and (2) the $Ca2+$ dependence of CME kinetics was shifted by PS addition.

S10.1 VASEY, G.; LUKEMAN, R.; WYETH, R.C.*; St. Francis Xavier University; *rwyeth@stfx.ca*
Where was that smell coming from? A mathematical model of odor−gated rheotaxis in variable flow direction conditions indicates variation in adaptive navigational strategies.
The navigation strategies animals use to find odor sources depend on the odor stimuli, the fluid flow properties, and the locomotory capabilities of the animal. In high reynold's number environments, animals typically use odor−gated rheotaxis (OGR) to find the source of turbulent odor plumes. This strategy succeeds because although turbulence creates an intermittent chemical cue, the animal follows the (continuous) flow cue that is transporting the chemical. However, in nature, animals may lose all contact with an odor plume as variations in bulk flow direction cause the plume to be rotated away before the animal reaches the source. Our goal was to use a mathematical model to explore the range of circumstances where different strategies that augment OGR might be beneficial for finding an odour source in such variable flow. The model links a stochastic variable−direction odor plume with a turbulence−based intermittent chemical signal and four different movement strategies, including: OGR alone (as a control), OGR followed by further rheotaxis in the absence of odor, OGR followed by a random walk, and OGR followed by movement actively guided by the last flow heading detected with odor present. We found that any of the three augmented strategies could improve on strict odor−gated rheotaxis. Moreover, the best strategy depended on the distance from the odor source, rate of movement of the animal, and the magnitude of flow variation. Our results suggest that animals that rely on odor cues to navigate in turbulent environments may be subject to selective forces affecting both immediate responses to odor cues as well as more delayed responses that could more fully exploit the information that can be derived from odor plumes.

55.2 VAUGHT, RC*; HELMS, BS; SUCIU, SK; SANTOS, SR; Auburn University, Emory University; *RCV0004@auburn.edu*
Is there more to a "species" than meets the eye? A tale of two crayfishes in the Tallapoosa Basin, Alabama
The state of Alabama is among the most specious in regards to aquatic fauna. However, much of this biodiversity remains unexplored, particularly from a population genetics perspective. Here, 30 locations across the Middle, Upper, and Little Tallapoosa drainages in eastern Alabama were surveyed and sampled for populations of two native crayfish species, *Cambarus englishi* and *C. halli*. Using mitochondrial cytochrome oxidase subunit I (COI) sequencing, genetic structure was quantified and surprising ecological and evolutionary associations were identified. Specifically, *C. englishi* exhibited lower genetic diversity than *C. halli*, suggesting the two species have experienced differing evolutionary histories across the Tallapoosa River Basin. Along with this, both species possessed highly divergent mitochondrial COI haplotypes, implying that *C. englishi* and *C. halli* may each represent multiple genetic "species" belonging to single, respective morphological "species". Unexpectedly, individuals of the two "species" from populations in the same geographic region typically belonged to a common genetic/haplotype network (i.e., *C. englishi* and *C. halli* from the Middle Tallapoosa are more closely related to each other than either is to members of the same "species" in other drainages). The importance of geography in the context of the population structure of *C. englishi* and *C. halli* was further supported by the fact that 45 of 46 total pairwise comparisons across the two "species" approached the upper limit of 1.0, meaning the sharing of haplotypes across populations was non−existent. Due to the exceptional endemism of these two "species", streams inhabited by *C. halli or C. englishi* should be considered for conservation efforts in Alabama.

P1.174 VEGA, CM*; CHADWELL, B; ASHLEY−ROSS, MA; Wake Forest University, NEOMED; *vegacm11@wfu.edu*
Turtling the salamander: the role of lateral undulation in sprawling locomotion
Lateral undulation of the vertebral column is an important characteristic of sprawling postured tetrapods' locomotion. The goal of this study was to determine the role of the lateral movement of the trunk vertebrae in terrestrial locomotion of tiger salamanders (*Ambystoma tigrinum*) by artificially limiting trunk flexibility by attaching a 2−piece "shell" around their trunk between the pectoral and pelvic girdles. Adult tiger salamanders ($n = 3$) walked on a 1 m trackway under three different conditions: no shell, flexible shell (tygon tubing), and rigid shell (PVC tubing). Trials were filmed in a single, dorsal view using a Kodak Playsport camera (30 fps). Kinematic markers were located on the wrist, elbow, and shoulder joints of the forelimb. A custom−written MATLAB program was used to track the midline and the forelimb movements of the salamanders and analyze midline and kinematic variables. Average and maximum curvatures over the entire midline and trunk/tail regions were compared over multiple strides. We predict that average and maximum curvatures should decrease with the rigid shell and there should be no difference between no shell and the flexible shell. The average and maximum curvatures for the trunk region may be less than those of the tail region if tail movement increases to compensate for reduced trunk flexibility.

P2.28 VELEZ−JUARBE, J.; Natural History Museum of Los Angeles County; *jvelezjuar@nhm.org*

Paleoecology of Marine Mammal Herbivores in the Eastern Pacific Ocean

Seacows (manatees and dugongs) are the only extant marine mammal herbivores. However, the fossil record reveals two other groups of marine mammal herbivores that co−existed with sirenians in the Neogene: desmostylians, in the northern Pacific region; and thalassocnine sloths, in the southeastern Pacific region. There is no extant analog for these co−occurring species of marine herbivore assemblages in the northern Pacific (sirenians and desmostylians) and southeastern Pacific (sirenians and thalassocnines). So, how did these multiple, co−occurring marine herbivores partition their resources? To undertake this problem, I use a multidisciplinary approach to evaluate the paleoecology of sirenians, desmostylians and thlassocnines that combines stable isotope geochemistry with ecomorphological and body size data. The first approach examines isotopic values of δ13C and δ18O from sirenians, desmostylians and thalassocnines, obtained from their enamel and bone samples, which reflect their diet and habitat, respectively. Second, morphological data from the skull, teeth and jaws clarify ecologically linked functional traits that will be used to make inferences about feeding modes. Third, body size estimates clarify niche partitioning from nonmorphological dimension. This combined multidisciplinary approach aims to determine: 1) What kind of marine vegetation did each group consume; 2) ecological interactions between the groups; 3) differences between these multigroup marine mammal assemblages, compared to sirenian−only multispecies assemblages.

S3.8 VENEGAS−ANAYA, M. D. *; DENSMORE III, L. D.; ESCOBEDO−GALVAN, A. H.; BALAGUERA−REINA, S.A.; SANJUR, O. I.; LESSIOS, H. A.; Texas Tech University, Smithsonian Tropical Research Institute, Texas Tech University, Lubbock, TX, 3Centro del Cambio Global y la Sustentabilidad en el Sureste A.C, Tabasco, México, Smithsonian Tropical Research Institute, Ancon, Panama , Smithsonian Tropical Research Institute, Ancon, Panama; *dracocorilo@hotmail.com*

BASELINE DATA THE FOR AMERICAN CROCODILE (Crocodylus acutus) AS A CONSERVATION TOOL FOR MARINE−COASTAL HABITATS: ECOLOGICAL RATIONALE, ASSUMPTIONS, AND EFFICACY

We generated ecological baseline data that will allow us to evaluate the potential compatibility between top predators and biodiversity conservation, and examine the effectiveness of top predators as surrogate species. It has been shown that species within the Crocodylia are top predators and promote species richness and/or are spatio−temporally associated with local or regional biodiversity richness. The American crocodile "*"(Crocodylus acutus)"*"could be used as a model to establish a predator−centered−conservation for marine coastal environments and achieve the desired conservation goals for these environments. To this end, we have begun quantitative tests to generate evidence suggesting American crocodile may function as structuring agent and biodiversity indicator for such environments. Our study is being carried out in a Chiriquí conservation site that includes Coiba National Park (a World Heritage Sites of UNESCO) and its continental buffer zone from the port of Remedios to Punta Mariato, Panama. We report here population genetics, population ecology, reproductive ecology, and trophic ecology preliminary data to support American crocodile as surrogate species for marine−coastal environments.

59.3 VEZINA, F*; DUBOIS, K; HALLOT, F; Univ. Quebec at Rimouski, Canada; *francois_vezina@uqar.ca*

Short−term adjustments of metabolic performance in response to rapid changes in ambient temperature in small passerines

One expected consequences of climate change, in addition to extreme climatic events, is increased short−term variation in ambient temperature. Although avian thermal adaptations have been studied for decades, we have limited knowledge of the physiological responses of birds to rapid changes in Ta. Using species contrasted by their natural thermal environments (black−capped chickadees, white throated sparrows and snow buntings), we tested whether and how components of metabolic performance (basal and summit metabolic rates, BMR and Msum respectively) responded to a rapid (<24h) 15−18°C change in Ta. In a parallel experiment, we investigated how the rate and amplitude of metabolic flexibility were affected by previous regimes of temperature oscillations in zebra finches. In wild species, we found that both BMR and Msum can change significantly within 8 days following a change in temperature but that these parameters respond at different rates, likely reflecting changes in different physiological body components. We also found that metabolic performance may take 1−4 weeks to reach a new stable phenotype in zebra finches and that the amplitude of phenotypic differences between acclimation temperatures (7 and 35°C) is twice as large in birds that experienced previous temperature oscillations relative to those that were maintained in a stable thermal environment.

P1.95 VIAR, SJ*; STURGILL, ML; JACOBS, MW; McDaniel College; *sjv002@connections.mcdaniel.edu*

Effect of Body Length and Abdominal Spine Length on Activity Level and Hiding Behavior in Larval Dragonflies (Leuchorhinia dubia)

Avoiding and defending oneself from predators is essential for survival; however, the behavioral changes and structures needed to do so can be energetically costly. Larvae of the dragonfly *Leuchorhinia dubia* can defend against predators behaviorally by reducing activity or hiding, or physically with defensive spines located on the abdomen. We investigated the tradeoffs between these physical and behavioral defenses in a field experiment. We placed individual larvae into floating behavioral arenas at Lake Hashawha in Westminster, Maryland containing two hiding places and an embedded grid system. We recorded the position of each larva every 10 minutes for 2 hours and calculated the activity level and the percent of time spent hiding. Body length and abdominal spine length were measured using photographs taken in the field. The percent of time larvae spent hiding appeared to be inversely correlated with spine length ($P=0.1030$) and body length ($P=0.1062$). Body and spine length did not affect activity level. Our data suggest that as dragonfly larvae grow, their increased size and morphological defenses may release them from the need to hide from predators, potentially increasing their foraging efficiency.

9.7 VICKERS, M.E.*; ROBERTSON, M.W.; WILCOXEN, T.E.; Millikin University; *mvickers−alum@millikin.edu*

The effect of food deprivation on sexual cannibalism in an obligate predator, the jumping spider Phidippus audax (Araneae: Salticidae).

We examined the effect of food deprivation on the rate of sexual cannibalism in the jumping spider *Phidippus audax*. We separated 138 adult virgin female *P. audax* into three feeding treatments. We fed control spiders (n = 36) daily. We deprived one group of experimental spiders (n = 42) of food for 14 days, and we deprived a second group of experimental spiders (n = 59) of food for 28 days. We recorded weight loss (14−day and 28−day treatments) and survival rates, and we conducted mating trials to measure the frequency of non−aggressive and aggressive mating behaviors, mating success, and cannibalism. Food deprivation does effect *P. audax* females. Spiders deprived of food for 14 days had lower weight loss and higher survival rates than spiders deprived of food for 28 days. Food deprived spiders exhibited lower frequencies of non−aggressive behaviors than control spiders, and spiders deprived of food for 14 days exhibited a higher frequency of aggressive behaviors than control spiders. Food deprived spiders in both treatments exhibited a lower percentage of mating success, and a higher frequency of cannibalism than control spiders.

P2.193 VILLEGAS, PI*; STAAB, KL; McDaniel College; *piv001@connections.mcdaniel.edu*

Functional Properties of Cypriniform Gill Rakers Across Trophic Niches

Fish possess several morphological features that characterize their feeding habits and strategies as unique. Gill rakers, located on the pharyngeal (medial) side of the gill arches, fall within this category. While their role in feeding behavior and diet has been well studied in individual teleost species, much remains to be learned about their exact function and histological structure, especially in a comparative context. Previous studies have observed that gill rakers are covered with asymmetrical arrangements of polygonal epithelial cells. The taste buds found at the peak of these cells demonstrate a morphological adaptation to protrude them, thereby increasing their efficiency in food selection. In addition to taste buds, gill rakers possess mucous cells that aid in the passage of food through the aggregation and lubrication of small food particles. The present study sought to characterize raker functional properties across trophic niches (herbivore, carnivore, omnivore) and feeding modes (filter−feeder, benthic), through the use of histological staining and morphological data in Cypriniformes. Dane's mucosal stain reveals the presence of mucopolysaccharides, important mucous cell components. Morphological data was obtained through microdissection of 13 species, in which the entire branchial arch structure and individual ceratobranchial were removed. The total number, average spacing, length and width (tip, base) of each gill raker were measured. Benthic feeders present shorter, narrower−spaced rakers while omnivores and carnivores demonstrate longer, wider−spaced rakers. Such results indicate an association of gill raker structure with diet, wherein gill raker morphology may play a role in the size of the food particles that can be consumed.

P3.7 VO, N; KELLER, JS; KNIGHT, JAH*; ROSEMARIE, Q; HU, H; LEE, R; AYUKAEV, V; Univ. of Minnesota, Minneapolis; *voxxx129@umn.edu*

Undergraduate−led Primary Literature Discussion Group Promotes Diversity

Several institutions across the nation are pioneering the reform of biology education to improve primary literature comprehension and research skills among undergraduates. Educators are also endeavoring to increase scientific awareness and enthusiasm among the general public through partnership with secondary schools and social media. As part of the movement, we, the Health and Biological Research News Foundation (HBR), have collaborated with the University of Minnesota to establish a student group pilot that facilitates peer discussion and publication of student−written synopses of primary research literature. Our group fosters inquiry of science and primary research deconstruction skills, motivating students by synthesizing abstract scientific ideas into relatable articles suitable for the layperson that also serve as resume−boosters. Previous analyses supports HBR−mediated students improvement in research comprehension and writing skills. Unexpectedly, our program has attracted a disproportionate diversity in majors, backgrounds, and spoken languages relative to the University as a whole. 20 student group members participated in a self−reported demographic survey at the University of Minnesota. Results showed a young population of members from 17 to 21 years old, with 80% of the participants younger or equal to 20 years old and 60% underclassmen. The survey participants are enrolled in a total of 26 different academic programs (a total of 14 different majors) offered by 4 different colleges at the University of Minnesota. Nearly one third of the students are planning on obtaining dual degrees. Cultural diversity data reported that participants identified a total of 7 different countries of origin and backgrounds in 18 distinct languages. We are currently coupling these data with a more intensive academic survey to investigate the complementary effects of the our model and a more diverse member body.

92.7 VOISIN, A−S.*; LOCREL, M.; FLAMION, E.; FALISSE, E.; FELLOUS, A.; DORTS, J.; EARLEY, R.L.; SILVESTRE, F. ; University of Namur, Belgium, University of Alabama, Tuscaloosa, USA; *anne−sophie.voisin@unamur.be*

DNA methylation in the mangrove rivulus and effects of EE2 on its developmental plasticity

The mangrove rivulus, *Kryptolebias marmoratus*, is one of the two known self−fertilizing hermaphroditic vertebrates, resulting in populations composed of distinct homozygous and isogenic strains. Despite no or low genetic diversity within a strain, this fish displays remarkable levels of phenotypic plasticity. The present study investigated developmental plasticity induced by a chronic exposure to 17−&alpha−ethynylestradiol (EE2) in rivulus, and the role of DNA methylation in driving this plastic response. Hatchlings from a single isogenic lineage were individually exposed during 28 days post hatching (dph) to solvent control, 4 and 120 ng/L of EE2, and then transferred to clean salt water until 180 dph. We aim to link global DNA methylation and methylation at specific GpG sites of selected genes to both cellular (proteome) and organismal phenotypes (hormone levels, behavior, growth, reproductive success) measured during the course of the experiment. Preliminary results show that at 28 dph, both standard length (SL; 12.6 ± 0.4 vs 13.4 ± 0.4 mm) and mass (31.9 ± 3.4 vs 37.8 ± 3.6 mg) were significantly lower in fish exposed to 120 ng/L compared to control. In the 4 ng/L group, only SL was significantly lower than control (13.0 ± 0.5 vs 13.4 ± 0.4 mm). At 56 dph, only SL of individuals exposed to 120 ng/L treatment differed from control (16.5 ± 0.4 vs 17.0 ± 0.5 mm). A first examination of global DNA methylation showed that the proportion of methylated CpG sites might be lower than what is reported in other fish species.

57.3 VOLKENBORN, N.; Stony Brook University;
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The "sound" of the seafloor: porewater pressure sensors as tools for studying infaunal activity

In 2005 Wethey and Woodin published the paper "Infaunal Hydraulics Generate Porewater Pressure Signals" in which they demonstrated that the sphere of influence of infaunal organisms may extend far beyond the immediate vicinity of individuals and their burrows through the propagation of porewater pressure waves. This phenomenon had been predicted from porous media flow theory but it was the first time that such pressure fluctuations in the porewater were actually measured in−situ. Since then porewater pressure dynamics have been measured in the presence of a range of large infaunal organisms including burrowing crustaceans, bivalves, and polychaetes. These measurements turned out to be highly useful to explore the frequencies and durations of behaviors such as burrowing or pumping and to link infaunal activities to biogeochemical and ecological processes in soft−sediment systems. In this presentation I will give a brief introduction to porewater pressure sensing in aquatic sediments and highlight some of the key findings and perspectives using this technology.

36.3 VOYLES, J*; RICHARDS−ZAWACKI, C; PEREZ, R; SAENZ, V; New Mexico Tech, Tulane University; *jvoyles@nmt.edu*

How does it end? Evolution of virulence in amphibian chytridiomycosis

A shift in virulence, or a transition away from the outbreak phase of a disease, toward a stable co−existence of host and pathogen can occur following the emergence of highly pathogenic infectious agents. Yet the mechanisms that underpin such transitions remain obscure. We are investigating the role of evolution in both the host and the pathogen in this process by focusing on one of the most lethal diseases of vertebrate hosts available for study, amphibian chytridiomycosis. A decade ago, the fungal pathogen *Batrachochytrium dendrobatidis* (Bd) spread through western Panama in a wave−like pattern, causing mass mortality events, dramatic declines and even local extinction of many amphibian species. However, surviving populations of some susceptible species were recently rediscovered. Although Bd is present in these persisting populations, pathogen prevalence is surprisingly low, contrary to modeling predictions. This finding suggests that there has been a shift in host−pathogen dynamics since the initial chytridiomcyosis outbreaks occurred. We collected and cryo−archived isolates during chytridomycosis outbreaks and 8−10 years following initial outbreaks. These isolates were used in laboratory infection experiments and found to be differentially pathogenic to a susceptible amphibian species. We are also currently evaluating the effectiveness of anti−microbial peptides (a component of the amphibian immune defenses) that were collected and preserved from these two time points. Understanding evolution in host−pathogen dynamics will have far−reaching implications for understanding, predicting and controlling the spread of infectious diseases and will be integral to the conservation of amphibian biodiversity in post−epidemic disease systems.

P3.35 WADDELL, D*; MENKE, J; University of North Florida;
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Identification and Characterization of the Transcriptional Regulation of Tetratricopeptide Repeat Doman 39c in Skeletal Muscle

Tetratricopeptide repeat domain 39c (Ttc39c) was identified as a novel gene that is differentially regulated under conditions of neurogenic skeletal muscle atrophy in wild−type mice compared to Muscle−specific RING Finger 1 (MuRF1) knockout mice. MuRF1 is a ubiquitin E3 ligase that has previously been shown to be an important mediator of muscle wasting, however recent evidence suggests that MuRF1 may also function as a regulator of atrophy−induced gene expression. The transcriptional regulation of Ttc39c was examined by cloning the promoter region of this gene and fusing it to the secreted alkaline phosphatase (SEAP) reporter gene. This reporter construct was then transfected into muscle cells along with an expression plasmid for MuRF1. MuRF1 overexpression repressed Ttc39c reporter activity, while overexpression of a MuRF1 RING domain mutant failed to repress the Ttc39c reporter. Furthermore, overexpression of myogenin, which is a myogenic regulatory factor (MRF) that regulates the expression of muscle−specific genes by binding to elements called E−boxes, also repressed Ttc39c reporter gene activity. A conserved E−box element in the Ttc39c proximal promoter was identified, mutated and analyzed for its role in the regulation of Ttc39c expression. The mutation of the conserved E−box rendered the Ttc39c reporter gene inactive, demonstrating that the element is necessary for Ttc39c expression. The identification of Ttc39c as a novel gene that is activated under neurogenic atrophy conditions and the characterization of how this gene is transcriptionally regulated helps improve our understanding of the molecular genetic events that lead to skeletal muscle atrophy.

73.5 WAGNER, DN*; OLEKSIAK, MF; CRAWFORD, DL; University of Miami; *dwagner@rsmas.miami.edu*

Genome wide analyses reveal population divergence among estuarine microhabitats in Fundulus heteroclitus

Environmental differences affect genetic and phenotypic variation among individuals. For *Fundulus heteroclitus* there are meaningful environmental differences within a single estuary; upper−tidal ponds have higher daily maximum temperatures and lower nightly oxygen concentration than do tidal creeks or the basins, which these creeks drain into. Individuals from three microhabitats 1) tidal basins, 2) inter−tidal creeks, and 3) tidal ponds share the same breeding areas, thus one might expect the populations to be panmictic. Yet, mark−recapture studies indicate that fish have high habitat fidelity to each of the three microhabitats. To examine any microhabitat differences in genotypes that might be the result of natural selection, individuals from the 3 different microhabitat types from 3 replicate locations along the New Jersey Coast (Mantoloking, Tuckerton, and Stone Harbor) were genotyped at more than 10,000 loci using genotyping−by−sequencing (GBS). Dependent on replicate location, analyses identified between 250−600 loci (p−val < 0.01, FDR = 0.01) with significant F_{ST} values between populations of tidal basin and pond resident fish. These loci may be adaptively important and, suggest that selection is affecting allele frequencies over very small geographical distances. This research will allow for the identification of potentially adaptively relevant genes, and further investigates the molecular basis for how the physiological response to even slightly different environments causes a change in genetic structure.

