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Skeletal muscle architecture determines propensity for muscle damage during eccentric contractions

Skeletal muscles not only accelerate our bodies during movement, they also play a crucial role in deceleration. During decelerating tasks, such as landing and braking, muscles are stretched while actively producing force in order to dissipate mechanical energy. One negative consequence of energy dissipation is that active lengthening can cause muscle damage. While we know a lot about the implication of different architectures and fiber-type compositions for force production, it is unclear how these muscle parameters affect the likelihood of damage. We used the natural variation in muscle fiber type and architecture in rat muscles to investigate the link between muscle parameters and injury. Soleus is a slow, parallel fiber muscle (20% fast fibers, 4° pennation) while plantaris is a fast, pennate fiber muscle (95% fast fibers, 16° pennation). We used an *in situ* muscle preparation where a servomotor measured the force, velocity and length of the entire MTU. Eccentric stretches applied to the muscles were made relative to P_0 . After an eccentric contraction, the extent of the muscle injury was estimated by the amount of force decline and a leftward shift in the muscle's force-length curve. We observed that the pennate muscle could withstand an eccentric contraction up to 200% P_0 while the parallel muscle experienced complete failure at 150% P_0 . This is consistent with studies that propose that architectural gear ratio of pennate muscles provide protection from stretch-induced damage and studies showing an increase in pennation angle with eccentric training. These results suggest that variation in muscle architecture may serve to predict a muscle's propensity for damage during energy dissipating tasks.

49-3 ACKERLY, KL.*; KRAHE, R; CHAPMAN, LJ; McGill University; kerr.ackerly@mail.mcgill.ca

The effects of chronic and acute exposure to hypoxia on swim performance and electric signaling in an African mormyrid, *Gnathonemus victoriae*

Dissolved oxygen (DO) concentration is a key factor limiting the aerobic capabilities of fishes, and low DO concentration (hypoxia) associated with eutrophication and pollution is now considered to be one of the greatest threats currently facing fishes. Hypoxia can severely limit fish performance, especially aerobically expensive fitness-related behaviours including swimming and sensory information acquisition. Fishes can lessen oxygen requirements and metabolic demands by altering these behaviours under hypoxia, though the exact mechanisms by which they do so can be difficult to quantify. We use weakly electric fishes as a model system for exploring potential effects of hypoxia on swim performance and sensory information acquisition, as we can non-invasively quantify the electric organ discharges (EODs) they use for active acquisition of sensory information during swimming. To quantify potential effects of hypoxia, we measured critical swim speed and concurrent EOD production under high- and low-DO concentrations in a hypoxia-tolerant African mormyrid, *Gnathonemus victoriae*, following chronic and acute exposure to hypoxia. Our findings indicate that hypoxia exposure resulted in a significant decline in both swim speed and EOD production in fish without previous acclimation to hypoxia. However, individuals acclimated to chronic hypoxia for eight weeks were characterized by a higher critical swim speed under both hypoxia and normoxia than fish acclimated to normoxia. Our results highlight the effects of hypoxia on aerobic swim performance and sensory information acquisition, and the ability of fish to heighten aerobic performance under stressful conditions through acclimation processes.

15-4 ABOLINS-ABOLS, M*; HANAUER, RE; PETERSON, MP; ROSVALL, KA; KETTERSON, ED; Indiana University, Viterbo University; mabolins@indiana.edu

Stress and reproduction: repeated disturbance reduces circulating testosterone but not the capacity to produce it

The life-history trade-off between self-maintenance and reproduction is mediated by two hormonal networks: the hypothalamic-pituitary-adrenal axis (HPA), which mediates the stress response, an essential aspect of self-maintenance, and hypothalamic-pituitary-gonadal axis (HPG), which mediates reproduction. HPA and HPG have a capacity for a significant crosstalk, and, under some environmental conditions, activation of the HPA can suppress the HPG, potentially interfering with reproduction. If we are to predict how animals will respond to environmental changes that alter this trade-off, we need to know more about how the HPA and HPG interact. We experimentally investigated whether chronic disturbance affects gonadal development and the gonad's ability to produce and release testosterone (T) in a songbird, the Dark-eyed Junco (*Junco hyemalis*). In the high-disturbance treatment, captive males were repeatedly exposed to stressors for three weeks; controls were undisturbed except for animal husbandry. To assess impact of disturbance on the HPG, we measured baseline levels of testosterone (T) in peripheral blood within 5 min of capture, and gonadal capacity to produce T 30 min after an injection with GnRH. We then measured gonadal mass and gene expression related to the signaling of the HPG. Birds in the high-disturbance treatment showed significantly lower baseline T levels than control birds. However, neither GnRH-induced levels nor gonadal mass showed significant differences between treatments, suggesting that the gonadal capacity to produce T is not affected by disturbance. We conclude that high levels of disturbance in the wild may reduce expression of T and T-mediated traits. Analysis of gonadal gene expression will shed light on the mechanisms by which disturbance affects HPG function.