14.1 WAINWRIGHT, DK*; LAUDER, GV; Harvard University; *dylan.wainwright@gmail.com*
The three−dimensional structure of fish scales
Fish scales are morphologically diverse, both among species, within species, and on an individual. Scales are often categorized into three main types: cycloid scales have smooth edges; spinoid scales have spines protruding from the body of the scale; ctenoid scales have interdigitating spines protruding from the edge of the scale. For this study, we used 3D visualization techniques to investigate the scale morphology of the Bluegill sunfish (*Lepomis macrochirus*) over different parts of the body. Micro CT scanning was used to visualize individual scales taken from different parts of the bluegill. Also, a new technique called Gelsight was used to rapidly measure the 3D surface structure of scale patches from different parts of the fish. We used these data to compare scales on different parts of the fish, using simple morphological measurements and surface metrology metrics to amass a set of variables. We found that bluegill scales do change across the body − scales are cycloid on the opercle, ctenoid on the body and tail, and the proportion of ctenii coverage increases ventrally on the fish. Scales on the opercle and below the start of the dorsal fin were also shorter in height and length and less thick than scales elsewhere on the body. Surface roughness does not appear to change over the body of the fish, although scales at the start of the caudal peduncle have higher skew than other scales, indicating they have a surface that contains more peaks than valleys. Scale shape also changes, with scales near the base of the tail having a more elongated shape. This study illustrates how fish scale structure can vary over the body, and demonstrates how Gelsight can be used to image fish surface structures in 3D.

S12.7 WAINWRIGHT, P.C.; Univ. of California, Davis; *pcwainwright@ucdavis.edu*
Suction Feeding Evolution: Innovations and Major Patterns of Diversification
With a few minor exceptions, suction feeding is unique to vertebrates, where it is almost ubiquitous among fish and aquatic tetrapods. This dominance reflects both effectiveness and constraints as even the aquatic lineages that have abandoned prey capture by suction feeding retain the mechanism and use it at some stage in the feeding process, during prey processing and manipulation if not during capture. I review major innovations in the suction feeding mechanism of teleosts, where this mechanism of prey capture is dominant among the over 32,000 species. Most teleosts have sufficient kinesis of cranial bones to allow the corners of the mouth opening to be filled during mouth opening. This produces a planar mouth opening that is often nearly circular in shape. Both features contribute to efficient flow of water into the mouth and help direct the region of influence to the area directly in front of the mouth aperture. In lineages that have secondarily lost the planar mouth aperture, which occurs in many groups that grab their prey with elongate jaws, suction is retained but is not effective until the prey reaches the region where the buccal cavity fully surrounds it, well posterior to the toothed region of the jaws. Jaw protrusion has multiple functions and has been shown to enhance the hydrodynamic forces that suction feeders exert on prey by increasing the rate of approach and hence the acceleration of fluid at the prey. Premaxillary protrusion has evolved five times in ray−finned fishes including two of the most successful teleost radiations, cypriniforms and acanthomorphs (spiny−rayed fishes), and is found in about 60 percent of living teleost species. Diversification of the suction feeding mechanism and feeding behavior reveals that suction feeders with high suction capacity rarely approach the prey rapidly, while slender−bodied predators with low suction capacity show the full range of attack speeds.

94.7 WAITS, D.S.*; THORNHILL, D.J.; SANTOS, S.R.; HALANYCH, K.M.; Department of Biological Sciences, Auburn University, Auburn, Department of Conservation Science and Policy, Defenders of Wildlife, Washington, DC; *dsw0002@auburn.edu*
Evolution of Sulfur Binding in Hemoglobin in Siboglinidae (Annelida) with Special Reference to Bone Eating Worms, Osedax
Siboglinid symbioses are enabled by specialized hemoglobin that is able to bind hydrogen sulfide for transportation to their chemosynthetic endosymbionts. Sulfur−binding capabilities are hypothesized to be due to cysteine residues at key positions in both vascular and coelomic hemoglobins. Interestingly, members of the genus *Osedax*, which live on whale bone, do not have chemosynthetic endosymbionts, but instead house heterotrophic bacteria capable of breaking down complex organic compounds. Although sulfur−binding capabilities are important in other siboglinids, we questioned whether *Osedax* retained the ability to bind hydrogen sulfide. We sought to answer this question using high throughput sequencing to isolate and analyze hemoglobin sequences from nine siboglinid lineages including *Osedax mucofloris*. Once identified, hemoglobin sequences from gene subfamilies A2 and B2 were translated and aligned to determine conservation of cysteine residues at key positions in these sequences. Our results suggest that hemoglobin in *O. mucofloris* has retained some ability to bind hydrogen sulfide. This characteristic may have been retained when *Osedax* diverged from other siboglinids. However, toxic hydrogen sulfide has been shown to bind with a higher affinity to hemoglobin than cytochrome−c oxidase in other siboglinids suggesting there could still be selection for this trait due to the abundance of hydrogen sulfide production within whalebones.

S9.7 WALDROP, LD*; PRAIRIE, JC; Univ. of North Carolina at Chapel Hill, Univ. of San Diego; *lwaldrop@email.unc.edu*
Using small, interdisciplinary groups to engage students as participant−scientists in mathematical biology
We will present our experiences teaching in consecutive years of an upper−division undergraduate class in mathematical modeling at UNC Chapel Hill where these small−group activities formed a large part of the students' final grades. These assignments focused on a specific type of active learning that increases student engagement by having students take on the role of participant−scientist in structured, small−group activities. By inhabiting this role, students can experience many aspects of research in interdisciplinary fields including generating and testing hypotheses, evaluating model assumptions, communicating research through writing and oral presentation, and anonymous peer review. Additionally, the intentional structuring of interdisciplinary groups mimicked the type of working conditions that students will eventually face outside university, in which their expertise is unique and deep compared to their colleagues, and is unlike the conditions posed by single−major lecture and lab activities. We believe that this method of building small, interdisciplinary working groups to solve structured problems is widely applicable to interdisciplinary classroom teaching.

S1.5 WALL−SCHEFFLER, C.M.; Seattle Pacific University; University of Washington; *cwallsch@spu.edu*

Optimal movement speeds in human locomotion

It is clear that humans have a speed at which their energetic costs are minimized when traveling a given distance, either when running or walking. Early studies further showed that humans chose to walk at their optimum speed, when walking alone, unburdened, and on a level surface. In recent years, a variety of studies looking at various perturbations of the original walking work have suggested there are nuances pertaining to human choice, particularly when tasks increase in difficulty as well as when people are walking with others. "Increase in difficulty" appears to be anything that makes the overall cost of transport (CoT) curve increase or shift for example, walking on an incline, running, carrying a burden, and being of an increased mass. When humans walk on inclines and are of larger body masses, they are more likely to choose a speed closer to the optimum speed as their preference this is reasonable because both the CoT curvature is more acute (so penalties for moving away from the optimum are increased) as well as because the overall cost is high. Interestingly, while carrying novel burdens, females seem to have an ability to deviate from the optimum speed; this may be due to changes in thermoregulation, kinematic cues, as well as to the fact that females have a broader CoT curvature generally. These preferences can shift in the context of group walking however; whereas females seem more likely to maintain optimality when walking with other females, their speed increases when walking with (larger, faster) males. Males conversely change their speeds continually when walking with others speeding up when walking with other men and slowing down to various degrees when walking with females. Thus, the social dynamics of walking are such that physiological and kinematic cues can be ignored, at least for a time.

P1.172 WALTER, RM*; BALACCO, JR; BEAUVAIS, S; Bloomfield College; *rebecca_walter@bloomfield.edu*

What makes some runners better on inclines?

Distance runners with similar abilities on level terrain often differ significantly in their ability to run on inclines. This study investigates the causes of these interindividual differences in relative incline running ability. Performance determining factors such as mass specific leg muscle strength and running kinematics are likely to affect uphill and level running differentially. As most of the work to raise the center of mass on inclines is done at the hip joint, the strength of the hip retractor muscles might be correlated with incline running performance. Since heart and metabolic rates are tightly correlated within each individual, runners with less efficient incline running kinematics should have greater increases in heart rate when running uphill. In this study 30 subjects performed incremental treadmill runs to exhaustion at 0° and 10° inclines. The treadmill was started at 2.2ms^{-1} and 1.8ms^{-1} for the level and incline trials respectively. Speed was increased by 0.09ms^{-1} at the end of each minute until subjects could no longer maintain the pace. Relative incline running ability was taken as the ratio of the incline: level distance covered. Subjects' heart rates were measured throughout the trials and their stride kinematics were tracked with a motion capture system. The strengths of their hamstring and quadriceps muscle groups were measured by having them use their legs to pull isometrically on a rope attached to a strain gage. Subjects ran 3.8±1.6 and 1.6±1.0 km in incline and level trials respectively. Incline to level distance ratios ranged from 0.25 to 0.56. Relatively better incline runners tended to have lower incline: level heart rate ratios and to have a higher ratio of hamstring to quadriceps muscle strength. Runners may be able to improve their performance on inclines by strengthening their hamstring muscles and increasing their efficiency by modifying their gait kinematics.

P2.1 WALTERS, LJ; Univ. of Central Florida, Orlando; *linda.walters@ucf.edu*

Workforce Readiness: Combining Authentic Research and Service−Learning in Undergraduate Marine Biology Classes to Prepare Students for Life after Graduation

Undergraduates involved in independent research receive a competitive edge so that at graduation they can boast having technical expertise, transferable oral/written communication skills, and confidence in themselves and their abilities. However, most universities do not have enough faculty to mentor all students one−on−one. One alternative that I have adapted is creating a classroom where all students participate in authentic research and communicate their findings to both scientific and K−12 public school audiences. Students in my upper−division, elective Marine Biology course showcase what can be achieved. In this 25−person class, all individuals collaborated on research projects over the course of the semester. Students selected from topics that were feasible within time and budget constraints, and would add to the current literature. Results were presented at our university−wide Showcase of Undergraduate Research Excellence. As part of the class's service−learning pedagogy, students were connected with public school educators. UCF students developed a plan to visit the classroom where they shared information on their topic (i.e. invasive species) and how their research fit into better understanding this topic. A novel, related hands−on activity was also developed and presented at the school. Their final product was presented at our University's annual Service−Learning Showcase.

45.3 WALTERS, LJ*; SACKS, PE; PALMER, J; Univ. of Central Florida, Orlando, Winter Springs High School, Brevard Zoo; *linda.walters@ucf.edu*

Oyster Reef Restoration and Recreational Boating: Compatible or Not?

We document significant declines of intertidal oysters within Mosquito Lagoon, Florida, with the most serious losses occurring within Canaveral National Seashore, where reef acreage has decreased by 40% since 1943. In these shallow, microtidal waters, piles of bleached shells extend above mean high water where live reefs were historically located. Dead reefs begin as dead margins that are created as sediment erodes from the base of the seaward oyster clusters, dislodging clusters that then wash into piles above the intertidal zone. Dead margins transform into dead reefs within a few years as the dead margins migrate toward shore (mean rate: 1.3 m/yr) covering over additional live oysters. Eventually only shells remain (= dead reef) and this shoreward migration continues until all shells wash up into the marsh and no intertidal reef footprint remains. Boat wakes from recreational vessels are an important source of initial oyster cluster dislodgement, subsequent shell movement, and, thus, dead reef formation. In 2007 we began restoring oyster reefs negatively impacted by boat wakes and have now developed a method that is transferable to other locations experiencing similar problems. 68 oyster reefs have been restored by UCF/Brevard Zoo/TNC and over 38,000 community volunteers. Our methodology that couples dead margin leveling with placement of stabilized shell on the leveled substrate is exceeding our structural and functional objectives as: 1) no dead margins have reformed, 2) recruitment on 2007 reefs continues to increase and now averages over 115 live oysters/0.25 m^2, and 3) seagrass recruited seaward of 37% of the restored reefs. Overall, our project has been exceptionally successful in terms of oyster recruitment, habitat improvement, and community engagement.

69.3 WANG, J.*; JANECH, M.G.; BURNETT, L.E.; BURNETT, K.G.; College of Charleston, Medical University of South Carolina; *jasonwang103@gmail.com*

Quantification of novel hemocyanin isoforms following hypoxic exposure in the Pacific whiteleg shrimp, Litopenaeus vannamei

The Pacific whiteleg shrimp, *Litopenaeus vannamei*, is farmed in environments where O_2 fluctuates widely. Its respiratory pigment hemocyanin (Hc) is composed of subunits arranged as n×6−oligomers which have intrinsic O_2 binding properties. Shrimp Hc has been reported to have a large and small subunit. However, high throughput RNA−Seq suggests that the large subunit exists as several variants, and that hypoxia might induce changes in their expression. Here we characterize the protein oligomer and subunit compositions of Hc between shrimp exposed to hypoxia for 24h or 14d, compared to normoxic controls. Ratios of 1×6−mer and 2×6−mer Hc were quantified using SEC−HPLC monitored at 280 and 338nm. Oligomers were trypsin−digested to analyze subunit compositions by LC−MS/MS. Proteins were identified by MASCOT searches against combined *L. vannamei* RNA−Seq assembly, Uniprot penaeid shrimp proteins excluding Hc, and contamination databases. Regardless of hypoxic treatment, *L. vannamei* Hc existed primarily as 1×6−mer. One Hc small subunit was identified in both 1×6−mer and 2×6−mer, and accounted for 49 and 44% of total Hc normalized spectral counts (NSC) respectively. Three novel large subunit isoforms were identified in both oligomers, and ranged from 14 to 24% of total Hc NSC each. Two novel Hc C−domain variants were identified exclusively in the 2×6−mer at 1% of total Hc NSC. Future use of isobaric tags with LC−MS/MS will more reliably quantify isoform usage in hypoxia relative to normoxia. Understanding how *L. vannamei* changes Hc in response to hypoxia is important for shrimp aquaculture, and has implications for hypoxic responses in the wild. (NSF IOS−1147008)

70.4 WANG, L*; WU, W; WIKRAMANAYAKE, AH; Univ. of Miami, Coral Gables; *cellcreator@bio.miami.edu*

Investigating the molecular determinants for polarity in sea urchin embryogenesis

The Dishevelled (Dsh) protein in the Wnt signaling pathway is essential for endomesoderm specification in sea urchin embryos. Dsh is asymmetrically enriched in a vegetal cortical domain (VCD) of the unfertilized egg, and several lines of evidence indicate that activation of Dsh in the canonical Wnt (cWnt) pathway during endomesoderm specification requires the VCD. First, while Dsh is required for activation of cWnt signaling in vegetal cells, overexpression of Dsh is not sufficient for ectopic endomesoderm formation in mesomeres. Second, a differentially modified form of Dsh accumulates in the VCD and this domain is selectively inherited by the vegetal blastomeres that nuclearize beta−catenin in early embryos. Moreover, embryological extirpation of the VCD from eggs blocks activation of cWnt signaling in embryos developing from VCD minus eggs. All of these observations indicate Dsh must work with some molecules at the VCD to regulate cWnt signaling activity and endomesoderm specification. To identify such candidate molecules, we carried out two separate molecular screens. To identify RNAs asymmetrically enriched in the egg cortex in general, we did a RNA−seq screen using eggs, egg cortices and different blastomeres from 16−cell stage embryos. To identify candidate proteins that regulate Dsh activity directly, we performed Dsh co−immunoprecipitation using lysates from eggs and isolated cortices. These screens have identified several intriguing candidates. Overexpression of one particular candidate produced severely vegetalized embryos indicating that this protein may play a critical role in the local activation of Dsh in the VCD during endomesoderm specification. We will discuss our ongoing studies to characterize the respective roles of these candidates in regulating cWnt pathway and endomesoderm specification in sea urchin embryogenesis.

73.3 WANG, S.S.*; SCHMITZ, L; Pomona College, Claremont McKenna, Pitzer, and Scripps Colleges; *ssw12010@mymail.pomona.edu*

The effect of eye size and habitat on the evolution of scleral thickness in mammals

Marine mammals and reptiles are characterized by an array of morphological features that are considered to be adaptations towards secondary aquatic lifestyles. One of such features is found in the eye: it has been noted since the 19th century that the sclera, the fibrous protective outer layer of the eye, is unusually thick in marine mammals and reptiles. However, while the role of the thick sclera has been hypothesized about, differences in the thickness of sclera across different mammals have never been rigorously quantified. Here we show that the sclera of aquatic and semiaquatic mammals is thicker than the sclera of terrestrial mammals even when eye size is accounted for, using a sample of 70 species and 128 individual specimens. This is true for both the sclera at the posterior pole of the eye and sclera near the cornea. We also saw that phylogeny has a strong effect on this relationship, and therefore must be accounted for when determining variance in scleral thickness between habitat groups. We argue that the most plausible hypothesis is that increasing intraocular pressure as a method of visual accommodation causes increased scleral thickness, though other aspects of aquatic life like temperature and pressure may play small roles.

7.6 WARD, CV*; PEACOCK, SJ; WINKLER, Z; HAMMOND, AS; MADDUX, SD; University of Missouri; *wardcv@missouri.edu*

Torso form and locomotion in anthropoid primates

It is generally assumed that great apes share a homologous pattern of torso morphology related to below−branch arboreality that is found in an intermediate state in hylobatids and atelines. This hypothesized variation in torso structure is pivotal to interpretations of fossil ape and hominin body shape and locomotor adaptation. Paleoanthropologists have also presumed that certain morphologies of isolated ribs, vertebrae and pelvis reflect these presumed differences in torso shape and locomotor adaptation. However, little is actually known about the overall 3D shape of the primate torso, or how this is reflected in the morphology of individual bones. To evaluate torso shape, 56 anthropoid cadavers were CT−scanned. In addition, standard landmark and metric data were collected from the pelvis, vertebrae, ribs, and sterna of over 200 primate skeletons. Morphology of the intact torso and that of individual bones were compared across taxa and among locomotor groups, and covariation assessed among skeletal elements and with aspects of whole torso shape. Results broadly support previous hypotheses about basic skeletal variation among taxa for individual bones. 3D reconstruction of intact torsos, though, show more varied and subtle patterns of overall torso shape. Upper thoracic breadth appears to reflect quadrupedality. Iliac morphology reflects as much about axial musculature as about rib cage shape. Strong patterns of allometry are present in the pelvis and in aspects of lumbar vertebral form, but not in rib cage shape. These data support the hypothesis that variation in torso form is associated with locomotion in anthropoids, but reveal nuances of morphological variability that provide much greater insight into the functional consequences that likely have underlain selection for variation in torso structure.

55.1 WARES, JP*; EWERS−SAUCEDO, C; NAVARRETE, SA; BYERS, JE; SEPúLVEDA, A; PRINGLE, JM; University of Georgia, Pontificia Universidad Católica de Chile, Universidad de Concepción, University of New Hampshire; *jpwares@uga.edu*
The relationship between biogeography and phylogeography: Case study of a Chilean intertidal barnacle (Notochthamalus scabrosus)
Marine intertidal systems provide a useful, near−linear framework for examining the interactions between isolation and adaptation. Species with large geographic ranges are exposed to large environmental gradients and mechanisms that may isolate regions from one another, yet these species also tend to have broad dispersal potential. Here we expand geographic and genetic sampling of the intertidal barnacle Notochthamalus scabrosus to completely identify a cline in the distribution of two genealogical lineages, and use a coupled hydrodynamic particle tracking model to explore the likelihood that this cline is maintained by dispersal limitation alone as opposed to some form of natural selection. Our data indicate that although it is likely that the two lineages still hybridize and/or introgress, there has been considerable evolutionary divergence that is probably adaptive in nature. The relationship between these results and the overall biogeographic pattern along the Chilean coast is explored, and we suggest that oceanographic and environmental transitions near the island of Chiloé and Gulf of Ancud are likely factors in maintaining both the diversity in N. scabrosus as well as broader biogeographic transitions on the Chilean coast.

P2.23 WARNER, D.A.*; SECOR, S.M.; JOHNSON, M.S.; NAGY, T.R.; University of Alabama at Birmingham, University of Alabama; *dawarner@uab.edu*
A Preliminary Evaluation of Energy and Nutrient Availability across an Island Landscape, and its Fitness Consequences in the Brown Anole Lizard
Variation in food resources during early life stages (e.g., embryo, juvenile) can generate variation in future body composition and reproductive output, and hence has critical consequences for fitness. In this study, we evaluate spatial variation in food resources and body composition in the brown anole lizard (*Anolis sagrei*) across different habitat types on an island in Florida. Body composition was determined with quantitative magnetic resonance (QMR), and compared between lizards collected from the interior (forested) and perimeter (shoreline) of the island. After validating that QMR provides accurate estimates of fat mass, lean mass and water mass for *A. sagrei*, we show that lizards that occupy territories in the interior of the island have more fat mass and less lean mass than individuals that occupy the shoreline of the island. Habitat differences in prey type and/or composition might provide an explanation for this pattern. Indeed, preliminary invertebrate surveys indicate that more marine−based prey (isopods, amphipods) are found in shoreline habitats than in the interior of the island. We have recently initiated detailed studies of the invertebrate community across the study island and will assess energetic and nutrient contents of different prey types found in different habitats. These data will form a foundation for future studies focused on understanding (1) the fitness consequences of early life nutrition, and (2) how organisms distribute themselves across nutritionally−variable landscapes relative to nutrients or energy available during early life stages.

109.5 WARREN, M/F*; RIEDL, N/E; KLASING, K/C; Auburn University, University of California, Davis; *mfw0006@auburn.edu*
Interactions between Lymphoid Tissues and Antigenic Challenges in Cockatiels
Altricial birds are blind and naked when they hatch and must defend themselves against a pathogen−rich world with an immature immune system. Little is known about lymphoid system development in altricial birds and how it is affected by antigenic challenges. The cockatiel (*Nymphicus hollandicus*) is an excellent model for studying altricial birds because their amenability to handling, popular for aviculturists to breed, and a study has been done to compare the development of their lymphoid tissues to chickens. This study explores lymphoid system development of cockatiels following an antigenic challenge. Sixteen one−day old cockatiels were used for the study. Cockatiels were assigned to one of two treatments in a completely randomized design (n=8). To elicit an immune response, the experimental treatment group was immunized with dinitrophenyl keyhole limpet hemocyanin (DNP−KLH) on the seventh day of age by subcutaneous injection to the inner thigh. Seven and 30 days post−immunization (day 14 and 37 days post−hatching), four cockatiels from each treatment group were euthanized by CO_2 asphyxiation. The bursa of Fabricius and thymus were collected, weighed, and sectioned for Hemotoxylin and Eosin (H&E) staining to quantify number of lymphocytes present. Blood was collected and the plasma was used in the bacteria−killing assay to evaluate efficacy of innate immunity against non−pathogenic *E.coli*. There was a significance in bactericidal activity between treatment groups with the KLH−challenged group having a higher killing rate. The thymus mass and thymus mass to body mass ratio was significantly lower in 37 day old KLH−challenged birds relative to control birds. Comparisons of altricial bird development and precocial bird developed will be discussed.

P2.84 WARREN, KJ*; BROWNE, WE; University of Miami; *k.warren2@umiami.edu*
The Establishment and Characterization of Primary Cell Cultures derived from the ctenophore Mnemiopsis leidyi
Primary cell cultures are derived from tissue explants removed from an organism and maintained in an artificial environment. These *in vitro* cell cultures can be used to approximate the *in vivo* cellular environment, facilitate the isolation of specific cell types, and often provide a better representation of normal cell biology than immortalized cell lines. We have developed a primary cell culture system for the marine invertebrate *Mnemiopsis leidyi*, a lobate ctenophore. These primary cell cultures can serve as a proxy for adult somatic cells. Treated media derived from adult animals is used to generate both a solid matrix for cell adhesion and support as well as a liquid overlay. This complex media provides essential nutrients to isolated explant cells. Approximately 24 hours after explant removal several different cell morphologies are consistently observed. Many cells have cytoplasmic processes and are highly motile. Extensive, active cell processes often connect cells. A distinct class of round proliferative cells characterized by a lack of cytoplasmic processes are also reliably isolated. We are currently employing several methods to further characterize these cells that can be loosely classified by morphology as either round, bipolar, multipolar, or hyper−elongated cells. A rt−PCR approach is being used to develop gene expression profiles associated with distinct cell morphologies as well as changes in gene expression over time. We are also performing experiments to monitor the functional response of Calcium channels via trafficking of labeled small molecules. Experiments to further characterize discrete cell types associated with these primary cell cultures will facilitate our ongoing molecular genetic analysis of unique aspects of ctenophore cell differentiation during development and ctenophore evolutionary history from a cell biological perspective.

S2.4 WASSER, SK*; LUNDIN, J; University of Washington; *wassers@uw.edu*
Untangling the cumulative effects of human disturbance, nutritional stress and toxin loads on killer whales in deep water and woodland caribou in deep snow
Wildlife biologists are commonly challenged with addressing the cumulative effects of multiple pressures facing wildlife. This often requires integrating multiple metrics and acquiring sufficient sample size to gain the needed statistical power. Noninvasive measures from scat can be ideally suited for these purposes owing to high sample accessibility and numerous genetic, physiological, toxicological and dietary metrics that can be obtained from these samples. This talk describes the acquisition and integration of multiple metrics from scat of two difficult to observe species at risk: free−ranging Southern resident killer whales (SRKW) in the Salish Sea of WA and BC and Woodland Caribou wintering in deep snow in the Canadian Oil Sands. SRKW experience cumulative pressures from reduced prey availability, heavy toxin loads and commercial and private vessel traffic. Wintering woodland caribou experience cumulative pressures from rapid influx of oil workers on the landscape, limited access to dietary lichen, wolf predation and toxin loads. In SRKW, we show that high rates of spontaneous abortion in genotyped females are correlated with increased nutritional stress and toxicant levels. In caribou, we show how human use of the landscape exacerbates nutritional stress, compromising pregnancy health among females, as well as how toxin loads may be impacting this system.

58.2 WATSON, C. M.*; MERCHANT, M. E.; Midwestern State University, McNeese State University; *charles.watson@mwsu.edu*
Thermal Effects on Innate Immune Response, Respiration, and Locomotor Performance in the Spectacled Caiman, Caiman crocodilus.
The spectacled caiman is a small, widespread crocodilian found in Central and South America. Due to escapes from the pet trade and niches opened by overhunting of natural competitors, this species has expanded its range in South America and can now be found in Southern Florida and Cuba. While this is a very adaptable and widespread species, previous studies and personal observations indicate that the spectacled caiman cannot survive the cold winters of temperate areas and therefore poses a minimal threat of invasiveness to other parts of North America. However, with continuously warming climates, this may not always prove true. Here, we characterize the spectacled caiman's thermal physiology by measuring innate immune response, establishing resting metabolic rate, sprint speed, and swim speed over a range of ecologically−relevant temperatures as well as the temperature sensitivity (Q10) of these measures. By better understanding the physiology of this crocodilian, we can make more informed conservation decisions regarding potential invasiveness and management of this species.

17.2 WEAVER, R.J.*; COBINE, P.A.; HILL, G.E.; Auburn University, Auburn AL, Auburn University; *rjw0019@auburn.edu*
Plasticity in carotenoid metabolic pathways in a marine copepod suggests strong selection for ketocarotenoid production
Astaxanthin is the dominant carotenoid pigment found in the marine copepod, *Tigriopus californicus*, giving these animals red coloration along with protection from UV radiation in their shallow−water rock pool habitat. Like all metazoans, *T. californicus* must convert carotenes and hydroxy−carotenoids present in their algal diet to astaxanthin, a ketocarotenoid. Other astaxanthin−pigmented crustaceans have been shown to use a precursor−specific bioconversion pathway to astaxanthin. The aim of this study was to identify the metabolic pathway used by *T. californicus* for the production of astaxanthin. Copepods were maintained on a carotenoid−free diet on which they lost all carotenoid coloration. To identify which pathways are used for astaxanthin production, copepods were fed one of three microalgae strains that contained particular dietary carotenoids (lutein, zeaxanthin, or both) that are precursors to specific astaxanthin bioconversion pathways. We found that copepods from each precursor pigment group were able to produce astaxanthin. Previous work on carotenoid metabolism in other Harpacticoid copepods revealed a single astaxanthin pathway. Here we show that *T. californicus* has facultative control of conversion pathways for the production of astaxanthin. Strong selection for photoprotection from UV radiation by ketocarotenoids in this species likely drives the plasticity of astaxanthin production pathways.

S7.11 WEBB, P.W.*; WEIHS, D; Univ. of Michigan, Ann Arbor, Technion, Haifa; *pwebb@umich.edu*
Stability and swimming in aquatic vertebrates: evolutionary patterns and possible future directions
Bauplans typical of aquatic vertebrates create intrinsic hydrostatic and hydrodynamic destabilizing forces and torques. Reliance on oscillatory propulsors creates additional intrinsic instabilities. These instabilities are continuously corrected by trimming and powered control forces and torques, which can be energetically costly. Intrinsic instabilities have arisen over evolutionary time and various associated adaptations have been postulated to reduce the magnitude and impact of perturbations. The largest perturbing forces and torques arise from body/caudal fin propulsion, for which anatomy and morphology of propulsors and other body parts damp, correct or cancel disturbances. Future challenges to understanding the challenges and solutions for stability in aquatic vertebrates include methods for repeatable experiments, probably at stability limits. Traditional comparative approaches will be insufficient. Biomimetic robotic models with fish−like motions will be essential, especially to explore stability through control of trailing edge shape and motions. An emergent feature of oscillatory propulsors is whole−body accelerations that can be recorded in free−living animals. While such accelerometry cannot determine power consumption for locomotion by free−living aquatic animals, patterns correlating with various behaviors may provide a basis for constructing ethograms. In terms of extrinsic perturbations, fishes are readily able to detect, respond and use local flow unsteadiness. It remains unknown if or how well fishes can anticipate and negotiate flow fields to minimize transport costs as postulated for some migrants.

111.2 WEBB, JF*; RAMSAY, J; University of Rhode Island; *jacqueline_webb@mail.uri.edu*
3−D Configuration of Teleost Lateral line Scales and the Lateral Line Canal Contained Within Them: The Textbooks are Wrong
The lateral line (LL) scales are an important functional component of the mechanosensory lateral line system of bony fishes and a source of meristic characters for taxonomic study. A section through the overlapping scales that compose the LL canal is a common illustration in most comparative anatomy and ichthyology textbooks. Upon dissection, it is clear that the scales sit in the dermis, each flat LL scale contains a tubular LL canal segment, and adjacent scales overlap so that the canal segments in the linear series of scales form a continuous canal (the trunk canal). However, these observations are not consistent with the diagrammatic illustrations of the LL scales provided in textbooks. Thus, we re−examined the 3−D configuration of the lateral line scales and the lateral line canal contained with them, using histological sections cut through the trunk canal of embiotocids, pomacentrids and pleuronectids (n=10 spp.) which all have well−developed trunk canal and unremarkable LL scales. The 3−D configuration of the LL scale and LL canal was consistent within and among the families examined, with some variation. The scales overlap (to various degrees; no overlap in pleuronectids) and sit at a shallow angle relative to each other. The LL canal runs parallel to the skin surface and its lumen (which varies in diameter, among pleuronectids) runs through the tubular canal segments in the LL scales. A neuromast receptor organ is found in the canal segment in each scale, and pores (not apparent in pleuronectids) are simply perforations in the overlying epithelium between scales. The 3−D relationship of LL scales and tubular canal segments and neuromast location in canal segments are thus dramatically different than that portrayed in textbooks, as well as on the WWW where inaccurate anatomy can rapidly and reliably perpetuated.

61.4 WEBB, J.F.*; HOBBS, N.−V.; SEIBEL, B.A.; FORRESTER, G.E.; U. Rhode Island; *jacqueline_webb@mail.uri.edu*
The "Out of Classroom" Experience: Teaching Marine Biology at the University of Rhode Island
For students in Marine Biology and Environmental Sciences, field work generates a great deal of excitement, and we all recognize that it is a critical component of their education. However, the campus−based courses that provide disciplinary training in biology and ancillary sciences makes it difficult to integrate more extensive or remote marine field experiences into a normal semester schedule (especially in seasonal New England). URI offers three very different intense field courses that take place outside of the normal semester. In "Marine Invertebrates of Southern New England" students study invertebrates in their backyards (literally) where local biodiversity is challenged by coastal development and the effects of climate change. "Pelagic Ecology" provides undergraduates with their first off−shore, deep water cruise experience aboard URI's 185' R/V *Endeavor* off the continental shelf, 120 miles due south of Rhode Island. Students collect delicate, little−known pelagic animals using sophisticated nets, conduct physiological experiments, and have the opportunity to observe these animals in situ while blue water diving. Finally, "Coral Reef Conservation and Analysis" is offered at a remote field site (a CIEE field station) in tropical Bonaire during J−term. The critical analysis of primary literature and local case studies is integrated with daily SCUBA−based investigations that allow students to hone practical skills with the goal of designing field studies that focus on solving conservation problems. The diversity of these very successful field courses complements more traditional campus−based courses. They give our students unique experiences that allow them to put their knowledge of marine biology into larger and more practical contexts, which is so critical for the cultivation of longer−term career interests.

P1.42 WEBSTER, K. J.*; WHELAN, N.V.; HALANYCH, K.M.; Auburn University; *kjw0018@auburn.edu*
A Molecular Investigation into the Biodiversity and Biogeography of Antarctic Thouarella (Cnidaria: Octocorallia: Primnoidae)
Global climate change has had a profound impact on the health of Antarctic communities, but little is known about the ecosystems in this region. Found within the benthic communities of this area are members of the soft coral genus *Thouarella*. Few studies have been done to investigate the species richness of this genus in the Antarctic despite these organisms playing an important role in benthic communities and providing habitat for Antarctic annelids. We used a DNA barcoding approach to investigate the biodiversity of Antarctic *Thouarella* species using mitochondrial DNA sequences. Geographical distributions of identified species were examined to assess differences in distributions among species and population connectivity. This study will provide a better understanding of species−level diversity in *Thouarella* and population structure around the Antarctic continent.

112.3 WEHRLE, BA*; TADI , Z; KRAJNOVI , M; HERREL, A; GERMAN, DP; Univ. of California, Irvine, Univ. of Zagreb, CNRS/MNHN; *bwehrle@uci.edu*
Changes in digestive performance and gut structure and function in a newly herbivorous lizard
Although evolution is generally thought to happen over long timescales, examples of rapid evolutionary change are becoming more common. One example, a population of Italian Wall Lizards (*Podarcis sicula*) in Croatia has become primarily herbivorous and morphologically distinct from its source population in ~30 generations. By studying what these animals are ingesting and digesting, we can investigate if their physiology and morphology are optimized for their diets. The Adaptive Modulation Hypothesis posits diet specialization should lead to gut specialization. With previously documented changes in diet and gut structure in these lizards, we hypothesized concomitant changes in gut function to accommodate a plant diet. Indeed, we found the herbivorous population was more efficient at digesting plants than the source population lizards. Thus, we compared the gut morphology and physiology of the herbivorous population, its source population, and two outgroup populations of *P. sicula* to discern the mechanisms of their digestive capabilities. We expected the plant−eating population would have increased gut length and intestinal surface area to absorb nutrients. We found differences in gut length by population and sex, but not in intestinal cross sectional area. We anticipated higher carbohydrase activities in the herbivorous population, but have found inconsistent patterns across populations and enzymes. In experiments underway, we predicted the herbivorous population would have increased microbial fermentation and food transit time, as is found in other herbivorous lizards. In progress metabolic measurements aim to investigate effects of diet and diet specialization on performance. Our study addresses mechanisms of how diet specializations arise and their effects on fitness.

P3.118 WEINNIG, A.M.; California Academy of Sciences ; *alexismweinnig@gmail.com*

It's What's on the Inside that Counts: Investigating the Role of Axis Elemental Composition in Octocoral Phylogenetics

There is still much to be learned about seafloor ecosystems. They are delicate systems that are constantly being threatened by human activity. In order to better understand these vulnerable ecosystems we must focus on the organisms that play a key role in their health. Some such organisms are members of the subclass Octocorallia, commonly known as octocorals. Octocorals are some of the least well−understood organisms in the phylum Cnidaria. In order to achieve a better understanding of these organisms, and the role they play in seafloor ecosystems, I will examine a specific part of their structure, the solid internal axis. The actual elemental composition of the axes in various octocorals is till unknown. Examining the elemental composition of the axis in certain octocorals of the group Calcaxonia and order Pennatulacea could provide insight into the weakly supported phylogenetics of these octocorals. The elemental composition of the axes will be obtained using scanning electron microscopy (SEM) and energy dispersive spectrometry (EDS). EDS will provide an analysis of the weight percent of each element that contributes to the axis (ex. carbon 17.13%). After all the elemental composition data is collected the weight percent data can be used to compare organisms on a family level. Studying these octocorals can provide insight into the health of the seafloor ecosystem, and then by understanding the current ecosystem health we can knowledgably implicate conservation efforts for seafloor ecosystems.

104.4 WEISS, TM*; JUNG, S; VLACHOS, PP; SOCHA, JJ; Virginia Tech, Purdue University; *talcat@vt.edu*

Modulation of forces in water−based jumps by the frog Euphlyctis cyanophlyctis

Although multiple aquatic or semi−aquatic vertebrates can launch from the water in the midst of a locomotor event, very few can do so from a stationary position. Among frogs capable of jumping out of water when floating, *Euphlyctis* species appear to excel in their ability to control the height to which they jump. When targeting an insect, these frogs appear to match jump height with insect height above the water, with maximum height roughly 9 times the snout−vent length. Although the simple physics of ballistic jumps would suggest that the frog's maximum jump height is entirely dependent on the exit velocity, water−leaping frogs entrain a considerable amount of water. This water is partially shed mid−air, complicating the factors that determine the ultimate jump height. *Euphlyctis* must be able to precisely control the force required to reach a desired height, even with such complex fluid dynamics in play. However, the mechanism and degree of this control of jumping from water is unknown. We tested the hypothesis that frogs modulate the area and shape of foot webbing during the power stroke and leg extension rate by recording high speed video of *Euphlyctis cyanophlyctis* launching from water using insects held at various heights. We additionally used the projected area of the foot and stroke velocity to estimate the force the frog exerts on the water using Bernoulli's equation for unsteady potential flow. Preliminary results from one frog (m=30 g; n=10 trials) using a target 12.7 − 25.4 cm above the water surface indicates no clear relationship of height with propulsive stroke length (avg=2.5 cm) or stroke duration (avg=58 ms). This suggests that the system cannot be fully understood without investigating the underlying fluid mechanics. Supported by NSF 1205642.

1.6 WELCH, A.M.*; SMITH, M.J.; GERHARDT, H.C.; College of Charleston, SC, University of Missouri, Columbia; *welcha@cofc.edu*

Growth and maturation in gray tree frogs: Genetic variation and the ontogeny of sexual size dimorphism

Maturation is a critical life−history milestone that reflects a trade−off between age and size, with consequences for survival and lifetime reproductive success. Many ectotherms show female−biased sexual size dimorphism, often reflecting delayed maturation of females relative to males. Within each sex, variation in the timing of metamorphosis can be an important source of variation in fitness. We investigated maturation in the gray tree frog, *Hyla versicolor*, examining variation in age at maturity as a function of diet, sex and parentage. Maternal half−sibship offspring were reared to maturity in captivity under two dietary regimes. Age at maturation was strongly related to sex, size and maternal identity. Males were smaller than females, grew more slowly and tended to mature earlier. While larger individuals were more likely to mature in the first year regardless of sex, early maturation in females was more strongly associated with reaching a larger size. Genetic variation in post−metamorphic growth contributed to variation in maturation through its effects on body size, but maternal effects alone influenced on the propensity to mature at a given size. Thus, we found no evidence of genetic variation in the trade−off between age and size at metamorphosis in our study population. Our results reveal sex differences in growth and development, with females not only delaying maturation but also growing more rapidly both before and during maturation. These differences in the ontogeny of sexual size dimorphism may relate to the evolution of different tactics to optimize lifetime fitness in this species.

77.2 WEN, L*; THORNYCROFT, PJM; WEAVER, JC; LAUDER, GV; Beihang University, Harvard University; *liwen@buaa.edu.cn*

Hydrodynamic function of biomimetic shark skin: effect of denticle pattern and spacing

The morphology of shark skin denticles varies considerably over the body of individual animals, and also displays remarkable variation among species. However, the hydrodynamic functions of denticle pattern and spacing remain unexplored. In previous work, we used high−resolution micro−CT scanning to construct a three−dimensional model of shortfin mako (Isurus oxyrinchus) shark skin denticle. Based on this model we have designed and 3D printed flexible foils with different denticle patterns and spacings: (1) staggered overlapped, (2) linear overlapped, and (3) linear non−overlapped. These 3D printed shark skin models were then tested in water tank using a robotic flapping device that allowed us to either hold the models in a stationary position or move them dynamically. We swam the foils at a frequency of 1Hz with different heave amplitudes (from ±1 cm to ±3 cm) while measuring forces, torques, self−propelled swimming speed, and cost of transport (COT). Compared with a smooth control foil without denticles, we found that the foil with staggered overlapped denticles produced significantly faster swimming speeds with slightly increased COT. For instance, at a heave frequency of 1 Hz and amplitude of ±1 cm, swimming speed increased by 34%, while the cost−of−transport increased 8.7%. However, lower swimming speeds and higher COT than the smooth control was generated by foils with both linear overlapped and linear non−overlapped denticles. Quantitative hydrodynamic comparisons among 3D printed models provide a sophisticated experimental approach for understanding the considerable natural diversity of shark skin denticles both among species and on different body locations.

P2.67 WERNER II, L.C.*; ESSNER JR., R.L.; WILLIAMS, J; Southern Illinois University Edwardsville; *lwerner@siue.edu*

Exploring the Overwintering Strategies of a Cold−Water Anuran, Ascaphus montanus

The Rocky Mountain Tailed Frog, *Ascaphus montanus* is a cryophile that is associated with permanent mountain streams in the northwestern United States and Canada. Adults overwinter in these cold, fast moving streams, which requires surviving extended bouts of subzero temperatures. The purpose of this study was to determine if these frogs can tolerate winter conditions found in mountain streams by either surviving internal ice formation or avoiding freezing by resisting ice inoculation and supercooling. Winter acclimated frogs cooled from 2°C at 0.2°C h^{-1} had relatively low supercooling points compared to other frog species (−5.0 ± 0.1°C;n=3). To test their ability to remain supercooled and/or resist inoculative freezing, two additional groups were cooled at the above rate until reaching and being held at −1°C. Frogs maintained at −1°C in the absence of ice were able to maintain a supercooled state prior to freezing for considerably longer than most other freeze tolerant species of frogs (73 ± 22 h; n=4). Similar to other frogs, *A. montanus* did not resist inoculative freezing well. Frogs cooled to and maintained at −1°C froze within 30 minutes (16.1 ± 4.6 min; n=4), following addition of a 500mg piece of ice to their skin. After the last frog froze in the supercooling point determination trial or after being held at −1°C for seven days, all frogs were warmed at 0.2°C h^{-1} until reaching 2°C prior to assessing survival. No frogs survived the supercooling point trials or after being frozen by ice inoculation. However, two of the four frogs that were held at −1°C in the absence of ice survived supercooling for ~2 days followed by being frozen for ~5 days. In sum, *A. montanus* may be able to survive the high sub−zero temperatures found in montane streams during winter by either supercooling and/or surviving mild freezing.

2.5 WERNING, S; Stony Brook Univ; *sarah.werning@stonybrook.edu*

Bone tissue variation suggests stem crocodylians were capable of fast growth

Extant crocodylians are characterized by slow growth and low metabolic rates, historically considered the plesiomorphic condition for Archosauria. Recent histological studies have established that some stem archosaurs had bone tissue more similar to that of birds and mammals than to living crocodylians (i.e., osteohistological correlates of faster growth and higher metabolism), which strongly suggests that the slow growth physiology of living crocodylians is secondarily derived. The origin of this physiological slow−down among croc−line archosaurs is unknown. In order to determine the point of origin of crocodylian metabolism, I histologically sampled representative taxa from several extinct lineages outside Crocodylia (phytosaurs, aetosaurs, shuvosaurids, rauisuchians, and early crocodylomorphs). I included individuals from several localities when possible to test how differences in paleoenvironment influenced interpretations of growth rate. I analyzed mid−diaphyseal femoral microstructure for characters known to vary with growth rate in living tetrapods (density and organization of blood vessels, bone cells, and collagen fibers; number of annual growth lines; annual bone deposition rate). In nearly every case, taxa varied in their histology and inferred capacity for faster growth among localities. Clades hypothesized to grow slowly based on 1−2 individuals were actually capable of much faster growth (e.g., bone deposition rates in some phytosaurs were ~10 times faster than extant *Alligator*). My results establish that the ancestral archosaurian condition of faster growth was still present in early crocodylomorphs. Because individual specimens or localities cannot capture the true range of histological or growth variation, greater caution should be taken when inferring the capacity for fast growth in fossil animals, and in reconstructing the evolutionary history of growth rates.

10.4 WESTERMAN, E.*; TROLANDER, A.; LETCHINGER, R.; GARCIA, G.; MASSARDO, D.; KRONFORST, M.; University of Chicago, University of Chicago ; *ewesterman@uchicago.edu*

Male courting strategies may facilitate the maintenance of female polymorphism in a mimetic butterfly

The maintenance of female limited polymorphism in species where some, but not all, of female morphs are Batesian mimics is puzzling because it is unclear what selective pressures drive the maintenance of the non−mimetic female form. Three current hypotheses are that the non−mimetic form is maintained as a result of sexual selection (mate preference for the non−mimetic form), life−history trade−offs (non−mimetic females produce more offspring than mimetic females) or frequency dependent selection (mimetic forms incur increasing fitness costs with increasing frequency). Here we test the sexual selection hypothesis by conducting a series of group choice, individual choice, and no−choice male preference assays in the butterfly *Papilio polytes*. We find that males exhibit a preference for mimetic over non−mimetic females, and that this preference does not change throughout an individual's lifespan, suggesting that male preference for non−mimetic females is not driving the maintenance of female polymorphism. However, males who experienced unsuccessful courtship attempts with mimetic females were observed to then court non−mimetic females, even when given a choice of a mimetic and a non−mimetic female. Unsuccessful courtship was associated with this switch throughout male lifetime: the more often a male engaged in courtship, the more likely he was to have courted both mimetic and non−mimetic forms. These results suggest that, though males prefer mimetic over non−mimetic females, male receptivity of non−mimetic females may change over time. Thus, change in male receptivity has the potential to facilitate the maintenance of the non−mimetic female morph.