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Nest environment and embryonic development in the northwestern range of the wide-ranging painted turtle *Chrysemys picta*

Different populations of wide-ranging species may respond to geographic variation in local climate in various ways. For these species, better understanding of how separate populations respond to environmental variation throughout the range may be required to predict species-level responses to climate change. We measured nest microhabitat to examine the effects of temperature on embryos of the painted turtle (*Chrysemys picta*) from a relatively understudied population in the northwestern part of its range. Compared to other geographic locations of the painted turtle range, this northwestern climate was expected to be cooler and wetter. However, we found thermal nest profiles to be comparable to other parts of the species' range, experiencing similar mean, minimum, and maximum temperatures. A wider range in mean daily temperature range was observed among nests when measuring daily extremes. Curiously, the frequency of external abnormalities was higher than reported for hatchling painted turtles from nests in populations elsewhere in the range. Overall, we show developing embryos of a northwestern population of painted turtles experience thermal conditions similar to other geographically distinct populations and that this population may have higher intrinsically induced abnormalities.

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Evolution of the neurosensory system mediates gain and loss of phenotypic plasticity

Phenotypic plasticity has been heralded as an essential mechanism for surviving climate change and an important consideration in speciation. Since plasticity is likely to enable expansion and radiation into new environments, it has hypothesized to be an ancestral trait that is then lost as the new populations become specialized. Less clear, is how and when plasticity arises. A phenotypic response to an external cue starts with translation of the environment, often by neurosensation. Genes that encode components of neurosensory systems, such as sensory receptors, are known to undergo rapid radiations, with both duplications and losses that allow for niche expansion and host shifts. I hypothesize that the evolvability of neurosensory systems controls the gain and loss of phenotypic plasticity. To test this hypothesis, I surveyed Echinoidea for pre-feeding plasticity in arm length in response to food availability and for the underlying neurosensory mechanism. Many echinoids can inhibit elongation of their feeding arms via food-induced dopamine signaling during development. My data suggest that pre-feeding plasticity arose in the regular urchins, with numerous subsequent losses within this clade. These losses appear to have been driven by 1) temporal shifts in the development of catecholaminergic neurons and 2) changes in expression or function of sensory components - supporting my hypothesis. The establishment of the developmental response may have been constrained by the temporal alignment of neural development and skeletal development. Since TGF-signaling mediates both neurogenesis and skeletal development, the pleiotropic effects underlying the heterochronic shift in skeletogenesis may have initially inhibited catecholaminergic neural development.

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***Mycoplasma gallisepticum* infection reduces anti-predator behaviors in house finches**

Although many pathogens cause host mortality by directly damaging host tissues, others increase mortality through indirect mechanisms. Among the best studied of these is an increased risk of predation during infection, particularly for systems in which pathogens are transmitted trophically from prey to predators. However, in systems without trophic transmission, we know considerably less about the impacts of infection on anti-predator defenses and the mechanisms involved. Here we tested how *Mycoplasma gallisepticum*, an emerging pathogen of wild birds that is not transmitted across trophic levels, impacts anti-predator behaviors in its primary free-living host species, the house finch (*Haemorrhous mexicanus*). Using wild-caught finches in a controlled laboratory environment, we found that infected birds spent more time near a stuff predator (Cooper's hawk) while feeding than did uninfected birds. Additionally, during a simulated predation attempt (hand capture by researchers) infected birds were captured significantly more rapidly. Because this pathogen induces both severe swelling around the eyes and pronounced sickness behaviors (e.g., lethargy) in house finches, obscured vision and diminished locomotion could each play a role in reducing anti-predator behaviors. However, when we excluded birds with visible eye swelling from our analyses, infected birds still exhibited reduced anti-predation behaviors, suggesting a primary role for lethargy or other sickness behaviors in these differences. More broadly, our results suggest that the costs of sickness behaviors include reduced anti-predator behaviors, even in non-trophically transmitted infections.

26-3 ADDIS, E.A.*; PRICE, K.; CARR, K.E.; KITTRIDGE, C.; Gonzaga University; addis@gonzaga.edu

Is there physiological variation between urban and rural dwelling marmots (*Marmota flaviventris*)?