57.1 WETHEY, DS; Univ South Carolina, Columbia; *wethey@biol.sc.edu*

Biogeography of range edges in intertidal populations − effects of larval transport

The barnacle *Semibalanus balanoides* and the polychaetes *Diopatra neapolitana* and *Diopatra biscayensis* have multiple geographic limits in France, Spain, and Portugal. Population densities near range edges decay exponentially with distance from the population centers in *Semibalanus*, yet range edges are abrupt in *Diopatra*. The difference in geometry of range edges could be the result of differences in planktonic larval duration, or to local hydrodynamic barriers to dispersal. To distinguish between these hypotheses, larval transport was modeled with Lagrangian particle tracking, using velocity fields from ocean models developed by the UK Met Office, IFREMER, US Navy, French Navy, and the Spanish Puertos del Estado. Despite large differences in predictions among the different ocean models, Lagrangian particle tracking predicted that the decline in population density from larval source populations was exponential and the slope of the relationship was proportional to the planktonic larval duration. The abrupt range boundaries in *Diopatra* do not appear to be related to hydrodynamic barriers, rather they derive from a short larval period (< 6 d), and the gradual *Semibalanus* range edges are most likely due to a longer planktonic period (>30 d).

S1.6 WHEATLEY, R*; BROWN, C; ANGILLETTA, M/J; NIEHAUS, A/C; WILSON, R/S; The University of Queensland, Arizona State University; *r.wheatley@uq.edu.au*
Optimising performance by balancing trade−offs between speed and accuracy
Many ecologically relevant tasks require an animal to perform quickly, powerfully, and accurately. However these endeavours are not mutually conducive; biomechanical constraints mean that in almost all cases, increasing speed results in a decrease in accuracy. In order to maximise their probability of success, animals should attempt to achieve the best possible combination of performance values to optimise their trade−off between performance traits. Our work uses optimality modelling to predict exactly what these performance values are and tests to see whether this is how animals perform in nature. We are using this process to examine the trade−off between speed and accuracy in two different systems: a rule−based human system (elite tennis), and a natural population of *Antechinus flavipes*. We determined the optimal serve speed for elite tennis players in order to win a game at various points in the match, and found that optimal speed was heavily dependent on the individual's trade−off between serve speed and serve accuracy. We also found that players did not often serve at their optimal speed, despite it frequently being lower than their maximum and less physiologically challenging. We are also investigating this question in a natural population by examining the speed an individual runs along a branch of constant thickness in order to catch a prey item. Using optimality modelling, we will determine the optimal running speed for different individuals on different branch thicknesses, and determine whether they perform at this speed in a nature−simulating environment.

101.4 WHEELER, JD*; ANDERSON, EJ; MULLINEAUX, LS; CHAN, KYK; Woods Hole Oceanographic Institution, Grove City College, Woods Hole Oceanographic Institution , Hong Kong University of Science and Technology, Woods Hole Oceanographic Institution; *jwheeler@whoi.edu*
Keep swimming and start spinning: Effects of turbulence on swimming and orientation in larval urchins
Many marine organisms have complex life histories, having limited mobility as adults and relying on the plankontic larval period for dispersal. Larval life stages thus play a significant role in determining population and community dynamics. Larvae swim and disperse in a complex fluid environment and the effect of ambient flow conditions on larval behaviour remains a question of interest. In this study, we examine how local flow and ontogeny influence swimming behaviour in pre−competent sea urchin (*Arbacia punctulata*) larvae. We exposed larvae to grid−stirred turbulence and recorded their behaviour during two life stages (four and six−armed plutei). Using particle image velocimetry to quantify and subtract local flow, we tested the hypothesis that larvae respond to turbulence by increasing swimming speed, and that the increase varies with ontogeny. Contrary to our hypothesis, and to prior studies of larval molluscs, changes in local flow properties (acceleration, vorticity, and deformation) did not induce a significant change in larval swimming velocities. Increased turbulence intensity, however, decreased the relative time that larvae spent in the typical upright orientation. Larger, older 6−armed larvae were tilted more frequently in turbulence, in contrast to younger 4−armed larvae. This observation suggests that as larvae increase in size and add pairs of arms they are more likely to be passively re−oriented by moving water, despite the increase in weight (ballast), potentially leading to differential transport. Our results show that turbulence plays an important role in the larval life history, not just during settlement but also in earlier stages through morphology−flow interactions.

S5.9 WHELAN, Nathan V*; KOCOT, Kevin M; HALANYCH, Kenneth M; Auburn University, University of Queensland; *nwhelan@auburn.edu*
Resolving the metazoan tree of life with advanced bioinformatic pipelines and phylogenetic methods
The branching pattern at the base of the metazoan phylogeny has been a long−standing, unanswered question that must be resolved before issues concerning the transition from unicellularity to multicellularity can be appropriately addressed. Numerous studies have attempted to resolve the relative position of Ctenophora, Porifera, Placozoa, Cnidaria, and Bilataria, but the results of these studies have been alternative hypotheses that fail to fully clarify metazoan phylogeny. Recent advances in sequencing technologies can be employed to compile a phylogenomic dataset with more complete character matrices and greater outgroup, Ctenophora, Porifera, and Cnidarian taxon sampling than employed in previous studies. Despite technological advances, there are still limits to the amount of overlap that can be expected concerning which genes are sequenced for each taxon. Therefore, we discuss a bioinformatics pipeline that emphasizes quality of data to ensure accurate orthology determination. Such a pipeline also works to limit the amount of missing data in the overall data matrix with the goal of reducing phylogenetic inference artifacts. New methods for model testing can also be employed to find best fit amino acid substitution models and data partitioning schemes. Using this approach, a Maximum Likelihood phylogenetic reconstruction resolved Ctenophora as the most basal metazoan lineage with 100% bootstrap support for all major nodes. Hypotheses inferred with different datasets, Maximum Likelihood analysis, traditional Bayesian phylogenetics, and Bayesian concordance analysis will be compared in an effort to highlight best practices for resolving deep nodes in the tree of life.

P3.5 WHITENACK, LB; Allegheny College, Meadville, PA; *lwhitena@allegheny.edu*
Partnering school districts and colleges via their science faculty: piloting the Allegheny College−Crawford Central STEM Partnership
K−12 teachers have been pushed to adapt to meet changing standards due to the implementation of initiatives such as Common Core. Standardized testing links student mastery of these standards to graduation, school funding, and job security. As teachers focus on meeting content and test goals, they are left little time to try new methodologies such as guided inquiry, despite evidence that these are effective practices. These policy changes spill over to undergraduate education, as students enter their courses with different skills and competencies than what was expected even just a few years ago. To address these challenges, we established a partnership between Allegheny College and Crawford Central School District (CCSD) high school STEM faculty. Four faculty each (2 biology, 2 chemistry) from Allegheny and CCSD were paired together for 10 days in summer 2014 to develop curriculum and pedagogy in line with state standards and inform Allegheny faculty about current issues in our local school system. The partners then ran a teacher in−service day in October for non−partner teachers in their respective departments to share their work. Assessments indicate that all parties were satisfied with the results of the partnership, and are in the process of implementing the developed activities into their classrooms. Biology activities centered on scientific method, meiosis, cellular respiration, and evolution. We found that close reading, quantitative skills, and willingness to fail were areas that students struggled in both high school and college. Success of the partnership was due to careful matching of partners, allowing participants autonomy for choosing meeting dates and setting specific goals, and providing supply funds and equal stipends for professors and teachers.

30.6 WHITENACK, LB*; SHERRY, RS; HABEGGER, ML; Allegheny College, Meadville, PA, Univ. of South Florida, Tampa; *lwhitena@allegheny.edu*

Bite force calculations of two long−faced fishes, the northern pike Esox lucius and great barracuda Sphyraena barracuda, through ontogeny

The freshwater northern pike *Esox lucius* and marine great barracuda *Sphyraena barracuda* are superficially similar in appearance and hunting behavior. Both possess elongate bodies with long pointed snouts and are ambush predators that utilize short bursts of high speeds to prey upon fishes throughout ontogeny. However, these fishes are in different orders (Esociformes and Perciformes, respectively) and last shared a common ancestor in the Triassic. The goals of this study were to describe the adductor mandibulae complex, calculate the theoretical bite force and mechanical advantage using a three−dimensional static equilibrium model, and examine the scaling of bite force in 27 *E. lucius* (9.2−83.8 cm TL). We then compared these measures to previously published data for *S. barracuda*. All measurements for *E. lucius* scaled with isometry, except for the in−lever which was negatively allometric. This is contrary to *S. barracuda*, where all measurements except the anterior out−lever were isometric. Posterior bite force for the largest pike was 44.0 N, compared to 63.8 N for the same sized barracuda. This is likely due to the differences in adductor anatomy. Despite the fact *E. lucius* have higher mechanical advantage, they lack an A1 and have a smaller A3 adductor division than barracuda. Pike have large, sharp, blade−like teeth on the posterior dentary, which may make high bite forces unnecessary.

P1.9 WHITTINGHAM, L.A.*; FREEMAN−GALLANT, C.R.; TAFF, C.C.; DUNN, P.O.; Univ. of Wisconsin−Milwaukee, Skidmore College, Univ. of California−Davis; *whitting@uwm.edu*

Different Ornaments Signal Similar Aspects of Immunity in Two Populations of a Warbler

Males often display ornaments that have presumably evolved as a result of sexual selection. Although male−male competition and female choice may favor the same or different ornaments, we expect that female choice will act on the ornament that is more revealing of male quality. We studied common yellowthroats (Geothlypis trichas) in two populations that differ in the male plumage ornament associated with female choice and male reproductive success. In Wisconsin females favor males with a larger black facial mask, a trait that is also related to immune function, survival and variation at immunity genes of the major histocompatibility complex (MHC). In New York females favor males with larger and brighter yellow bibs, a trait that is also associated with greater antibody production and survival. In this study, we examined whether the size and brightness of the yellow bib also reveals MHC variation for NY males. Using 454 pyrosequencing, we found that bib brightness was positively related to the number of MHC class II alleles with intermediate frequency and negatively related to the number of rare class II alleles, as predicted if the frequency of MHC alleles is influenced by host−parasite coevolution. Furthermore, males with more MHC class I alleles that were unique to NY had greater apparent survival, and resistance to malaria infection was associated with the presence of a particular MHC class II allele. Thus, similar to the black mask in WI, the yellow bib provides a signal to NY females that males have immunity genes that are related to parasite resistance and survival, consistent with good genes models of sexual selection.

70.7 WIJESENA, N.M.*; SIMMONS, D.; MARTINDALE, M.Q.; University of Florida; *naveen@whitney.ufl.edu*

Inputs of BMP signaling in to the cnidarian endomesoderm GRN

The genesis of gastrulation was arguably a key evolutionary innovation that enabled metazoan diversification, leading to the formation of distinct germ layers that gives rise to specialized tissues. The gene expression profile of the cells that give rise to these different germ layers is regulated by the transcriptional activators/repressors whose activity is governed by the inputs of intracellular and/or extracellular signals. A recent study in the basal metazoan *Nematostella vectensis* has characterized the NvTcf/canonical−Wnt (cWnt) signaling inputs in to the cnidarian endomesodermal gene regulatory network (GRN). To extend the functional analysis of signaling pathways in the GRN, we knocked down the TGF² molecule *NvBMP 2/4*, a putative key player of the cnidarian endomesodermal GRN using a translation blocking morpholino. A previous study has shown that BMP signaling in *Nematostella* might be playing a role in patterning the endoderm and the dorso−ventral (DV) axis but these conclusions were based on the expression patterns of a limited number of marker genes. In our study, confocal microscopy showed that the NvBMP 2/4 morphant embryos failed to form a normal epithelial gut, indicating to defects in cell−fate specification. Further analysis of gene expression profiles of morphant embryos using *in−situ* hybridization showed that *NvBMP 2/4* knock down affected the expression of a subset of genes including *NvSnailB* and *NvFgf1a*, which were not affected by NvTcf/cWnt inhibition in the cnidarian endomesodermal GRN. These results suggest that BMP 2/4 signaling has additional inputs in to the endomesodermal GRN in *Nematostella*. Further analysis of these inputs would provide critical information for a detailed understanding of the transcriptional regulation/interaction of key players of the cnidarian endomesodermal GRN.

90.4 WIJESENA, N.M.*; SIMMONS, D.; MARTINDALE, M.Q.; University of Florida, Unversity of Florida; *naveenw@whitney.ufl.edu*

Inputs of BMP signaling in to the cnidarian endomesoderm GRN

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P3.150 WILCOX, S.C.*; CLARK, C.J.; Univ. of California, Riverside; *swilc002@ucr.edu*
Kinematic Tradeoffs in Hummingbird Aerial Courtship Displays
The athletic courtship displays of hummingbirds can be striking and might be physically strenuous. Aerial dives (Pearson, 1960; Mitchell, 2000; Clark 2009) as well as short−range "shuttle" displays are performed by male Allen's (*Selasphorus sasin*) and Black−chinned Hummingbirds (*Archilochus alexandri*) during courtship. During a shuttle display, a male flies acrobatically from side to side within a meter of a perched female. Throughout these displays, wingbeat frequency increases dramatically, and trill sounds are produced as a male flies side to side. We hypothesize that, during the display, males face tradeoffs between wingbeat frequency and stroke amplitude, and between the frequency and amplitude of the display itself. Hence, the shuttle display may function to advertise individual flight performance as it relates to kinematic tradeoffs experienced during the shuttle (Byers et al., 2010; Barske et al., 2011). We measured wingbeat frequency, stroke amplitude, and wingtip velocity, as well as the frequency, amplitude, and velocity of individual displays by using high−speed and conventional cameras. We analyzed the kinematic tradeoffs endured by Allen's and Black−chinned Hummingbird males during shuttle displays using new kinematic analysis software (Theriault et al., 2014).

109.3 WILCOXEN, TE*; WROBEL, ER; SEITZ, J; NUZZO, J; Millikin University, Illinois Raptor Center, Illinois Raptor Center; *twilcoxen@millikin.edu*
Parasite prevalence and leukocyte differentials in injured, malnourished, and orphaned birds of prey.
Haemoparasites are prevalent among free−living birds, but the intensity of infection varies greatly and is known to be highly context−dependent. Further, the consequences for avian hosts living with common parasites are only well understood for domestic species and for a few free−living species. We assessed parasite prevalence in over 200 birds of prey admitted to the Illinois Raptor Center in 2014 and determined leukocyte differentials as well as a number of other immunological and physiological metrics to assess host condition. As expected, eosinophilia was common in individuals with heavy haemoparasite loads; however, our findings revealed additional correlations between parasite prevalence and intensity and immune function that offer new insights into the role of life history stage, season, and ontogeny on both susceptibility to parasitism and the impact of parasitism on raptor hosts.

30.1 WILGA, C*; SCOTT, B; SUMMERS, A; Univ. of Rhode Island, Univ. of Washington, Friday Harbor; *cwilga@uri.edu*
Stiffness in the Jaws and Hyoid Arch of Sharks
Jaw suspension type in sharks is characterized by the amount of support they provide to the jaws. We predict that those that provide relatively more support should be stiffer in response to biological load. The jaw and hyoid arches of sharks have mineralized blocks of cartilage surrounding an inner core of hyaline cartilage. Greater mineralization of the hyomandibula confers greater stiffness a previous study. Here we perform mechanical property tests on the jaw and hyoid cartilages of several shark species to characterize the response to load. The hyomandibula, ceratohyal, palatoquadrate, and Meckel's cartilages of several species that vary by jaw suspension and morphology were removed and tested individually in a material testing system. Axial and transverse length changes in the cartilages were measured under compression using sonometric crystals, which measure distance via ultrasound. Strain, Young's Modulus, and Poisson's ratio were then calculated using the distance changes and load. Young's modulus was higher in those species with greater mineralization of the jaw and hyoid elements. Poisson's ratio varied widely and was smaller in those species with greater mineralization. Those species with higher Young's modulus and smaller Poisson's ratio use suction or crushing modes of feeding, while those with lower moduli are bite feeders. Strain in the hyoid arch elements was higher in those species with relatively shorter elements and those with relatively smaller cross−sectional areas, while strain was similar in the jaw cartilage. A complicated relationship exists between jaw suspension type and mechanical property. It appears that tessellated cartilage allows similar levels of strain among the jaw suspension types while mineralization levels vary among the jaw suspension types.

P1.187 WILKINSON, K. C.*; LEE, D. V.; University of Nevada, Las Vegas; *wilkinso@unlv.nevada.edu*
An instrumented beam for measurement of six axis forces and torques in grasping arboreal vertebrates
Grasping in vertebrates is important for locomotion, prehension, and reproduction. Grasp can be achieved with the manus, pes, tail, mouth, trunk, or tongue. Manual grasping has received attention for its obvious use by humans, however these studies are not comprehensive in understanding of the structure−function relationships in other grasping appendages or the evolution of grasping in early tetrapod clades. Previous locomotion studies on grasping have included the use of high−speed X−ray videography and force platforms, however few have analyzed torques. Here, we use a beam that is divided into four serial segments. Each beam segment is instrumented with a six axis force and torque transducer (ATI, Nano 17) and is diagonally offset. Using high−speed biplanar X−ray videography in combination with our beam system, investigations of grasping evolution and structure−function relationships can be performed.

S7.3 WILLIAMS, T.M.; Univ. of California, Santa Cruz; *williams@biology.ucsc.edu*

The Moveable Feast: A comparison of foraging tactics and energetics in large, stealthy marine and terrestrial carnivores

Foraging by large (> 25 kg), mammalian carnivores often entails cryptic tactics to surreptitiously locate and overcome highly mobile prey. Many forms of unsteady locomotion from stroke−and−glide maneuvers by marine mammals to sneak−and−pounce behaviors by terrestrial canids, ursids and felids are involved. While affording proximity to vigilant prey, these tactics are also associated with unique energetic costs and benefits to the predator. Here we examine the energetic consequences of interrupted locomotion in mammalian carnivores and assess the role of these behaviors in overall foraging efficiency. Behaviorally−linked 3−axis accelerometers were calibrated to provide instantaneous energetics from Overall Dynamic Body Acceleration (ODBA), as well as the cost per stroke or step in marine and terrestrial mammals, respectively. The instruments were deployed on wild adult Weddell seals (*Leptonychotes weddellii*) and mountain lions (*Puma concolor*), and compared to previously published values for other carnivores. We found that intermittent locomotion resulted in significant energetic savings for both aquatic and terrestrial hunters. The cost of a foraging dive by the seals decreased 9.2 to 59.6% depending on the proportion of time gliding. Similarly, hunting costs in mountain lions was reduced by >40% by changing from constant movement to sneak attacks. These energetic savings help to mitigate the comparatively high field metabolic rate (FMR, kJ.day^{-1}) of large carnivores, where $FMR_{\text{marine carnivore, wild canids}} = 1367.7 mass^{0.76}$ ($n = 26$ species, $r^2 = 0.95$, $p<0.001$), and demonstrate the importance of locomotor versatility in highly active predators. (Supported by the Office of Naval Research and NSF −Polar Programs and IDBR.)

59.5 WILLIAMS, CT*; RADONICH, M; BARNES, BM; BUCK, CL; Univ. of Alaska Anchorage, Univ. of Alaska Fairbanks; *ctwilliams@uaa.alaska.edu*

Hibernation and circadian rhythms of body temperature in ground squirrels

Circadian systems provide animals with the ability to coordinate their physiological and metabolic functions in anticipation of predictable daily changes in their environment. However, whether circadian rhythms persist during hibernation is contentious. We hypothesized that circadian clocks are arrested during hibernation and that the post−hibernation resumption of rhythmicity is triggered by exposure to light when ground squirrels first emerge to the surface. We investigated the association between timing of emergence and resumption of body temperature (T_b) rhythms in free−living arctic ground squirrels and experimentally assessed the responsiveness of rhythmicity by manipulating light exposure and hibernation in animals in the lab. During deep torpor, T_b of squirrels was arrhythmic within the 0.02ºC resolution of our data loggers and remained arrhythmic in males returning to high T_b in spring but remaining in their burrows for up to 3 weeks; T_b rhythms re−emerged coincident with emergence from the hibernacula, though some individuals developed weak, but significant, rhythms following exposure to low−intensity light from within the hibernacula. Squirrels maintained in the lab in constant darkness spontaneously developed weak, but significant, body temperature rhythms within three weeks of terminating hibernation. Individuals exposed to a 5−second pulse of light within 5 days of terminating hibernation, however, immediately developed robust circadian T_b rhythms. Our results are consistent with the hypothesis that low T_b during torpor inhibits clock function. Exposure to light following hibernation may be accelerating the resumption of circadian T_b rhythms by synchronizing loosely coupled circadian oscillators within the suprachiasmatic nucleus.

P2.63 WILLIAMS, J.B.*; REGER, K; Southern Illinois University; *jasowil@siue.edu*

Multiple bouts of anoxia induce oxidative stress and limits cold tolerance in the freeze−tolerant goldenrod gall fly, Eurosta solidaginis.

Recent studies indicate that freeze tolerant insects subjected to multiple bouts of low temperature have reduced survival compared to animals exposed to a single freeze of the same cumulative duration. However, it is unclear if the reduced survival is due to repeated cellular osmotic stress and/or oxidative stress during oxygen reperfusion upon thawing. To determine if multiple anoxic events reduce survival and influence factors associated with oxidative stress we measured levels of oxidative damage to lipids, aqueous and lipophilic antioxidant activity levels, pupation rates, and cold tolerance of *Eurosta solidaginis* larvae subjected to either 0, 10, 20, or 30 cycles of diurnal anoxia/reperfusion or a single bout of anoxia for 15 days. Repeated exposure to anoxia reduced both aqueous and lipophilic antioxidant activity levels in all groups by approximately half compared to controls, which averaged 47 ± 10 and 9 ± 2 mm trolox"ng protein^{-1} respectively. Oxidative damage to lipids was greatest in those subjected to 30 bouts of anoxia (18 ± 6 µm MDA"ng protein^{-1}), while levels in all other groups were similar (7 ± 2 µm MDA"ng protein^{-1}). Even though repeated anoxia subjected animals to oxidative stress, it had little effect on animal survival, as pupation percentages averaged 75.2% for all groups. Interestingly, repeated oxygen reperfusion did limit cold tolerance as animals subjected to repeated anoxia followed by an exposure to −80°C for five days had reduced fat body cell survival (61.3 ± 2.5%) compared to controls (69.3 ± 2.9%). In conclusion, repeated anoxia and oxygen reperfusion did not reduce survival, but did result in oxidative stress and may limit cold tolerance.

4.3 WILLIAMS IV, R.; HALE, M. E.*; University of Chicago; *rwilliams@uchicago.edu*

Roles of pectoral fin proprioception in aquatic hovering

Proprioceptive feedback from the limbs is fundamental to an organism's sense of body position and movement. The pectoral fins of fishes have been shown to function as proprioceptive as well as propulsive structures. Here we examine the functions of pectoral fin−based proprioceptive feedback in hovering behavior. Hovering fish are dynamically unstable and must finely tune force production with their fins to remain balanced, suggesting proprioceptive feedback is important to this behavior. We examined hovering in the bluegill sunfish (*Lepomis macrochirus*), a model species for studying the behavior, biomechanics, and physiology of pectoral fin−based swimming. The bluegill beats its pectoral fins rhythmically, in coordination with median fin movement, to maintain a stationary position while hovering. To determine how pectoral fin proprioceptive feedback is used in bluegill fin−based hovering, we performed a series of experiments where we transected the sensory nerves innervating the pectoral fins and examined the effect on hovering behavior. The transection procedure involved severing all sensory nerves innervating the fin rays either unilaterally or bilaterally. Results of the bilateral transection experiments indicate that both the pattern and timing of fin movements change post−transection and that median fins may compensate for changes in pectoral fin function. After unilateral transections, asymmetries in kinematics were identified between the intact fin and the fin with transected nerves. In both unilateral and bilateral transection conditions removal of sensory inputs from the fin rays and membrane resulted in significant changes in pectoral fin use during hovering. These results suggest that proprioceptive feedback is critical for generating and maintaining a normal hovering gait.

S2.11 WILLIS, Craig; University of Winnipeg;
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Using Physiology and Behavior to Tackle Wildlife Disease: Lessons from White Nose Syndrome in Hibernating Bats
Infectious diseases are increasingly recognized as a global conservation issue and disease management is an important aspect of wildlife conservation. Physiological responses of hosts to pathogens (e.g., innate and acquired immunity) form the basis of the classic "SIR" population models which define hosts as Susceptible, Infected or Resistant to predict disease consequences. However, behavioral responses of hosts to infection, or infection risk, have received less theoretical and empirical attention despite their potential to inform our understanding of disease pathophysiology, and improve our ability to design strategies for management. The recently emerged fungal disease, white−nose syndrome (WNS), has caused catastrophic population declines of hibernating bats in eastern North America. Research on WNS has highlighted the value of combining approaches from conservation physiology and conservation behavior to address questions about the pathophysiology of disease in individual animals, and resulting impacts of disease on populations. Using WNS as an example, I propose a framework to better integrate measures of physiology and behaviour, particularly measures that reflect host susceptibility and fitness, and pathogen fitness, into the classic SIR paradigm. This integrative approach to understanding emerging diseases of wildlife could help address the daunting task of disease management in natural systems.

89.3 WILLIS, M.A.*; MILLIGAN, J.M.; COX, A.S.; DUTTON, J.A.; Case Western Reserve University, Shaw High School, Shaw High School; *maw27@case.edu*
Details of odor sampling strategies are revealed by the responses of moths with unilateral and bilateral antennae in different environments.
Flying or swimming animals tracking odor plumes through air or water typically generate different looking paths than those walking or crawling on the substrate. These differences could arise from: (1) changes in flows and odor plumes resulting from environmental differences between the free stream and boundary layers near the substrate, (2) differences in the odor inputs of animals flying or swimming rapidly vs. walking slowly through their environments, or (3) different control rules used when walking or flying. It has been proposed that insects walking slowly along plumes in boundary layer flows use spatial cues generated from comparisons across their bilaterally symmetrical antennae, while insects flying rapidly through plumes in free stream flows may only be able to use the timing of odor encounters. Insects are ideal organisms to test these ideas because many of them track odors while flying and walking, providing the opportunity to observe behavioral changes that occur as they transition from flying to walking. Results from our studies of male oriental fruit moths, *Grapholita molesta*, as they transition from flying to walking plume tracking, show that the tracks of intact individuals change from typical side−to−side zigzag in flight to walking a nearly straight line to the odor source. Individuals that have had either antenna surgically removed change from symmetrical zigzag tracks identical to flying males, to walking tracks that loop toward their intact antenna (left or right). Comparisons of these results to walking tracks generated in clean air confirm and extend these results by showing that in the absence of odor all males walk in a straight line. This work was supported by NSF grant IOS−1121498.

P3.24 WILM, KR*; KRAJNIAK, KG; Southern Ill Univ Edwardsville; *kwilm@siue.edu*
A Correlative Study into the Structure−Function Relationship using FMRFamide−related peptides within Invertebrate intestinal tissue
FMRFamide modifies muscular activity of the crop−gizzard in the earthworm, *Lumbricus terrestris* and therefore we decided to examine the effects of FMRFamide−related peptides (FaRPs) on the isolated intestine. After removing 6−8 mm of intestinal tissue, the sample was suspended in a saline solution and connected to a Grass force transducer. The contractions were allowed to stabilize and recording on a computer using iWorx software. Increasing concentrations of peptide were added to the bath and the response were used to construct log concentration response curves for the change in amplitude and frequency. FMRFamide had an excitatory effect on both the amplitude and frequency with a threshold of 10^{-6} M. APKQYVRFamide, which is native to the genus *Lumbricus*, elicited an excitatory effect in both amplitude and frequency at 10^{-9} M, while increasing concentrations inhibited these variables until they returned to the baseline. PAKHYVRFamide, an annelid FaRP, caused an increase in amplitude with a threshold of 10^{-6} M with little effect on the rate. To explore the roles of valine (V) and tyrosine (Y) in the C−terminal tetrapeptide we also examined the effects of FVRFamide and YVRFamide. At 10^{-9} M FVRFamide caused an increase in amplitude and at 10^{-8} M a decrease. It also caused an increase in rate with a threshold of 10^{-7} M and a decrease at 10^{-6} M. YVRFamide caused an increase in amplitude with a threshold of 10^{-5} M and a decrease in rate with a threshold of 10^{-7} M. These data suggest that FMRFamide and APKQYVRFamide may be working on different receptors. The responses to PAKHYVRFamide and the tetrapeptides suggest that these differences may be due to more than just the tyrosine and valine substitutions in the C−terminal.

77.4 WILSHIN, SD*; STARR, J; CLARK, GC; KODITSCHEK, DE; SPENCE, AJ; Royal Veterinary College, University of Pennsylvania, Carnegie Mellon University, Temple University; *swilshin@rvc.ac.uk*
Using a physical model to investigate dog walking behaviour on rough terrain
The knowledge biologists have uncovered studying animal systems has and continues to improve robotic systems through a program of bioinspired design. We extend this program by transferring dog control strategies to a robotic system and measuring performance changes. When dogs move at walking speeds on uneven terrain their walk becomes more variable, taking on some characteristics of a trotting gait. This behaviour is consistent with the recovery of the dogs gait being optimized for static stability, but could also be a result of the recovery of the gait being optimal for some other factors (such as energetics, angular stability), or a result of symmetries or constraints on the animal. In an effort to better understand the causes of this dynamic in the dog walk (and potentially improve the control of robotic legged systems) we employ a physical model, transferring a putative mathematical representation of this control strategy to the RHex robot with the aim of inducing analogous behaviour. We measure the degree to which this changes the angular stability of the robot, as well as measuring the change in cost of transport with the aim of trying to resolve which factors benefit most from this change in control strategy. We compare three different control strategies, the standard RHex feed−forward controller, a controller with feedback, and a controller with feedback and recovery to the standard walk structured so that on rough ground the gait takes on some characteristics of a trot.

P2.66 WILSON, C.D.*; STEVENSON, T.J.; STECYK, J.A.; DUDDLESTON, K.N.; Univ. of North Carolina at Pembroke, Univ. of Alaska Anchorage; *cathiwilson6@gmail.com*

Influence of Cold Temperature and Anoxia on the Red−eared Slider Turtle Gut Microbiota

The red−eared slider turtle *Trachemys scripta elegans* is equipped with impressive physiological adaptations to survive the extreme environmental condidtions of low temperature (5°C) and anoxia (lack of oxygen) it experiences while overwintering in ice−covered waters. These conditions hold the potential to impact the composition, diversity, and abundance of the turtle gut microbial community. We characterized trends in diversity (454 pyrosequencing) of the cecal mucosal microbial community of turtles that were either maintained at 21°C in normoxia, acclimated to 5°C for 5 weeks in normoxia, or acclimated to 5°C for 5 weeks in normoxia and then exposed to 2 weeks of anoxia at 5°C. Alpha diversity was lowest for 5° C anoxic turtles. Beta diversity was shifted for each exposure group, suggesting an effect of temperature, followed by an effect of anoxia on the mucosal microbiota. At the phylum level, the bacteria identified were typical of gut microbiotas of other vertebrates, but interesting differences existed among the treatment groups. The relative abundance of *Aeromonadaceae* was about 11 times greater in 5°C anoxic turtles compared to 21°C and 5°C normoxic turtles. By contrast, the relative abundance of *Enterobacteriaceae* was about 10 times higher in 5°C normoxic turtles compared to 21°C normoxic and 5°C anoxic turtles. The results add to the knowledge base on host−gut microbe interactions and provide a perspective on how gut microbiota is altered in a vertebrate host that is exposed to environmental stressors. The results may contribute to our understanding of the importance of the gut microbiota in health and disease.

33.3 WILSON, W.H.; Colby College; *whwilson@colby.edu*

Variation in life history of the amphipod Corophium volutator in the Bay of Fundy: effects of temperature and shorebird predation

The amphipod, *Corophium volutator*, is the primary prey for Semipalmated Sandpipers in the upper Bay of Fundy during fall migration. In the upper Bay, *Corophium* populations have two barely overlapping generations a year. The summer generation, born in May and reproducing in late August, provides the majority of the food for the sandpipers. Size−selective predation by the birds ameliorates inter−generational competition between the adults and juvenile *Corophium*. The preferential removal of large, post−reproductive *Corophium* by sandpipers can be viewed as resource management, increasing the probability that the juvenile *Corophium* released in August will overwinter to give rise to the next summer generation. In the lower Bay of Fundy, *Corophium* display a single generation each year with reproduction beginning in July. The lower Bay hosts few shorebirds during the fall migration. However, the lower Bay has significantly colder water than the upper Bay. The differences in *Corophium* life history within the Bay of Fundy could be explained by the warmer upper Bay of water temperatures promoting faster growth, permitting two generations a year. Alternatively, the sandpiper−*Corophium* interaction could be viewed as the result of coevolution between predator and prey. To tease apart these hypotheses, I documented the life history of *Corophium* along the central Maine coast at Lowes Cove, Walpole, ME. The water temperature at Lowes Cove is relatively warm, like upper Bay waters. Shorebird use at Lowes Cove and most intertidal mudflats in central Maine is sparse. *Corophium* at Lowes Cove display the two generations per year pattern seen in the upper Bay of Fundy, rejecting the hypothesis that shorebird predation drives the life history of *Corophium* in the upper Bay.

62.3 WILSON, J.K.*; WOODS, H.A.; University of Montana; *keatonwilson@me.com*

Tracking hosts: insect parasitoids use olfactory cues, are capable of learning and affect herbivore fitness and feeding

All animals have to find resources in their environments. For insect parasitoids, this problem is challenging because they must not only find food and mates but also suitable hosts. Like all animals, hosts emit olfactory cues into the environment. Additionally, because hosts are often herbivorous insects, the olfactory cues of the host plant can also be used parasitoids for tracking hosts. In many systems, it is unclear which (if any) type of olfactory cues parasitoids use, and whether or not scent use is a learned or innate behavior. Here, we examine a tri−trophic interaction between the broad−leafed desert perennial *Datura wrightii*, its main herbivore in southeastern Arizona (caterpillars of *Manduca sexta*), and two groups of parasitoids that attack *M. sexta* (wasps that are egg parasitoids and flies that are larval parasitoids). In both groups of parasitoids, we tested whether insects found their hosts using olfactory cues emitted by the host or olfactory cues emitted by the plant on which the host is feeding. We show that tachinid flies were attracted to olfactory cues generated by *M. sexta* frass (a combination of both host and plant olfactory cues), and that *Trichogramma* wasps preferentially moved towards *Datura* plants that were attacked by *M. sexta*. Furthermore, *Trichogramma* were capable of learning olfactory cues as adults. Finally, we show that parasitized caterpillars ate less, grew slower, and left the plant at lower body mass, indicating that parasitization benefits the plant.

P1.119 WILSON, RC*; BARRIGA−HERNANDEZ, J; EHLERS, HA; FRENCH, SS; DENARDO, DF; STRAND, CR; California State University San Luis Obispo, Alan Hancock Community College, Utah State University , Arizona State University ; *rwilson@calpoly.edu*

Effects of testosterone on spatial ecology and cortical brain regions in western fence lizards

The ability to navigate around an individual's habitat and is necessary for territoriality, mate choice, and acquisition of food resources. In many species, males exhibit superior spatial navigation abilities than females. This sexual dimorphism suggests this difference may be due to testosterone. Testosterone increases territorial behavior and home range size, thus, it may also affect the brain region associated with spatial memory. In reptiles, the medial and dorsal cortices are involved in spatial memory and these brain regions have been found to be larger in animals with larger territories. We hypothesize that testosterone affects home range size, cortical volumes, and neurogenesis in these brain regions. Western fence lizards were captured, marked, and castrated. Subjects were then implanted with either testosterone−filled or blank silastic capsules. After returning subjects to their initial capture site, individuals were located approximately ever other day to determine home range size. In addition, a control group not subjected to the surgical treatment was captured, marked, and re−sighted. After approximately a month, individuals were recaptured and sacrificed. Brain tissue was analyzed to determine volumes of cortical regions. Neither medial nor dorsal cortical volumes were affected by treatment. However, cortical volumes may be affected by home range size directly and it is possible testosterone treatment didn't affect home range size during this experiment. These results will help determine testosterone's role in not only regulating territorial behavior, but also in regulating growth of brain regions directly or indirectly by affecting territorial behaviors.

S1.1 WILSON, Alan M; The Royal Veterinary College; *awilson@rvc.ac.uk*

Optimal locomotion speeds in wild African carnivores during hunting and ranging.

We are interested in the factors that define how fast an animal choses to move when commuting and hunting particularly in free ranging wild animals in Southern Africa. We make these measurements using tracking collars of our own design containing high accuracy GPS and inertial sensors. It is a consistent observation across a range of species that, for an individual, the metabolic energy required to move a metre is fairly independent of speed of locomotion. When normalised for body mass the metabolic cost of transport (COT), is lower in larger animals. It has long been recognised that animals will usually choose to move at a preferred speed for each gait and that those speeds equate to the minimum metabolic cost of transport for that gait. The actual speed can be expressed in absolute terms or as dimensionless numbers to account for factors such as size or leg length. Whilst ranging may be undertaken at energetically optimum speeds and gaits, speed during coursing and hunting will be partially determined by the prey animal and the hunt strategy. At higher speeds other factors come into play and, for instance, cheetahs (*Acinonyx jubatus*) rarely gallop at their maximum speed when hunting, rather they move slower so they have greater manoeuvrability and they appear to trade off between using their superior high speed to get close to prey and slowing down to enable greater acceleration and turning to outmanoeuvre and capture their prey. African wild dogs (*Lycaon pictus*) do not use the very high turning forces or accelerations of cheetahs when capturing the same prey but appear to be successful through having the endurance to make many hunting attempts and sharing kills.

S1.8 WILSON, RS; The University of Queensland; *r.wilson@uq.edu.au*

Can we predict how fast animals will move in their environment?

The burgeoning field of movement ecology has taken up the challenge of integrating studies of organismal movement, offering a unifying paradigm for the causes, consequences, underlying mechanisms, and patterns of all movement−related phenomena. Movement ecology highlights the interplay among the external and internal factors affecting movement, including the internal state (why move?), motion (how to move?), and navigational decision−making (when and where to move?) of individuals. In my talk I will outline a framework that links each of these mechanistic tenets within the behavioural framework of speed choice. An animal's movement speed dramatically affects its probability of survival and reproductive success, and so has the potential to structure populations, communities, and ecosystems. Yet we understand little about why animals select the speeds they do in nature. My talk will discuss how internal state and the external environment interact to drive speed choice in animals, allowing ecologists to predict how environmental change affects behaviours as diverse as dispersal, foraging, migration, fighting, signalling, and predator escape, as well as the success of conservation schemes and the spread of invasive species or infectious diseases. A universal framework for predicting animal movement speed should be applicable to the movement of any animal across different ecological contexts. In fact, the most appropriate studies to−date are those focusing on the flying speed of migrating birds and speed selection by (human) drivers of motor vehicles, though both areas are limited in certain key aspects.

114.3 WILSTERMAN, K*; WILLIAMS, CT; BUCK, CL; Univ. of California, Berkeley, Univ. of Alaska, Anchorage; *kwilsterman@berkeley.edu*

Circulating levels of thyroid hormone reflect seasonal changes in activity of free−living arctic ground squirrels

Organisms fundamentally adjust their physiological state throughout their life−cycle and in response to predictable and unpredictable changes in their environment. Thyroid hormones (THs) play an important role in governing homeostatic processes in vertebrates through the control of gross metabolism and thermogenesis. Research suggests that TH concentrations reflect an individual's metabolic expenditure; animals expending greater energy exhibit higher levels of circulating THs presumably to facilitate increased metabolic output. Data explicitly demonstrating the relationship between activity and TH levels in free−living animals is relatively sparse though TH levels are directly related to resting metabolic rate. We quantified above−ground activity and measured seasonal changes in plasma total T4 (TT4) and total T3 (TT3) across the short (3−5 mo) active season of female arctic ground squirrels. TT3 and TT4 became increasingly correlated across the active season, showing significant correlation only during weaning and early fattening. Female plasma TT4 was highest in the early season, while plasma TT3 peaked during lactation. TT3 was correlated with average time spent above ground during lactation, while TT4 was correlated with time above−ground during weaning and early fattening. These results suggest that circulating THs modulate activity of individuals, supporting an ecological context for seasonal changes in an individual's physiological state. Integrating components of physiological state, such as hormone concentrations, and fine−scale information on activity provides insight into how free−living animals govern homeostatic processes across their annual cycle and in response to changes in environmental conditions.

22.4 WINTERS, G. C.*; KOHN, A. B. ; CROOK, R.; YOSHIDA, M. A. ; STERN, N.; HOCHNER, B. ; WALTERS, E. T. ; MOROZ, L.L.; Whitney Lab, Univ. Florida, Univ. of Texas− Houston, Hebrew University− Jerusalem, Univ. of Texas− Houston; *gwinters@ufl.edu*

Cephalopod Transcriptomes Unravel Details of Nervous System Evolution Across Molluscan Lineages

Cephalopod molluscs (*Nautilus, Loligo, Octopus, Sepia*) are powerful models for comparative biology and neuroscience. The complexity of their nervous systems ranges from simpler cords (*Nautilus*) to one of the most intricate brains of the animal kingdom in *Octopus*. Of all cephalopod innovations, the most extraordinary structure is the vertical lobe (VL), where we find cell circuits modulating the most advanced learning and memory in all invertebrates. This is an analog of hippocampus in mammals and a perfect example of convergent evolution. To examine this structure and its cellular components, we sequenced neuronal transcriptomes of key model cephalopods from the VL and from the surrounding circuitry. We compared these datasets to one another and to sequenced genome and transcriptomes of the gastropod mollusc, *Aplysia*. This approach has allowed us to identify conserved neuronal genes and numerous genomic innovations within molluscs. For example, we have identified in cephalopods approximately 50% all known *Aplysia* neuropeptides (NP) in addition to novel cephalopod−specific NPs. Of all identified cephalopod NPs, we have cloned and localized expression of 17 in *Octopus vulgaris*, and 13 in the squid *Loligo pealei*. Additionally, in our transcriptome data, we have identified in *Octopus* 16 NPs in the VL that may play a role in cell signaling during memory function, four of which have been validated by in−situ localization: FLRIamide, Bradykinin, Conopressin, and Buccalin. This comparative anatomical and genomic approach provides unique opportunities to reconstruct ancestral neuronal lineages, identify conserved cell types across species, and reveal trends in evolution within neural circuits.

P3.191 WISE, TB*; MCLAUGHLIN, CJ; STAYTON, CT; Bucknell University; *tbw005@bucknell.edu*

Morphological evolution of the turtle shell and its mechanical implications, part I: empirical

Evolutionary biologists have considered understanding the relationship between organismal morphology and functional performance to be fundamental for understanding phenotypic diversification. Numerous studies have investigated performance and morphological evolution within lineages. However, far less attention has been paid to the relationship between performance and morphological diversification among lineages. This study develops the turtle shell as a model system for studying morphological and performance diversification in a comparative context. In particular, this study focused on differences between aquatic and terrestrial turtle species. Original data consisted of 3D landmark coordinates of 1962 turtle shells representing 254 separate species. Turtle shell performance was assessed for numerous functions through finite element modelling of strength and the computation of various shell shape indices. Phylogenetic MANOVA or ANOVA was used to test for differences in shell shape and performance between aquatic and terrestrial turtle species. In general, shape showed strong phylogenetic signal throughout the turtle phylogeny. Similarly, performance measures also showed strong phylogenetic signal. Significant differences in performance, but not morphology, were found between aquatic and terrestrial shells. The shells of terrestrial turtles, though not all the same shape, are stronger, easier to overturn, produce more drag, and exchange heat more slowly, than those of aquatic species. This combination of functional distinctiveness without morphological distinctiveness suggested the operation of many−to−one mapping of shell form onto function, which was investigated in Part II of this study.

69.7 WITTMANN, AC*; CHANG, ES; MYKLES, DL; Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany; Colorado State University, Bodega Marine Laboratory, Univ. of California, Davis, Colorado State University; *Astrid.Wittmann@awi.de*

Thermal tolerance and molt cycle−dependent gene expression in juvenile Dungeness crabs

We hypothesize that the mTOR pathway and AMP−dependent protein kinase (AMPK) are involved in the regulation of the molt cycle in response to temperature in juvenile Dungeness crabs *Metacarcinus magister*. We used PCR cloning to obtain partial cDNA sequences of mTOR, Rheb, AKT, S6K and AMPK. We incubated crabs at 12 d, 18 d and 26 d postmolt at 5, 10, 15, 20, 25 and 30°C for up to 14 d to study survival and progression of the molt cycle. We quantified gene expression in the molting gland of AKT, upstream of mTOR, and S6K, downstream of mTOR, of the possible housekeeping gene RbS3, and of Na^+/K^+−ATPase in crabs that had been held at 10, 15 or 20°C. Survival was 97−100% at temperatures from 5−20°C, and was time−dependent, but 0% after 14 d at 25°C. All animals had died after 24 h at 30°C. Significant progression of the molt cycle was observed at 15 and 20°C, but not at 5 and 10°C. An overall two−way ANOVA indicated an effect of temperature on expression of all four genes, whereas only AKT, RbS3 and Na^+/K^+−ATPase were significantly affected by molt stage. The post hoc Tukey multiple comparisons test revealed significant effects of temperature at either 26 d, 32 d or at both time points, gene expression being significantly lower at 20°C compared to 10°C. Molt−stage specific effects were prominent at 20°C, with increased gene expression in premolt. We conclude that AKT, an activator of mTOR, may be involved in the regulation of the molt cycle in a temperature−dependent manner. Funding: EU FP7 Marie Sklodovska Curie International Outgoing Fellowship PIOF−GA−2012−326483 to ACW, NSF grant IOS−1257732 to DLM.