The loss of habitat to urbanization is detrimental to many species, but not all. There are some that are able to survive, and in many cases thrive, in urban environments. To help us understand how some species are able to survive, and perhaps thrive, in urban environments, it is helpful to examine species that live in both urban and rural environments with the underlying assumption that most species did not evolve in conjunction with the habitation of humans. In the Inland Northwest (eastern Washington and Oregon and Northern Idaho), yellow-bellied marmots (*Marmota flaviventris*) are found not only in rural scrublands, but also in urban, highly developed areas, such as downtown Spokane, WA. Because of its ability to live along an urban-rural gradient, this species makes an exemplary organism for the examination of acclimation to urban environments. Allostatic load is predicted to differ between urban and rural environments based upon an individual's interpretation of the environment. Glucocorticoids are a useful measure of allostatic load because their levels fluctuate in response to varying energetic demands. Therefore, we measured glucocorticoid metabolite levels in feces of marmots living along an urban-rural gradient. Based upon the hypothesis that energetic demands and availability may vary between urban and rural locales, we predict that baseline levels of fecal glucocorticoid metabolites will also vary. Here we present first the results of a de novo construction of an urban-rural metric, and, second, levels of glucocorticoid metabolites of marmots residing along an urban-rural continuum in the Spokane area.

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Mechanical response of the tracheal system to hemolymph pressure in the beetle *Zophobas morio*

Insects possess a complex network of tracheal tubes throughout the body used for transport of gases to and from the tissues. In some species, parts of the network are rhythmically compressed, facilitating active ventilation in the insect. Previous work suggests that hemolymph pressure pulses may induce tube collapse, but it is not understood how tracheae respond mechanically to a pressure difference across the wall. Tracheal tubes vary in diameter, wall thickness, cross-sectional shape, and taenial density, which should influence patterns of collapse. To study how tracheae respond to hemolymph pressure, we artificially induced pressure rises in the thorax of 11 intact, sacrificed beetles (*Zophobas morio*) by manually compressing the abdomen, creating hemolymph pressures of similar magnitude to those observed in live animals (>2 kPa). Simultaneously, we captured synchrotron X-ray video to monitor tracheal tube diameter in several locations in the body, and measured internal pressure using a Fabry-Pirrot pressure sensor (Samba Preclin) inserted into the thorax. We found that pressure rises produce collapse patterns that are qualitatively similar to those found in the live animals. Preliminary analyses indicate that large tracheal tubes (diameter ~400 μ m) begin to collapse at an average pressure of 0.32 ± 0.02 kPa (n=3), whereas small tubes (diameter ~100 μ m) required nearly twice the pressure (0.63 ± 0.02 kPa, n=3). However, smaller tubes collapsed completely at lower average pressures (1.79 ± 0.02 kPa, n=3) than did larger tubes (2.32 ± 0.05 kPa, n=3). These results support the hypothesis that an increase in hemolymph pressure is a mechanism of tracheal tube collapse used for active ventilation in insects.

94-6 AGOSTA, S.J.*; HULSHOF, C.M.; Virginia Commonwealth University, Universidad de Puerto Rico, Mayaguez; sagosta@vcu.edu

Insect-plant interactions in a changing world: caterpillar performance, climate, and leaf traits in regenerating tropical dry forest

The effects of large-scale changes in global climate on biodiversity have received much attention, but the more acute form of climate change that results from local habitat alteration has been less explored. Each time a forest is cut, thinned, fragmented or otherwise altered in structure, local climates and microclimates change. Such changes can have both direct (e.g., on body temperature) and indirect (e.g., on plant traits) effects on herbivorous insects. In this study, we formulate an eco-physiological framework to study the impacts of forest change on herbivorous insects. Specifically, we predict that if tropical forest caterpillars are climate and resource specialists, then they should suffer reduced performance outside of mature forest-like conditions, such as those found in young secondary forests. We test this idea with a field experiment on the performance of the caterpillar *Rothschildia lebeau* feeding on its host plant *Casearia nitida* in two different aged forests in Area de Conservacion Guanacaste, Costa Rica. Compared to more mature closed-canopy forest, we found that (1) ambient conditions were hotter, drier, and more variable; (2) caterpillar growth, development and survival were reduced; and (3) leaves were thicker, tougher and drier in younger forest. In addition, variation in caterpillar performance was significantly related to variation in leaf traits. Based on the available evidence, we conclude that reduced caterpillar performance in younger forest could have been driven by differences in climate, leaf traits (which may be tied to climate), or both.

112-4 AIELLO, BR*; OLSEN, AM; WESTNEAT, MW; HALE, ME; Univ. of Chicago; braiello@uchicago.edu

Losing one's sense of control: how proprioceptive feedback impacts labriform swimming