86.5 WOFFORD, S.J.*; MOORE, P.A.; Bowling Green State University; *sjwofford1@gmail.com*

What's smell got to do with it? How does blocking chemical communication affect assessment in crayfish (Orconectes rusticus)?

Animals must gather information from their environment to make efficient decisions that maximize fitness and minimize injury and energy use. These decisions (i.e. assessment strategies) are especially important in the context of fighting behavior. The assessment strategy used by a particular species is dependent upon the neural complexity of the organism as well as surrounding environmental factors. One such factor is the ability of opponents to communicate effectively through various cues or signals. Sensory pollution can degrade or negate any attempt at communication with conspecifics which can increase fight times due to the inability to accurately assess oneself or an opponent. Consequently, longer contests equate to greater energy expenditure and an increased chance of being consumed by a predator. This study examined whether alterations in chemical communication affected the assessment strategy used by crayfish (*Orconectes rusticus*) in one−on−one contests. Female crayfish were randomly assigned to a contest in one of three treatments: both opponents able to communicate, one opponent unable to communicate, or both opponents unable to communicate. Communication was blocked by applying Devcon ® 5 minute epoxy gel to the crayfish's nephropores, their primary mode of chemical communication. Trials were scored to determine fight dynamics as well as the type of assessment strategy used in each treatment. Results indicate that the blocking of chemical communication appears to alter decision making in crayfish contests.

P2.199 WOLFE, A. F.; Lebanon Valley College; *wolfe@lvc.edu*

A Histological and Electron Microscopic Study of the Hemopoetic Organs in the Brine Shrimp, Artemia franciscana

The hemopoetic organs of *Artemia franciscana* have been described by several workers. These nodules are found in each of the eleven pairs of swimming appendages. The clusters of these blood cells are surrounded by a thin membrane and are located among the musculature of the appendages. Hemocytes from these nodules are released into the hemocoel. Several researchers have suggested that hemocytes produced in these nodules are the source for replenishing the blood cells. Using routine histological, transmission and scanning electron microscopic techniques, this study attempted to demonstrate the division of the blood cells in the nodules in adult as well as in several younger stages of the animals. In this study few, if any, mitotic figures were evident in these animals. Even in those animals exposed to several concentrations of colchicine, mitosis of developing blood cells within the nodules was not especially evident. In addition to adult animals, immature *Artemia* with 2, 5, and 7 appendages showed minimal evidence of cell division. Within these nodules there are cells with a high nucleus to cytoplasmic ratio and very few cytoplasmic granules. The cells contain large quantities of RNA, and at the EM level a well−developed RER and Golgi apparatus. As these cells mature there is an increase in the number of cytoplasmic granules. Since there are large numbers of mature hemocytes circulating within the hemocoel of adult and immature animals, these blood cells must be produced during the very early stages of development or in response to some physiological challenge to the organism, such as molting or the invasion of foreign organisms.

P2.74 WOOD, M.N.*; BOYLES, J; WARNE, R; Southern Illinois University Carbondale; *mnwood13@siu.edu*

Physiological Acclimation of Peromyscus to Heat Stress

Climate change is one of the most pressing issues facing modern society, and understanding how organisms will respond is among the most complex challenges faced by biologists. Anthropogenic climate change is predicted to have a number of effects, but two obvious changes will be general increases in environmental temperature, and increased frequency of heat waves. While the common paradigm is that animal populations will shift their range in response to climate change, extreme heat waves and acute heat stress are causing unprecedented die−offs, suggesting that physiological plasticity in thermal tolerance may be fundamental to adaptation. Here we test the thermal tolerance mechanisms, constraints, and costs for a widely distributed endotherm to acclimate to thermal stress associated with climate change and heat waves. We exposed Peromyscus species to a variety of heat shock regimes and measured a suite of physiological responses including heat shock protein gene expression, neuroendocrine stress function, as well as immune function. To examine how these thermal tolerance traits are associated with thermoregulatory traits and performance trade−offs we also coupled telemetry monitoring of body temperature and flow−through respirometry for metabolic costs with muscle performance testing.

68.6 WOODLEY, S.K.*; MATTES, B.M.; YATES, E.K.; RELYEA, R.A.; Duquesne University, Pittsburgh, PA, Rensselaer Polytechnic Institute, Troy, NY; *woodleys@duq.edu*

Developmental phenotypic plasticity in brain architecture: effects of predator cues and pesticides.

Naturally−occurring environmental factors shape developmental trajectories to produce variable phenotypes, a phenomenon called developmental phenotypic plasticity. Developmental phenotypic plasticity has been demonstrated for numerous behavioral and morphological traits and can have important effects on fitness. Surprisingly few studies have examined phenotypic plasticity of the nervous system in response to naturally−occurring environmental variation experienced during development. Here, we asked whether the brain is developmentally plastic by exposing larval amphibians to natural and anthropogenic factors. Leopard frog tadpoles were exposed to predator cues, low food, or sublethal concentrations of the pesticide chlorpyrifos. Tadpoles in the experimental treatments grew more slowly than controls, although developmental rates and survival were similar. Brains from tadpoles exposed to predator cues and a low dose of chlorpyrifos were relatively narrower and shorter in several dimensions compared to those of control tadpoles and tadpoles with low food availability. Changes in brain morphology present in the tadpole stage were no longer present in metamorphs. Our results show that brain morphology is a developmentally plastic trait and it responds to both natural and anthropogenic forces. This is one of the first studies to show that exposure to sublethal concentrations of pesticide affects brain morphology.

P3.6 WOODLEY, SK*; TRUN, N; Duquesne University, Pittsburgh, PA; *woodleys@duq.edu*

Application−based service learning: testing a novel pedagogy in microbiology and physiology laboratory courses.

Traditional upper−level laboratory courses emphasize hands−on experience with discipline−specific concepts and techniques. In order to increase student learning and engagement in such courses, we developed and implemented a novel pedagogy called Application−Based Service Learning (ABSL) into our laboratory courses. ABSL incorporates the high−impact practices of novel research, writing intensive assignments, collaborative projects and service learning applied to a community−based, real−world problem. The microbiology laboratory course centered on the community problem of feral cats, with students conducting novel research on feral cat microbial populations and by assisting at spay and neuter clinics. The physiology laboratory course centered on the community issue of water quality. Students conducted novel research on the effects of water contamination on physiological responses in aquatic animal models. The service learning component involved conducting water−based science activities with children at an after−school tutoring program while at the same time improving outreach skills and developing a sense of civic engagement. Student learning outcomes achieved with ABSL will be presented and the opportunities and challenges of implementing ABSL in a science laboratory course will be discussed.

S8.3 WOOLLEY, C.S.; Northwestern University; *cwoolley@northwestern.edu*

Acute Estrogen Actions in the Hippocampus: Implications for Epilepsy

It has been known for decades that estrogens acutely potentiate neuronal excitability and synaptic transmission in the hippocampus, a brain region involved in learning and memory, affective behavior, and in epilepsy. By what cellular mechanisms do these effects occur and what is their physiological significance? First, I will briefly review in vitro electrophysiological studies showing that estrogens act through membrane−associated receptors to initiate intracellular signaling that regulates synaptic function on a time scale of minutes. Then, I will present evidence that estrogens are produced as neurosteroids in the hippocampus of rats and that neurosteroid estrogens play a role in seizures related to epilepsy. We have used in vivo microdialysis to show that estrogens are synthesized in the hippocampus during limbic seizures and that that seizure severity is related to levels of hippocampal estrogens. Consistent with the seizure−promoting effect of estrogens that is predicted by their acute synaptic effects, blocking estrogen synthesis in the hippocampus strongly suppresses seizures. Behavioral and EEG studies indicate that this occurs through dampening seizure activity in the hippocampus and inhibiting the generalization of seizure activity from limbic to extra−limbic brain regions. Together, these results suggest that acute treatment with an aromatase (estrogen synthase) inhibitor may be a novel anti−seizure treatment. Beyond the implications for epilepsy, these findings raise important questions for future study. For example, how prevalent are extra−nuclear, membrane−associated estrogen receptors in the brain and what proteins do they interact with to alter cellular function? How is neuronal activity coupled to estrogen synthesis in the brain, and does this differ across species? What other normal and pathological brain functions are regulated by neurosteroid estrogens?

29.1 WOSTL, E*; SMITH, EN; University of Arlington, Texas; *ewostl@uta.edu*

Phylogeography of Philautus (Anura: Rhacophoridae) of Java, Indonesia

The island of Java, Indonesia lies within the Sunda Shelf, one of the most biodiverse regions of earth. Currently, accurate estimates of alpha and beta diversity are lacking. This is exemplified by the frogs in the genus *Philautus*, which are small, polymorphic, and easily overlooked. They occur in isolated populations at high elevations in undisturbed habitat. These populations tend to be widely separated by expanses of inhospitable lowlands. In such a situation, one would expect high levels of diversity. However, excluding two invalid and one extinct species, just a single widespread species is thought to occur on the island. In other regions where they have been studied, *Philautus* has proven to be a highly diverse genus. It is likely that this will be the case on Java as well. Our preliminary results reveal considerable genetic variation between populations of *Philautus* on Java, suggesting higher levels of biodiversity than are currently recognized. We are building on this preliminary assessment by using the entire mitochondrial genome to further examine the diversity, distribution, and phylogeographic relationships of this group of frogs.

87.4 WRIGHT, RM*; MATZ, MV; The University of Texas at Austin; *rachelwright8@gmail.com*

Molecular determinants of susceptibility to bacterial infection in the coral Acropora millepora

The unpredictable nature of coral disease outbreaks suggests that differences in host susceptibility may be the major factor influencing disease dynamics. To test this hypothesis we challenged eight genotypes of *Acropora millepora* adults from two populations (Lizard Island and Wilkie Island) with bacteria (*Vibrio owensii* and *V. diazotrophicus*) and assessed mortality rates over a period of seven days with daily re−inoculations. There was a significant difference in mortality between genotypes as well as between populations. Global gene expression analysis revealed thousands of genes differentially expressed between genotypes. A weighted gene coexpression network analysis was used to isolate groups of co−regulated genes differentially expressed with respect to population, genotype, and bacteria−induced mortality. The co−expression modules correlating strongly with genotype as well as mortality will provide molecular markers to assess genetically determined disease susceptibility in natural coral populations.

P1.27 WRIGHT, J.E.*; KUMAR, A.; BURLEIGH, J.G.; BRAUN, E.L.; KIMBALL, R.T.; University of Florida, Gainesville; *jwright1855@ufl.edu*

Unexpected Olfactory Receptor Gene Numbers Revealed In Two Cathartid Species That Demonstrate Discrete Sensory System Reliance During Foraging

Olfactory receptors (ORs) are the largest multigene family in mammals. Among animals that have been examined, OR numbers vary widely, ranging from ~100−2000. The number of ORs in an animal's repertoire is often an indication of olfactory acuity, and percent of pseudogenized ORs are found to be high in mammals that have shifted to reliance on visual systems. Olfaction has been poorly studied in most bird groups. Chicken (*Gallus gallus*), that does not demonstrate reliance on olfaction, has ~500 OR genes. Black (*Coragyps atratus*) and turkey (*Cathartes aura*) vultures occupy the same habitat, yet demonstrate differing reliance on discrete sensory systems for foraging. Limited data indicate that black vultures do not use olfaction, but rather appear to be dependent on vision to locate food, while turkey vultures rely on olfaction, capable of foraging using smell alone. Turkey and black vultures present an opportunity to study the underlying genetic basis for reliance on olfaction in two related avian species. Additionally, investigation of the OR repertoires in these species will contribute to our knowledge of what evolutionary changes are necessary in order for animals to shift reliance on sensory systems. We found that turkey vultures have approximately three times as many OR genes compared to the chicken and our outgroup, the red−tailed hawk (*Buteo jamaicensis*). Surprisingly, black vultures have an intermediate number of OR genes between turkey vultures and red tailed hawks. These results suggest that black vultures may use olfaction more than currently thought. Our results also indicate that a large amount of OR duplication occurred after the divergence between vultures and hawks.

P3.193 WRIGHT, LK*; ZANI, PA; Univ. of Wisconsin, Stevens Point; *pzani@uwsp.edu*

Are differences in limb morphology of lizards among populations due to evolved or plastic responses?

Recent research has indicated that limb−dimension differences among lizards may or may not be the result of phenotypic plasticity. However, previous studies of plastic limb responses in lizards analyzed data at the level of the individual, possibly inflating degrees of freedom. We tested whether 12 populations of side−blotched lizards (*Uta stansburiana*) that differ in predation pressure and show differences in limb dimensions in the field exhibit phenotypic plasticity in the lab by rearing animals in a common−garden environment. At the end of their first growing season hind limb dimensions were measured on 181 lab−reared male lizards (avg. = 15 per site). Analyses including all individuals reveal that pes and (marginally) 4th toe lengths, as well as total hind limb lengths are positively correlated to total predator density, specifically to the density of other predatory lizards. This result is consistent with previous analyses on field−fresh animals and suggests that limb−dimensions differences among populations are the result of evolution. However, when limb dimensions were averaged for each population and data are analyzed in this more statistically conservative manner, the results indicate no differences among populations. This result contradicts our finding that limb−dimensions differences among populations are the result of evolution and instead supports the role of phenotypic plasticity. Thus, these results do not clearly indicate that limb−morphology differences among populations are due to evolved or plastic responses.

105.3 WRIGHT, S.C.*; NGUYEN, Q.; GERMAN, D.P.; University of California, Irvine; *scwright@uci.edu*

The Role of Diet Type on Gut Size and Function of Zebrafish

As the most species−rich group of vertebrates on the planet, fish consume nearly every possible food type, and therefore must be capable of digesting different foods. Most studies of fish feeding stop with dietary analyses, leaving knowledge gaps about digestion, but it is clear that fishes eating lower−quality foods (i.e. those low in protein and rich in fiber) have larger guts and elevated activities of carbohydrate−degrading enzymes than fishes eating higher−quality foods. The exact genetic underpinnings enabling a fish to "specialize" on a low−quality food remain unknown. The aim of this project is to observe how a fish evolves the ability to make a living on a low−quality diet. Through experimental evolution, we seek to understand how three different diets (high−protein, low−fiber; moderate−protein, moderate−fiber; and low−protein, high−fiber) play a role in the gut size and function of Danio rerio (zebrafish) at the individual level and across generations. Here, we used dissections, digestive enzyme assays, and histological techniques to evaluate the physiological and morphological changes of the digestive tract of the zebrafish in response to the experimental diets in the parental generation. Overall, the activity levels of amylase, lipase, trypsin, aminopeptidase, maltase, and N−acetyl−²−D−glucosaminidase were higher in the guts of the high−fiber diet fish, and the guts of these fish were longer than those in the fish fed the high−protein diets. However, there was a trade−off in fecundity, as the fish eating the high−fiber diet produced fewer offspring than those on the high−protein diets. Thus, zebrafish are clearly able to modulate gut structure and function in the short−term, but the future generations of our experimental lines will allow us to explore what it takes to become a specialist.

26.2 WRIGHT, M.L.; University of California Berkley; *wrightml@berkeley.edu*

Is social monogamy associated with a sedentary lifestyle in Lysiosquilloid stomatopods?

Although social monogamy, when a male and female live together for at least one breeding episode, is characteristic of several crustaceans, the evolutionary origins of this mating system are not well understood. I assessed two alternative hypotheses for the origin of social monogamy in Lysiosquilloid stomatopod crustaceans using comparative phylogenetic methods. Most stomatopod species are promiscuous or serially monogamous animals that leave burrows and cavities to actively hunt prey. In contrast, Lysiosquilloid stomatopods include eight genera that form socially monogamous pairs. Many Lysiosquilloid stomatopods are sit−and−wait predators that seldom leave their burrows. I examined the novel hypothesis that the Lysiosquilloidea may have evolved long−term social monogamy in association with other behavioral traits that facilitated a sedentary lifestyle, allowing stomatopods to escape high levels of predation. I also examined the hypothesis that fitness benefits conferred by biparental care selected for the origin of social monogamy in Lysiosquilloids. The associations between social monogamy, predation strategy, burrowing behavior, parental care, and habitat preference were examined on a ML tree of 66 stomatopod species. Burrowing, sit−and−wait predation, and social monogamy evolved sequentially in the Stomatopoda, supporting the predictions of the sedentary lifestyle hypothesis. This novel evolutionary route to social monogamy through sit−and−wait predation may be associated with the marine lagoons that many Lysiosquilloids inhabit. I also found evidence that biparental care evolved after long−term social monogamy. These findings emphasize the importance of considering a diversity of taxa and environments when studying the evolution of behavioral traits.

P2.33 WROBEL, ER*; WILCOXEN, TE; SRINIVASAN, S; HORN, DJ; SEITZ, J; NUZZO, J; Millikin University, Illinois Raptor Center; *ewrobel@millikin.edu*

Prevalence and health impacts of avian pox and conjunctivitis in songbirds and raptors.

Pathogens are known to have a strong influence on fitness of wild birds. A well−known dynamic of disease ecology is the link between increased population density and increased pathogen prevalence. While many songbirds gather at bird feeders in large densities, birds of prey tend to be more solitary, or at least far less gregarious. We used a population of free−living songbirds and raptors to assess pathogen prevalence among birds and to assess the physiological consequences of harboring the pathogens. We used both field identification of pathological symptoms and PCR techniques to test for the presence of two different pathogens that can have a serious impact on the overall health of birds: the pathogenic bacteria, *Mycoplasma gallisepticum* and *Mycoplasma synoviae* (causative agents of conjunctivitis) and *Avipoxvirus* (the causative agent of avian pox). To estimate the impact of these diseases on host health, we also examined immune and physiological profiles of each bird. Severe symptoms were seen far more commonly in feeder−using birds at study sites with bird feeders than in songbirds at sites without feeders and raptors. In addition, birds with any of these pathogens showed greater heterophil to lymphocyte ratios and lower total antioxidant capacity. Overall, this study reveals important disease dynamics and host responses in multiple avian species.

P2.148 WU, W*; WANG, L; SARKAR, O; VANETTEN, J; WIKRAMANAYAKE, AH; University of Miami; *wei@bio.miami.edu*

Identification and functional characterization of Dishevelled−interacting proteins in the micromeres of sea urchin embryos

Wnt signaling plays a central role in early metazoan development. A key cytoplasmic component mediating Wnt signaling is the Dishevelled (Dsh) protein. Dsh is considered to be the "hub" of the Wnt signaling pathway, but the mechanisms regulating Dsh "activation" during Wnt signaling remains one of the least understood steps in this pathway. Dsh is highly enriched in a specialized vegetal cortical domain (VCD) of the sea urchin egg and vegetal blastomeres of early embryos. In addition, we found that Dvl is differentially modified at the VCD and in 16−cell stage micromeres. Functional analysis has shown that Dsh activity is essential for the initial activation of canonical Wnt (cWnt) signaling in 16−cell stage micromeres. However, the molecular basis of Dsh asymmetric localization and its activation remain as outstanding questions in the field. Therefore, identification and functional studies of Dsh interacting proteins (DIPs) in 16−cell stage micromeres will advance our understanding of how Dsh is enriched, maintained and activated at the vegetal pole of the sea urchin embryo by its regulatory partners. To identify DIPs in the micromeres, Dsh Co−immunoprecipitation coupled with mass spectrometry was applied to pull down and sequence DIPs. DIPs were then functionally annotated by Blast2GO to determine the enriched gene ontology terms and signaling pathways. Potential DIPs were further characterized by RT−PCR and RNA in situ hybridization. Functional studies will be performed to determine roles of potential DIPs in regulating Dsh activity. This work will provide critical insight into the molecular basis underlying the asymmetric activation of cWnt signaling that leads to the specification of endomesoderm in sea urchins.

33.2 WULFF, J/L; Florida State University; *wulff@bio.fsu.edu*
Common sense and chemical defense
Sally Woodin bestowed on me a need to see a clear and direct connection between the methods employed in an ecological endeavor and the motivating questions. Mismatch between methods and motivating questions has become especially jarring in the study of chemical defenses of marine invertebrates. Controlled laboratory experiments, so readily accomplished with insects and their host plants, tend to fail with marine organisms and their predators, as confinement often results in death or unnatural behavior. This problem is particularly acute for tropical sponges, and thus a variety of techniques have been developed for learning about the effectiveness of their chemical defenses, including assays for toxicity and palatability, evaluation of gut contents, and video monitoring of sponges placed in unusual settings. Field observations, over the last 35 years, of consumption or rejection of Caribbean sponges by a variety of piscine and invertebrate predators provide perspective on interactions between sponges and spongivores; and clear indications of how to apply common sense in matching methods of investigation to the questions asked.

46.1 WYNEKEN, J*; LOLAVAR, A; TEZAK, B; Florida Atlantic University; *jwyneken@fau.edu*
A Longitudinal Field and Laboratory Study of Loggerhead Turtle Sex Determination
Many species of turtles and all marine turtles have environmentally determined sex. Temperature is considered to be the leading environmental factor directing embryos toward male or female phenotypes. This developmental process has lead many authors to conclude that marine turtles may be particularly extinction−prone because elevated environmental temperatures (a product of global warming) will skew sex ratios to extreme and unsustainable levels. We review these and other assumptions and discuss field and laboratory evidence suggesting that sea turtles are more resilient to climate change than previously thought. We sampled primary sex ratios from *in situ* sea turtle nests at a major Florida rookery under typical and more extreme climatic conditions over 10 nesting seasons to examine predicted effects of increasing temperature on nest sex ratios. Sex was verified using gonad and gonadal duct morphology. Hatchling samples from *in situ* nests were 100% female when weather conditions were hotter and drier than normal. Eggs that incubated in hot but wet years produced mixed sex samples, including samples that were strongly male− or strongly female−biased. Experimental clutches reared under moist laboratory conditions at temperatures predicted to produce female−biased sex ratios instead produced ~ 90% males. Together these results suggest a potential source of resiliency due to an unappreciated variable (moisture) that modified the response to temperature. These findings cause us to question the generally accepted assumption that changes in temperature, alone, will have a negative impact on sex ratios.

8.6 YAHN, J/M; Univ. of Wisconsin, Madison; *jyahn@wisc.edu*
Effects of rearing temperature and polybrominated diphenyl ether (PBDE) on growth and metabolism of leopard frog (Lithobates pipiens) tadpoles
In a 2X2 design, we raised tadpoles from embryos at either 22 or 27 oC on a control diet, and then at day 17 post−hatch (approx. Gosner stage (GS) 27) we began feeding them food either with or without a commercial mix of PBDE congeners (DE−71; 100 ng/g wet food). Tadpoles developed (increased in GS) and grew (increased in mass) slower at cooler temperature and in the presence of PBDE. PBDE also changed the relation between mass and GS, which was linear (from GS 30 − 37) with no significant difference of temperature in the control animals but with a significant difference of temperature in tadpoles fed PBDE. We tested whether slower growth in tadpoles fed PBDE might be due to an effect of PBDE on resting metabolic rate (RMR), measured as O2 consumption. Between GS 30−40 (masses approx. 1 to 6.6 g, n=35 tadpoles), whole tadpole ln(RMR) linearly increased with ln(mass) ($P<0.001$) and with temperature ($P=0.001$) but there was no significant effect of PBDE exposure on mass−corrected RMR ($P>0.7$). The slope of ln(RMR) on ln(mass) was significantly steeper for tadpoles raised at 22C (0.50 +/− 0.04) than at 27 C (0.22 +/− 0.07) ($P < 0.001$). We conclude that slower growth and development in tadpoles exposed to PBDE is not due to proportionally greater allocation of ingested energy to respiration, but more likely to lower feeding or digestion rate. The relatively low scaling of ln(RMR) on ln(mass) (slopes <<3/4) may relate to relatively higher respiratory costs of growth at smaller masses. The data on respiration and production at different temperatures can be used to improve predictions on effects of warming climate on tadpole energetics. Funding provided by Sea Grant College Program, NOAA (Grant no. NA10OAR4170070, Project R/HCE−14).

106.4 YAMATO, M.*; PYENSON, N.D.; Smithsonian Institution, National Museum of Natural History; *yamatom@si.edu*
Unique acoustic funnel into the cetacean ear links evolution and ontogeny in the origin of underwater hearing
Whales and dolphins receive underwater sounds through a completely different mechanism than terrestrial mammals. Instead of hearing through the ear canal and the tympanic membrane, cetaceans hear through specialized fatty tissues leading to an acoustic funnel located just anterior to the tympanic aperture and the vestigial ear canal. We used X−ray computed tomography to trace the ontogenetic development of this unique feature in 57 fetal cetacean specimens from 10 different families of toothed (odontocete) and baleen (mysticete) whales, showing that the acoustic funnel arises from a V−shaped structure formed by the malleus and the goniale. This V−shaped acoustic funnel is one of the first features to develop in the ears and is a relatively well−ossified, prominent, and persistent feature of all early fetal cetaceans. Interestingly, in the echolocating odontocetes, the acoustic funnel develops into a cone−shaped feature facing anteriorly, directly into the intramandibular acoustic fats, which is likely related to their forwardly oriented, highly directional receiving beam. In contrast, the acoustic funnel of balaenopterid mysticetes rotates laterally later in fetal development, which is consistent with a recently hypothesized lateral sound reception pathway. Balaenid mysticetes and several fossil mysticete species retain a somewhat forwardly oriented acoustic funnel in the mature condition, indicating that the lateral sound reception pathway of balaenopterid mysticetes may be a later development both in the ontogenetic and evolutionary history of cetaceans.

93.8 YANAGITSURU, Y R*; GALLO, N D; TRESGUERRES, M; Scripps Institution of Oceanography; *yuzo.yanagitsuru@gmail.com*

Cellular Physiological Asymmetries Between the Blind and Ocular Side Gills of Marine Flatfish

Flatfishes likely experience a different chemical environment on each side of their bodies due to their lifestyle of lying on the sediment. However, there have been no studies on potential adaptations flatfishes have to cope with this asymmetry. Since gills are essential for regulating the effects of environmental stressors such as pH regulation in fishes, we quantified the relative protein abundance between the gills facing the water column (ocular side gills) and those facing the sediment (blind side gills) of the marine flatfish: slender sole (*Lyopsetta exilis*). Using Western blot, we quantified the relative abundance of sodium potassium ATPase (NKA), vacuolar proton pump (VHA), and carbonic anhydrase (CA) between the ocular and blind side gills. We found that NKA does not differ between the two sides; however, VHA and CA are 103±30% and 80±40% more abundant on the ocular side compared to the blind side gills, respectively. VHA appears to be localized on the apical membrane of ocular side gills, based on immunohistochemical analysis. Taken together, these results suggest that slender soles preferentially mediate ammonia excretion or acid secretion using their ocular side gills. Our study found, for the first time, an asymmetry in cellular physiology between the two sides of gills in a fish and lays the groundwork to better understand marine flatfish gill physiology.

P1.97 YANAGITSURU, Y R*; HASTINGS, P A; Scripps Institution of Oceanography; *yuzo.yanagitsuru@gmail.com*

Synchronous Air−Breathing in Polypterus (Actinopterygii)

Several aquatic air−breathing species of vertebrates exhibit synchronous air−breathing behavior, whereby individuals in a group breathe air in unison. This behavior likely reduces predation of individuals in a manner analogous to fish schooling. Anecdotal evidence from the early 1900s suggests that bichirs of the genus *Polypterus* also exhibit synchronous air−breathing behavior. However, there have been no studies confirming these observations. We video recorded a captive group of 10 *Polypterus* consisting of five individuals each of two species (*P. senegalus* and *P. endlicheri*) and analyzed the temporal frequency of air−breaths taken by the group under two conditions: undisturbed and disturbed by a stimulus mimicking a bird flying overhead. We found that undisturbed *Polypterus* exhibited a weakly uniform air−breathing behavior. However, disturbed *Polypterus* exhibited synchronous air−breathing. Our study confirms the observations of *Polypterus* synchronous air−breathing made in the early 1900s. Additionally we found, for the first time, synchronous air−breathing between two different species.

112.1 YANG, P*; DAO, D; LEHNER, R; HU, D; Georgia Institute of Technology; *peijyang@gatech.edu*

The Hydrodynamics of Defecation

According to the U.S. Department of Health and Human Services, digestive disease affects 60 to 70 million people and costs over 140 billion annually. Despite the significance of the gastrointestinal tract to hu− man health, the physics of both digestion and defecation remain poorly understood. In this combined experimental and theoretical study, we investigate the defecation of mammals, from mice to elephants. We film defecation events at Zoo Atlanta and apply plate−on−plate rheometry to measure the viscosity of mammalian feces. Among animals heavier than 3 kg, we find herbivores defecate for only 10 seconds (N = 13), while carnivores do so for 19 seconds (N = 8). We rationalize this surprising trend on the basis of the higher viscosity of carnivore feces. We compare defecation times to theoretical predictions based on a Poiseuille flow model of the rectum and parallel experiments with a synthetic defecator that extrudes pizza dough upon applied pressure. Our findings may help to diagnose digestive problems in animals.

P2.141 YANG, J*; AMATO, CA; BOYD, ML; MCCOY, KA; East Carolina University; *yangj11@students.ecu.edu*

Variation in Hypospadias Severity Across Time and Dose

Hypospadias occurs when the urethra does not exit at the tip of the penis, but along the ventral shaft. Incidence of hypospadias has increased 400% in the past 40 years, and is thought to be due to fetal exposure to endocrine disrupting chemicals (EDCs). Although model EDCs such as vinclozolin (V), a fungicide, are used to investigate the developmental processes causing hypospadias, we do not understand the molecular mechanisms driving variation in hypospadias severity. A first step toward understanding how variation in gene expression relates to variation in hypospadias severity requires that we can experimentally induce differences in hypospadias severity. To characterize variation induced by V, we conducted dose−response experiments at two overlapping developmental windows (DW). In the first DW, 12 pregnant dams were gavaged with either 0 (corn oil control), 100, 125, and 150 (mg/kg) of V on embryonic (E) days 14.5−16.5. In the second DW 12 pregnant dams were assigned to the same V dosage groups but were exposed on E 13.5−16.5. Genitalia of all pups were collected at E 18.5 and prepared for histology. To test the hypothesis that V induces variation in hypospadias severity across doses and exposure times, genitalia were cross sectioned at 10 mm, tubercle length, urethral length (UL) were measured and the morphology of the proximal urethra opening was characterized. Severity of hypospadias increased with increasing V exposure, but the first DW induced a shallower dose response than the second DW. Our data shows that to induce variance in hypospadias severity, timing and dose is critical. Exposure during E13.5 is important in genitalia development, and should be included in studies that attempt to understand the genetic mechanisms driving differences in hypospadias severity.

58.1 YANG, J.*; LIEN, E.; ELSEY, R.M.; OWERKOWICZ, T.; Department of Biology, California State University, San Bernardino, Saban Research Institute, Children's Hospital Los Angeles and Department of Surgery, University of Southern California, Rockerfeller Wildlife Refuge, Louisiana Department of Wildlife And Fisheries; *j.yang460@gmail.com*

Cardiac Regenerative Capacity of Alligator mississippiensis

Teleost fish and urodele amphibians are able to fully regenerate lost or damaged cardiomyocytes even as adults. Some mammal species (e.g., neonatal mice) appear to be able to regenerate the myocardium, whereas others (e.g., humans) are incapable of repair and regeneration. Whether this regenerative capacity exists in other vertebrate clades has not yet been described. In order to determine whether "reptiles" (non−avian sauropsids) have the capacity to regenerate cardiac tissue following injury, we developed experimental models similar to those used in zebrafish and mice ventricular resection and cryoinjury and tested them in the American alligator (*Alligator mississippiensis*). The alligator, with its four−chambered heart, and independent systemic and pulmonary pressure generation, can be a useful model in studies of cardiac regeneration. Hatchling alligators were injured or sham−operated, allowed to recover, and kept for up to four months. There is indication of significant increase in proliferation of cardiomyocytes in and around the wound area of injured hearts 14 days post−injury (dpi). However, by 60 dpi, a collagen−rich scar persists and assumes trabeculated morphology more similar to that seen in zebrafish. This suggests that regenerative capacity may not be present in crocodilia. Similar studies on more taxa are needed in order to elucidate evolutionary patterns with regard to regenerative capacity among vertebrate clades.

14.4 YAO, L.*; MARTIN, R.D.; University of Chicago, Chicago, The Field Museum, Chicago; *luyaozers@uchicago.edu*

Island dwarfing and cranial morphology in Southeast Asian mammals

The island rule states that large−bodied mammals generally undergo reduction in body size on islands (especially small ones) mostly due to resource limitation. But evolution of cranial morphology accompanying change in body size is poorly understood. Using 3D landmark data we analyzed cranial shape variation in three large−bodied taxa from Southeast Asia: 125 individuals from 11 gibbon species (family Hylobatidae), 64 individual longtailed macaques (*Macaca fascicularis*), and 32 individuals from six pig species (family Suidae). 75 landmarks were defined for the skull and 35 landmarks for the mandible. Sex, species, island type and island size were all taken into consideration. Size explains a large percentage of total variance in all three taxa (larger individuals have more cranial area for muscle attachment and more robust mandibles), indicating that functional aspects, such as diet, may be important in determining cranial shape on islands. However, comparison between islands faces the neglected problem of phylogenetic inertia within species. In a novel approach, intraspecific phylogenetic relationships have been determined and taken into account in analyzing the geometric morphometric data.

83.3 YAO, Z.*; GROSELL, M.; HEUER, R.M.; RUHR, I.; SCHAUER, K.; RSMAS, University of Miami East China Sea Fisheries Research Institute,CAFS, RSMAS, University of Miami; *zyao@rsmas.miami.edu*

Acid−base compensation in marine fish gill during osmoregulation

It is well known that marine fish must drink seawater to compensate for continual water loss caused by their dehydrating environment. Intestinal water absorption is linked to substantial intestinal base excretion. Previous research has shown that fish transferred to hypersalinity experience a perturbation in acid−base balance. The gill may play an important role in compensating for the increased intestinal base loss that occurs during hypersalinity exposure. To test this hypothesis, Gulf toadfish were exposed to hypersalinity (60ppt), which is known to increase intestinal HCO_3^- excretion. Exposure to 60ppt seawater resulted in an immediate metabolic acidosis with a significant decrease in blood pH and HCO_3^-, followed by a recovery of blood pH by a decrease in pCO_2 and an increase in HCO_3^-. A similar metabolic acidosis and recovery were found when fish were exposed to 60ppt HCO_3^- free seawater (HEPES buffered). These results suggest that compensation for intestinal base loss during hypersalinity is from gill H^+ excretion rather than from gill HCO_3^- uptake from seawater. This increased H^+ excretion may be regulated by relocation of the V−H^+−ATPase and/or increased abundance of NHE2 and/or NHE3. The immunolocalization of V−H^+−ATPase as well as, gene expression of NHE2 and NHE3 in the branchial epithelium is currently being investigated.

11.5 YAP, KN*; WILLIAMS, TD; Simon Fraser University; *knyap@sfu.ca*

Individual variation in workload, metabolic rate and hematology in zebra finches, Taeniopygia guttata

Animals often engage in specific behaviours, or have specific life−history stages, that impose substantial metabolic demands often for prolonged periods of time, e.g. during migration, reproduction and foraging. It seems intuitive that to be able to cope with these elevated metabolic demands, efficient oxygen transport and high aerobic capacity are essential, and that some individuals will be more physiologically adapted to meet these demands than others. Here we focused on the role of hematocrit (Hct) and hemoglobin (Hb), key determinants of oxygen−carrying capacity; specifically we investigated individual variation in, and relationships between, hematology, metabolic rate and aerobic capacity in relation to workload in zebra finches, *Taeniopygia guttata*. First, we measured basal metabolic rate (BMR), Hct and Hb in 16 males and 16 females. Then we subjected half of the subjects to high foraging cost condition (HF) and the other subjects to control forging condition (CTR). As soon as the birds adapted to the HF condition, we again blood sampled all birds and measured BMR. Initial analysis showed that although birds subjected to HF condition experienced higher workload and spent more time foraging (based on behavioural observation), their Hct and Hb did not differ from either baseline values or birds housed in CTR condition. We speculated that the uncoupled relationship between hematology and workload could be due to a lag between increased workload and physiological changes. We plan to measure BMR, Hct and Hb in all birds again at 60 days post−manipulation, after birds are housed in HF condition for an extended period of time, to determine if there is longer−term physiological adaptation associated with increased workload.

72.4 YEATON, IJ*; SOCHA, JJ; ROSS, SD; Virginia Tech; *iyeaton@vt.edu*

A generalized dynamical framework for non−equilibrium gliding in animals

Gliding has evolved numerous times in different lineages of animals, from lizards, squirrels, and frogs, to more unexpected species like ants and snakes. All gliders convert potential energy to kinetic energy, but there seems to be little commonality in the body plans and force−producing structures across all gliders. This makes identification of salient glide parameters and interspecies comparison difficult. Here we aim to discover a common dynamical framework for gliding in order to answer the question, what role does equilibrium play for animal gliders? We construct a reduced−order model of gliding that captures the large−scale features of the motion seen in a velocity−polar diagram, using force coefficients and launch velocities from experimental glide data as model inputs. By non−dimensionalizing the equations of motion, we find a common set of equations that we analyze via a dynamical systems approach. We look for equilibrium points, their stability, and other phase space structures that affect glide dynamics. For our analysis, we compare theory to experimental data from flying snakes (*Chrysopelea*) and northern flying squirrels (*Glaucomys*). The model shows that different gliding modes are possible in the velocity−polar space, even though the glide paths look similar in both theory and experiments. We attribute this to intricacies in the lift and drag curves and how pitch affects equilibrium glide angles. This suggests that natural gliders have more velocity−space complexity than shown in previous studies. This research was partially supported by NSF 1351322 to JJS, NSF 1150456 to SDR, and an NSF IGERT training grant (0966125) for IJY.

P2.43 YEE, S.*; QUINDE, J; BAYNHAM, H; MORANTE, K; MONHART, M; CHAVEZ, A; MAUCH, E; TEMKIN, M; HECKMAN, K; FATEYE, B; SCHREIBER, A; St. Lawrence University, NY; *aschreiber@stlawu.edu*

Effects of thyroid hormone and dexamethasone on thymocyte cell death and proliferation in Xenopus laevis tadpoles

Metamorphosis in anurans is accompanied by a dramatic loss of larval thymocytes as a new adult antibody repertoire is formed. Rising levels of glucocorticoids during metamorphosis have been shown to inhibit lymphocyte proliferation and induce thymus lymphocyte cell death. We have previously shown that treatment of tadpoles with exogenous thyroid hormone (T3, 5 nM) and the cortisol analog, dexamethasone (DEX, 2 uM), each separately induce thymus involution and apoptosis, and together exhibit a synergistic effect that accelerates these processes. To determine if each hormone affects the thymus directly, we cultured Nieuwkoop−Faber (NF) stage 54 thymus gland explants in the presence of either hormone. After 3 days of culture with DEX or T3, thymus gland surface areas decreased by 22% and 12% respectively (compared with no change in controls), indicating that each hormone affects the thymus directly. Using antibodies against epithelial−cadherin, active caspase−3 and phosphohistone−H3, we mapped thymus epithelial tissue, cell death, and proliferation (respectively) in thymus gland sections from NF54 tadpoles treated with either T3 or DEX. Proliferating cells were still present following T3 treatment, but completely absent following DEX treatment. Cell death and proliferation (when present) appeared to be confined to non−epithelial tissue (most likely T−cells). Our findings suggest that thymocyte cell death is induced directly by both T3 and DEX. In contrast, thymocyte proliferation is completely inhibited by DEX, but not by T3. We hypothesize that during natural metamorphosis thyroid hormones (TH) and glucocorticoids work synergistically to induce larval thymocyte apoptosis, and that TH simultaneously induces adult thymocyte proliferation.

S12.6 YEN, J.*; MURPHY, D.W.; WEBSTER, D.R.; Georgia Tech, Johns Hopkins ; *jeannette.yen@biology.gatech.edu*

Copepod escape from suction feeding fish

Copepods escape very well. As a key link in the aquatic food web, these small planktonic organisms often encounter suction feeding fish. Studies have identified certain hydrodynamic features that are created by the approach of this visual predator and the generation of its suction flow for food capture. Studies have identified certain hydrodynamic features evoke the evasive response of copepods. Analyses of the reaction time, threshold sensitivity, sensor design, and evasive behavior by this key prey of fish can be useful to evaluate the effectiveness of the suction flow−based feeding tactics. How does the extent of the fish flow field relate to the escape distance of the copepod? What is the importance of sensor orientation and signal structure? How do copepods accurately detect a predator and appropriately respond with a directed escape response? This review aggregates this information to increase our understanding of the fish predation− prey evasion interaction.

P1.146.5 YOON, T.H; KANG, H.E*; KIM, K.R; LEE, J.H; KIM, H.W; Pukyong National University; *bluemarine64@pknu.ac.kr*

Molecular characterization of Myostatin−like gene from abalone, Haliotis discus hannai

Myostatin (MSTN), also known as growth and differentiation factor 8 (GDF−8), and growth differentiation factor 11 (GDF11) are thought to have generated as result of gene duplication from an ancestral gene. In vertebrate, MSTN is expressed primarily in skeletal muscle inhibiting muscle differentiation and growth and GDF 11 is involved in development of the axial skeleton. In this study, cDNA sequence encoding a homolog of GDF8 and GDF11 (Had−MSTN/GDF 11) was isolated from abalone, *Haliotis discus hannai*. Its 2,605 bp sequence harbors an ORF (1,356 bp) encoding a protein with 451 amino acid residues. Amino acid sequence similarity analysis showed that Had−MSTN/GDF 11 exhibits the highest similarity to MSTN from *Mytilus chilensis* and it showed typical primary structure including a conserved RXXR proteolytic cleavage site and nine cysteine residues in the C−terminus. Although major production sites for Had−MSTN/GDF 11 were heart, its expression was also detected in other tissues including foot muscle, adductor muscle and hepatopancreas. Knockdown experiment of Had−MSTN/GDF gene by the injection of long dsRNA demonstrated that MSTN−like gene is important role in regulation of muscular growth and development.

107.7 YORK, C.A. *; BARTOL, I.K. ; Old Dominion University, Norfolk VA, Old Dominion University, Norfolk VA ; *csind001@odu.edu*

The role of the lateral line analogue and vision in predator evasion for brief squid Lolliguncula brevis

Squid have visual and mechanoreception systems that may be employed to sense and respond to an approaching predator. While vision plays a dominant role, the importance of the lateral line analogue for predator evasion has not been examined in squid. To test the respective roles of vision and the lateral line analogue, brief squid *Lolliguncula brevis* were observed in the presence of summer flounder *Paralichthys dentatus* under light and dark conditions with their lateral line analogue intact and ablated. Lateral line ablation was achieved through a pharmacological technique used for the first time on a cephalopod. Proportion of predator−prey interactions survived was significantly higher in the light non−ablated and light ablated groups compared to the dark ablated group. The mean number of interactions survived varied across treatment groups with the light non−ablated group having significantly more success than the light ablated, dark non−ablated and dark ablated groups. The results of this study demonstrate that the lateral line analogue contributes to predator evasion in squid.

S5.8 YOSHIDA, M.A.*; OGURA, A.; IKEO, K; KOHN, A.B.; WINTERS, G.; MOROZ, L.L.; Univ. of Florida, Whitney lab., Nagahama Inst. of Bio−Sci. and Tech., National Inst. of Genetics; *myoshida0215@gmail.com*

Convergent evolution of brains, eyes and vasculatures in cephalopod molluscs

Coleoid cephalopods (squids or octopuses), these primates of the seas, have been viewed as remarkable illustrations of independent origins of complex neural and sensory structures as well as highly centralized brains in invertebrates. Here, we will discuss three examples of convergent evolution of the neural organization: (i) Cephalopod eyes and visual system including optic lobes; (ii) Specialized parts of the brain controlling learning and memory such as vertical lobes (considered to be analogs of mammalian hippocampus); and (iii) Unique cephalopod vasculature to support such brain complexity. We performed deep sequencing of genomes and transcriptomes form five cephalopod species including *Nautilus* to decipher molecular bases of these critical examples of convergent evolution in a broad sense. In addition to comparative RNA−seq analysis across species, we also explored the dynamics of gene expression in the development of both *Nautilus* and squids. The data from *Nautilus* are most essential. Indeed, *Nautilus* has a simpler cord−like neuronal organization resembling a basic molluscan tetraneury and its embryos are amongst the most elusive in the animal kingdom. By combining phylogenomics, comparative transcriptomics and in situ hybridization approaches on representatives of several molluscan species, we will discuss the use of various molecular markers to trace both cephalopod neuronal innovations and possible homologous cell lineages within molluscs. We will also outline gene regulatory changes associated to lens and vascular development and briefly review our efforts to identify cephalopod novelties.

P3.44 YOST, J.T.*; BALTZLEY, M.J.; Western Oregon University; *jyost11@wou.edu*

Identification of GABA producing cells in the nervous system of Hirudo verbena

In the leech Hirudo verbana, each segmental ganglion has four pressure mechanosensory neurons (P cells) that innervate overlapping quadrants of the body wall. The excitation of one P cell by mechanical stimulation of the skin results in the inhibition of the other P cells within the body segment. The synaptic connections between P cells are not fully understood, but it has been hypothesized that the excited P cell stimulates an interneuron which in turn releases the neurotransmitter GABA at synapses with the other P cells. To test this hypothesis, it is necessary to first identify the GABA−producing cells in the leech nervous system. Using immunohistochemistry, we have identified three bilaterally symmetrical pairs of GABA−producing neurons in the midbody ganglia: one pair is located on the ventral surface of the anterior end of the ganglion, and the other two pairs are located on the dorsal surface of the anterior end. Our next step is to use intracellular electrophysiological recordings followed by dye injections to characterize and identify these three pairs of GABA−producing neurons. Once the neurons are identified, we will examine whether or not they have synaptic connections with the P cells.

P3.85 YOUNG, CM*; SALAZAR, TR; PASTOR, MJ; NARANJO, SM; GUNES, N; CAKMAK, I; HRANITZ, JM; Muhlenberg College, University of Chicago, San Francisco State University, University of Central Florida, Uluda University, Bursa, TURKEY, Bloomsburg University; *chelsea.young33@yahoo.com*

The effects of acetamiprid on the motor coordination and sucrose sensitivity of the honey bee, Apis mellifera

Neonicotinoid insecticides are used in worldwide commercial farming to control pests and have recently garnered attention for their potentially adverse effects on honey bees. While the relative doses of pesticides encountered in agriculture are typically below the designated LD50, assessment of the sublethal effects could reveal detrimental effects to honey bee foraging behavior. Acetamiprid, a known neonicotinoid pesticide used in farming, acts as a neurological agonist to acetylcholine with a high affinity to nicotinic acetylcholine receptors in invertebrates. Therefore, we expected sublethal doses of acetamiprid to result in impaired motor coordination and central nervous system (CNS) processing. For a comprehensive analysis of the physiological effects of acetamiprid at sublethal doses on honey bees, we tested the motor coordination and sucrose sensitivity of the honey bee. Captured bees were restrained and fed 10 uL of a designated acetamiprid solution in 1.5 M sucrose, with treatment doses ranging from 1/5 to 1/1000 of the LD50. Control treatments were fed 10uL of the 1.5 M sucrose stock solution. Subsequent tests for motor coordination and sucrose sensitivity were performed 4 hours after ingestion, with motor coordination tests assessing the proboscis extension reflex (PER), abdomen movement, leg movement, and wing movement. Bees did not differ in motor coordination and sucrose sensitivity among doses. These results show that acetamiprid, even at the most concentrated sublethal dose tested, had no significant effect on physiological and neurological characteristics fundamental to honey bee foraging behavior.

4.6 YOUNG, V.KH.*; BLOB, R.W.; Clemson University; *vkhilli@clemson.edu*

Humeral loads during swimming and walking in turtles: implications for the evolution of limb bone shape changes during reinvasions of water from land

In many vertebrate lineages that have reinvaded aquatic habitats, major morphological changes have evolved in the forelimb, including shifts from tubular limbs to elongate flippers. In contrast, changes to the hind limb have often involved limb reduction as well as flattening. How might changes in limb loading between environments have facilitated such changes? *In vivo* strain data from the hind limbs of semi−aquatic turtles have indicated that femoral strain magnitudes in water were only one fourth of those on land, and that torsion was particularly reduced during swimming. Given the retention of prominent forelimbs in most secondarily aquatic species, we predicted smaller differences between loads in water and on land for the forelimb, and tested this prediction by comparing strains on the humerus of a semi−aquatic turtle species (*Pseudemys concinna*) during aquatic swimming and terrestrial walking. In contrast to these predictions, aquatic bending strains on the humerus show a similar reduction, to levels roughly one fourth of those on the femur. Shear strains are also lower in water for the humerus; however, unlike the femur, this appears to relate to a reduction in overall strain magnitudes, rather than a reduction in limb twisting and the orientation of loads. These results indicate that similar changes in loading may occur between the forelimb and hind limb in swimming versus walking, but that they may occur through different mechanisms that relate to differences in the functional roles of these structures.

88.4 YOUNG, J. W.*; FOSTER, A. D.; THAKORE, A.; SMITH, G. A.; BUTCHER, M. T.; NEOMED, Kent State University at Stark, Youngstown State University; *jwyoung@neomed.edu*

Ontogeny of hind limb bone safety factors in eastern cottontail rabbits (Sylvilagus floridanus)

Decades of comparative research have established that across adult eutherian mammals, peak loads during locomotion rarely reach above 25−50% of bone structural capacity, maintaining safety factors (peak strength/peak locomotor stress) between 2 and 4. In contrast, existing data suggest that safety factors are not maintained during growth, but rather decline with age. As such, juvenile mammals are relatively "overbuilt", permitting them to exhibit adult−like levels of locomotor performance with reduced risk of skeletal injury. Here, we expand this dataset by examining the ontogeny of hind limb bone safety factors in Eastern cottontail rabbits (*Sylvilagus floridanus*). We used a combination of in vivo locomotor performance testing, free−body modeling, and in vitro material properties data to characterize ontogenetic changes in locomotor loading, long bone strength, and safety factor in *S. floridanus*. Peak long bone stresses during high−speed locomotion scaled to body mass with isometry (femur: $M^{0.385\pm0.246}$; tibia: $M^{0.261\pm0.150}$). Because the maximum bending strength of the femur and tibia similarly scaled with isometry (femur: $M^{0.307\pm0.132}$; tibia: $M^{0.307\pm0.307}$), safety factor was maintained between 2.5 and 2.6 in the femur and between 3.1 and 3.3 in the tibia across an order of magnitude in body size growth (106−1,277g range in body mass). Though our findings contrast with previous studies of mammalian long bone growth, rabbits are smaller than most previously studied taxa and have relatively reduced home ranges, perhaps mitigating the need for increased safety factors early in life. Supported by NSF IOS−1146916.

78.4 YOUNGQUIST, M.B.*; BOONE, M.D.; Miami University; *youngqmb@miamioh.edu*

Effects of habitat suitability and landscape connectivity on species distributions

The underlying mechanisms of what determines a species' range is a fundamental question in ecology and has garnered much attention due to the biodiversity crisis. The majority of species distribution models have focused on gradients in habitat suitability. However, due to dispersal limitation and landscape configuration (collectively called landscape connectivity), individuals often do not occupy all patches of suitable habitat. Using cricket frogs (*Acris blanchardi*) as a model system, we tested the hypothesis that gradients in habitat suitability and landscape connectivity interact to determine a species' realized distribution. We used a combination of species surveys, species distribution models (SDM using MaxEnt), and landscape connectivity models to address this hypothesis. Our SDM indicates that habitat suitability was influenced by annual mean temperature and land cover. Using call surveys, we found that cricket frogs have a patchy distribution, which can be explained by habitat suitability, in the interior of their range. However, at the edge of the range other factors become important. In the face of rapid ecological changes, it is imperative that methods are developed to assess the status and management species at large geographic scales. By combining SDM with landscape connectivity, this study offers a method for informed species management at a landscape level.

P3.109 YOUNGQUIST, M.B.*; BOONE, M.D.; Miami University; *youngqmb@miamioh.edu*

Structure in a fragmented landscape: effects of land use on cricket frog populations

Dispersal is vital for species persistence because it allows for colonization of new populations and for the rescue of declining populations. Successful dispersal depends on the habitat matrix and the permeability of different habitats. Effects of land use on dispersal may be especially strong in areas with high levels of fragmentation because individuals may encounter a variety of habitats that affect movement differently. One method to estimate movement and population connectivity is to use population genetics. We used microsatellite markers to investigate how different land uses affect population structure of cricket frogs (*Acris blanchardi*) in southwest Ohio. We sampled 14 populations in two counties. Analyses showed relatively high levels of genetic diversity within populations. Isolation by distance was slightly positive, suggesting historic panmixia. STRUCTURE analyses indicated seven distinct genetic clusters and that the structure may be due to high traffic roads and urbanization. Therefore, anthropogenic changes to the landscape likely impact dispersal and may have long term ramifications on population persistence.

6.7 ZAKAS, C*; ROCKMAN, MV.; New York University;
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Dimorphic development in the polychaete Streblospio benedicti: finding the genetic architecture of life−history traits

Understanding the genetic basis of life−history traits is a long−standing goal of evolutionary biology. Many closely related species have contrasting life−history strategies, suggesting that the switches in early development that lead to divergent life−histories evolve quickly and frequently. Life−history changes that originate in early development have profound downstream effects on a species' morphology, ecology, genetic diversity, and even speciation rate. How do such switches in development mode evolve, and what is the underlying genetic architecture? To address this, we use an emerging model in developmental evolution, the polychaete *Streblospio benedicti*, which has two contrasting, but highly−heritable offspring types. We compare transcriptome sequences of adult individuals of the two development modes to determine the extent of genomic differentiation that contributes to life−history mode. We find that there is extensive allele sharing across the two types, and minimal fixed differences, most of which are likely not associated with developmental mode. This suggests that the evolution of a genetic developmental dimorphism is not associated with longstanding genetic isolation or by genomically extensive divergence. Rather, differences at a few developmentally important loci, or modest allele−frequency differences at many loci, may be responsible for the drastic life−history differences.

63.2 ZANI, P.A.; Univ. of Wisconsin, Stevens Point;
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Effects of winter rainfall and drought on body condition and reproduction in side−blotched lizards

Winter rainfall has been implicated as a major determinant of desert lizard reproduction. Ongoing drought in the western United States provides an opportunity to observe the effects of rainfall on lizards. I used multi−year data from several populations of side−blotched lizards, *Uta stansburiana*, in Nevada to examine the effects of drought on body condition and reproduction. During 2012 drought developed in central Nevada and at one site only 73% of normal winter rains fell from October, 2011, to March, 2012. Drought persisted and intensified in the winter of 2012−13 when only 44% of normal rains fell. Drought corresponded to a marked reduction in lizard body condition (scaled mass index [Peig & Green, 2009]) such that lizards in 2013 were ~10% lighter than pre−drought lizards. In 2013 the condition of males (10% reduction from pre−drought levels) appeared worse than females (7% reduction). Drought eased somewhat in the winter of 2013−14 and rainfall was 84% of normal. In 2014 lizard body condition improved, but was still ~8% below pre−drought levels. Interestingly, in 2014 the condition of females (11% reduction from pre−drought) appeared worse than males (6% reduction). Drought also affected reproduction. In April, 2013, 36% of females were gravid, but by June only 4% were gravid. By way of comparison, females from nearby sites outside the area affected by exceptional drought reproduced both early (in April 32% were gravid) and late (in June 33% were gravid) in the breeding season. The easing of drought allowed females at the affected site to breed late as well (in June, 2014, 17% were gravid). This late−season reproduction may actually explain the reduced condition of females in 2014. Thus, winter rainfall and drought appear to create an interaction between body condition and reproduction in side−blotched lizards.

23.4 ZATTARA, E.E.*; NORENBURG, J.L.; BELY, A.E.; Smithsonian Institution, NMNH−IZ, University of Maryland, College Park; *ezattara@gmail.com*

A phylum−wide survey reveals multiple gains of regenerative ability in nemerteans

The ability to regenerate new body parts is broadly distributed across animals, yet this ability varies widely among them. To understand how regeneration evolves, we need to elucidate its gains and losses across the tree of life. Surveys across whole groups allow gains and losses of regenerative ability to be mapped onto phylogenies. We used this approach to study evolution of regeneration within the phylum Nemertea, the ribbon worms, a group of mostly marine animals known to have regenerative powers ranging from none to extraordinary. We collected 21 species across the phylum and assayed regenerative response to transverse amputations at 1/3 and 2/3 of body length. We mapped the regeneration experiments results onto a well−corroborated phylogeny. Our survey showed that while posterior regeneration ability is widespread, anterior regeneration, including regeneration of brain and eye structures, was relatively uncommon and found only for 5 out of 21 species. Four of the species represent first reports of successful anterior regeneration − two are first reports for a whole class, the Paleonemertea; and two are for species of the class Pilidiophora that were not known to regenerate heads. Our 6 examples of the third class, the Hoplonemertea, continues to confirm that members of this class are incapable of such feat. While ancestral character estimation analyses do not resolve if stem nemerteans could regenerate heads, they show that such ability has likely been gained multiple times within the Pilidiophora, including a recent gain in *Ramphogordius sanguineus*. Our work shows the potential of nemerteans as promising models for learning fundamental principles about regeneration mechanisms and their evolution.

5.4 ZELINKA, S.L.; BOURNE, K.J.; GLASS, S.V.; HERMANSON, J.C.*; WIEDENHOEFT, A.C.; USFS Forest Products Laboratory; *jhermans@wisc.edu*

Force−displacement measurements of pit membranes in gymnosperms

The fluid−structure behavior of the torus−margo pit structure in bordered pits has important implications in understanding sap flow and cavitation and subsequent air−seeding phenomena in living gymnosperms. Pit aspiration (the state of the torus − a pectic disc supported by a porous cellulosic membrane [margo] − sealing the pit aperture) is assumed to localize the embolism. Until now, the force−displacement relations of the pit membrane have been hypothesized but never experimentally quantified. We present the first force−displacement curves for pit membranes of circular bordered pits. The test system consists of a quartz microprobe attached to a microforce sensor which is positioned and advanced with a micromanipulator mounted to an inverted microscope. Pit membrane displacement is measured from digital image analysis using Matlab algorithms. Unaspirated pits from never−dried wood of *Larix* and *Pinus* and aspirated pits from dried wood of *Larix* were tested. The force−displacement relations to translate and deform pit membranes from unaspirated to aspirated positions and then beyond until the seal of the pit aperture failed (for the never−dried wood) and the force−displacement relations needed to unaspirate pits (for the dried wood) were recorded. We observed two modes that would negate the imputed physiological advantages of pit aspiration; rupture or tearing of the pit membrane by the microprobe tip, and the stretching of pit membrane until the torus was forced out of the pit chamber through the pit aperture − torus prolapse. These results raise interesting questions about the hypothesized in situ force−displacement behavior of these structures during normal sap flow and as they relate to embolism containment following a cavitation event.

P2.151 ZELLER, M.J.*; GARRITY, D.M.; Colorado State University; *mjeannez@gmail.com*

The Impact of Shear Stress on Cardiac Morphogenesis

Missteps in formation of the embryonic heart can have drastic consequences, making cardiac malformations one of the most common human birth defects. Abnormalities in blood flow, which start before the vertebrate heart is fully formed, are just one of the factors that may contribute to these malformations. Flow is not directly encoded by genes, but has an impact on heart development via the frictional force of blood. This force, known as shear stress, acts on the endocardial cells in the developing heart. The goal of our research is to investigate how altered shear stress on endocardial cells leads to genetic responses in the heart, and to define the genes responsible. The zinc finger transcription factor Kruppel−like factor 2 (KLF2) is a potential flow response gene that may link shear stress signals to changes in gene expression in vertebrates. Here, we investigate three zebrafish genes similar in sequence to mammalian KLF2: *klf2a*, *klf2b*, and *klf4*. To understand how alterations in shear stress trigger altered gene expression in endocardial cells, we used comparative qPCR to investigate *klf2a*, *klf2b*, and *klf4* expression levels in embryonic hearts subjected to altered shear stress conditions. Knockdown of the hematopoiesis genes *gata1* and *gata2* will lower hematocrit and alter blood viscosity, thereby altering shear stress within the embryonic heart in a defined manner. To discover Klf2−activated target genes, we will perform ChIP−seq on hearts of transgenic fish that express endocardial/vascular−specific Klf2a−eGFP fusion protein. Following validation, Klf2a target genes will be investigated by gene knockdown studies to define their functional roles in the heart. These studies will help identify the genes and molecular mechanisms involved in the cellular response to altered shear stress.

72.5 ZEYGHAMI, S*; DONG, H; University of Virginia; *haibo.dong@virginia.edu*

Coupled dynamics of the body and the wings in low flapping frequency insect flight

In order to survive, flying insects need to maneuver and steer in the air. The importance of agility in changing the flight direction is especially evident amongst aerial predators such as damselflies and dragonflies. Though long known as the masters of aerial maneuverability, there are only a limited number of experiments conducted toward understanding the dynamics of the wing and the body motion in Odonata flight. The majority of the previous studies focused on the flight dynamics of high flapping frequency insects, such as fruit flies. It is not quite clear whether the lessons we learned about the wing and the body dynamics in high flapping frequency flight are applicable to the damselflies and dragonflies. Here, we imaged free flight turn maneuvers of several damselflies and dragonflies. An accurate 3D surface reconstruction technique is then used to extract the wing and the body kinematics. By studying the connection between the motion of the wings and the body of these insects, we discovered that the dynamics of the wings couple with that of the body. In support of our findings we developed a physics−based model of the wing pitching which is used to simulate the interactions of the wings with the surrounding air. We show that the mechanics and kinematics of damselfly and dragonfly wings allow the wing motion to be controlled using minimal active regulation.

P1.89 ZHANG, V.Y.*; WILLIAMS, C.T.; WILSTERMAN, K; BUCK, C.L.; Univ. of Illinois at Urbana−Champaign, Univ. of Alaska Anchorage; *vzhang2@illinois.edu*

Determinants of Activity Patterns in Arctic Ground Squirrels of Alaska: Environmental Conditions More Influential than Sex−specific Differences

As the northern−most hibernator in North America, the arctic ground squirrel must reproduce, molt, and fatten for the subsequent hibernation cycle during a comparatively short 3−5 month active season. The timing of peak energy allocation to reproduction differs between males and females, with males peaking shortly after hibernation and females peaking some weeks later during gestation and lactation. We hypothesized that sex−specific differences in energy allocation to reproduction would be reflected in above−ground (foraging) and below−ground activity with weather events providing a significant, but lesser, impact on activity patterns. We recorded patterns of above− and below−ground activity of free−living adult male and female arctic ground squirrels with collar−mounted light loggers and collected environmental data using local meteorological stations. All animals showed dramatic fluctuations in time spent above−ground each day, which correlated to environmental conditions including ambient temperature, precipitation, and windspeed. Unexpectedly, sex had only a minor influence on patterns of above−ground activity with the exception that during the early breeding period, males were more active. Despite the energetic requirements of gestation and lactation, activity patterns of reproductive females were remarkably similar to both non−reproductive females and males. Thus, daily changes in environmental conditions exert a much greater influence on patterns of above−ground activity than reproductive status or sex.

P3.45 ZHONGMIN LU, ZL*; AMIT CHOUHAN, AC; ADAM ROSSANO, AR; GREGORY MACLEOD, GM; Florida Atlantic University ; *Zlu2014@fau.edu*

The capacity to sustain high neurotransmitter release rates is counter−balanced by low energy efficiency.

Synapses, building blocks for neural information processing, spend most of the energy in the brain. Large synaptic energy demands contrast with limitations on energy supplies, and it is therefore advantageous for synapses to adopt energy−efficient neurotransmitter release mechanisms. We proposed that energy−efficiency has been optimized and that the same energy−efficient mechanisms are found at most synapses. Here, using electrophysiology recordings and calcium imaging, we estimated energy−efficiency in the terminals of two Drosophila glutamatergic motor neurons innervating the same muscle fiber. Surprisingly, presynaptic energy−efficiency is not the same between terminals. The less efficient terminal performs most of the work, firing at higher frequency and for a greater portion of time during locomotion, but it is able to sustain these high rates of release better than the highly efficient terminal. To conclude, the price of sustaining high levels of neurotransmitter release is accompanied by both an increase in the energy budget and a decrease in energy−efficiency.

65.6 ZHU, J.; KEMP, T.; FISH, F. E.; BART−SMITH, H.*; University of Virginia, West Chester University; *hb8h@Virginia.EDU*

Development of a batoid−inspired autonomous underwater vehicle

Batoid fish such as manta and cownose rays outperform man−made autonomous underwater vehicles in maneuverability and efficiency over a wide range of speed. These capabilities can be attributed to their extremely flexible fins, which may flap and pitch in a way that optimizes the overall performance during swimming. In this study, we developed and tested the MantaBot, which was inspired by biological design criteria in batoid: flattened rigid body and flexible actuators. The MantaBot body was rendered from a computer tomography scanning image of a cownose ray. The flexible fins were made of elastomer in an airfoil cross−section shape. The fins were driven by active tensegrity structures. An additional rigid fin was attached to the rear of the body for pitch control. The vehicle was powered by a Li−ion battery pack and controlled by an Arduino microcontroller. A pressure sensor and a MEMS gyroscope/accelerometer device were equipped in the system for depth feedback control and navigation. The experiments were conducted in a water tank where the Mantabot was attached to a rail for rectilinear swimming. Optimal operation conditions (fin flapping amplitude and frequency) were determined for fastest swimming by surveying a wide range of parameters. Free swimming tests were done in a swimming pool. Our results show the MantaBot can swim faster than one body length per second and cruise about 7 km per charge. These results demonstrate that enhanced swimming performance can be achieved through bio−inspired designs based on rays.

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Major genomic expansions in annelids: Evidence from the genome of the earthworm Eisenia fetida

Genome evolution has shaped the remarkable diversity exhibited in the animal body plans of today's animals. Changes in Hox genes and other homeobox genes, in particular, have made considerable contributions to major transitions in animal morphology. Vertebrate genomes have undergone several rounds of whole−genome duplication giving rise to multiple clusters of Hox genes. These duplications, especially to developmental patterning genes like the Hox genes, have contributed to the vertebrate body plan. Genomic evidence from the annelids *Helobdella robusta* (class Clitellata) and *Capitella teleta* (class Polychaeta) suggest that large−scale duplications also occurred in the lineage leading to *H. robusta*. To better understand the nature of these duplications, we have sequenced and assembled the genome of the earthworm *Eisenia fetida* (class Clitellata). We have identified 250 homeobox genes and 33 Hox genes in the *E. fetida* genome. These numbers represent the largest number of Hox genes reported in an annelid (e.g., *C. teleta* has 11 Hox and *H. robusta* has 19 Hox genes). These data suggest a series of evolutionary expansions in the Clitellata, in particular along the lineage leading to *E. fetida*. Besides providing an important genomic resource for the community, these analyses provide timing information for important genomic duplication and loss events that undoubtedly have contributed to the evolution of annelid body plans.

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The modulation of foot position and adhesion during arboreal locomotion in day geckos (Phelsuma)

By using adhesion, geckos can navigate through challenging habitats. Given the importance of the foot in transmitting forces to the substrate and adhesive system application, the directionality of adhesion is likely critical. Behaviorally modulating how the adhesive system is applied can occur by altering the alignment of the foot relative to the long axis of the body and/or the angles between the digits (interdigital angle). Given the directionality of the adhesive system, we expect geckos to vary the application of the system via these mechanisms as they run. We quantified 3D movements (with high−speed video) of *Phelsuma madagascariensis* running on a range of ecologically relevant inclines (0°, 45°, 90 °) and perch diameters (1.5cm, 10cm and flat). We measured instantaneous interdigital angle and foot alignment relative to the body across each condition, as well as other kinematic variables. The geckos decreased speed with decreasing perch diameter, but increased speed at 45°. This suggests that *P. madagascariensis* may favor inclined perches. Additionally, proximal limb variables respond to substrate condition in a manner to increase stability and reduce toppling. Finally, foot alignment in the forelimb acts in opposition to that of the hindlimb, suggesting that *P. madagascariensis* is able to maintain multiple directions of adhesion at one time. The modulation of interdigital angle and foot alignment suggests that aspects other than the mechanism of adhesion are important for arboreal movement in geckos. Our study reveals patterns of foot usage in arboreal locomotion, which can lead to a better understanding of adhesive system constraints. This is essential for understanding how biomechanical traits respond to the evolution of novel adaptations and morphologies. Supported by NSF IOS−1147043.

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Future Meeting Dates

Portland, Oregon, 3-7 January 2016

New Orleans, Louisiana, 4-8 January 2017

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