Proprioceptive feedback, the sense of movement and position of one's body elements in space, is critical to the motor performance of many animals. The pectoral fins of fishes are highly innervated by the sensory system and perform dual roles as propulsors and sensors. Fish control the shape of their fins to maintain efficient propulsion in an unstable environment, which suggests that proprioceptive feedback is needed to complete these complex and precise movements. The objective of this study is to examine how the loss of proprioception impacts pectoral fin muscle activity patterns and kinematics of labriform swimmers. To determine how pectoral fin proprioceptive feedback is used in labriform swimming, we performed bilateral transections of all sensory nerves that innervate the pectoral fins of the princess parrotfish (*Scarus taeniopterus*) and examined the effects on fin kinematics and activity patterns of the muscles used to actuate the fin. The loss of sensory feedback resulted in bilaterally asymmetric fin movements, increased fin beat frequency, and a transition to the body-caudal fin gait at lower speeds. However, pectoral fin rhythmicity remained the same or increased after the loss of sensory feedback. In general, the order of muscle activation during the fin stroke did not change after transection. After the loss of sensory feedback, the duration of each muscle's activity relative to cycle duration increased and the relative lag between the onsets of activity decreased between muscles. The resultant increase in overlap of activity between abductor and adductor muscle pairs may stiffen the fin to enhance control after sensory loss. These results indicate that proprioceptive feedback is critical for the performance of typical pectoral fin motor patterns and kinematics.

79-3 AGRAWAL, S*; DICKINSON, MH; Univ. of Washington, Caltech; sagrawal@uw.edu

Influence of female orientation and pigmentation on male positioning during courtship

Despite its emergence as a premier model for visual processing, little is known about object recognition in *Drosophila*. One possible explanation for this deficit is that *Drosophila* do not display behaviors typically associated with exemplary feats of object recognition, like the flower shape memory exhibited by bees. In addition, *Drosophila* eyes provide poor spatial resolution. Nevertheless, visual object recognition may be important during courtship. Because courtship occurs at a very close distance, flies could distinguish fine-scale pigmentation patterns. At a greater distance, a chasing male would have access to cues such as shape, size, and patterns of motion. To understand how courting male flies use vision, we developed a behavioral apparatus, dubbed "Flyatar," consisting of a remotely actuated fly dummy. We can modify the dummy's appearance, pattern of motion, and pheromone coating. Males will robustly court the dummy, enabling us to delineate the relative contributions of visual and other sensory cues to male courtship behavior. We are using Flyatar to examine how a male uses vision and chemosensation to position its body during chases. To have a chance at successful copulation, a male must position itself appropriately around the female. Male flies preferentially bias their chasing towards the female's abdomen, irrespective of her body orientation and direction of movement. This preference is maintained towards females that have been genetically altered to not produce pheromones, suggesting that males can distinguish different parts of the female body using vision alone. In addition, males demonstrate a preference for chasing objects painted specific shades, and are not strongly attracted towards very dark or very light objects. These results suggest that, though simple, visual object recognition nevertheless plays an important role in courtship behavior.

2-5 AKANYETI, O*; THORNYCROFT, P/J/M; LAUDER, G/V; YANAGITSURU, Y; PETERSON, A/N; LIAO, J/C; University of Florida, Gainesville, Harvard University, Cambridge, University of California, Irvine; otar@whitney.ufl.edu

Concerted optimization of propulsion, sensing and respiration during swimming

Axial body undulation is the plesiomorphic motor pattern driving locomotion in vertebrates and predates the origin of paired fins and jaws. Previous work studied undulation as a means of propulsion without considering how it might affect other fundamental physiological processes such as sensing and respiration. Here we show that undulation in fishes optimizes propulsion, flow sensing and respiration concurrently without any apparent trade offs when head movements are coupled appropriately with body movements. We use a combination of theoretical, biological and physical experiments to reveal the hydrodynamic mechanisms underlying this concerted optimization. We reveal four key findings. First, we show that in freely-swimming rainbow trout (*Oncorhynchus mykiss*, body length = 18.5±2.1 cm), the phase difference between heave and yaw movements of the head increases with swimming speed ($y = 9.24x + 38.20$, $R^2 = 0.6$, $p < 0.01$, $n = 7$ fish). Second, experiments with a flexible 3D-printed fish model show that coupling head and body movements with the correct phase angle (which fell within the range displayed by live fish) minimizes power consumption by 50%. Third, trout move their heads in a way that automatically enhances lateral line sensing up to 50% by minimizing self-generated stimuli. Fourth, trout synchronize their respiratory movements with head movements, which likely minimize the energetic costs of pumping water. Based on our empirical results, we developed a control architecture that can be universally applied to all undulatory animals and machines.

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Modeling the co-evolution of social structure and behaviors in animal societies

The structure of animal and human societies, i.e., the distribution and arrangement of social bonds between individuals, is an important determinant of individual behavior, health, and ultimately fitness. Recently, there has been a lot of interest in quantifying social structure using tools from network science and understanding how social network structure affects behaviors and fitness. This work has largely been descriptive, and we currently lack generative models of how social networks form and are structured. I will present our recent work that provides a simple and general model that can explain important characteristics of social networks observed in animal societies. The crucial ingredient in this model is the process of social inheritance, the tendency of offspring to be connected to the same individuals as their parents. Building on this model, I will show results from an evolutionary model where social network position and the behavioral phenotypes of one's social connections affect individual fitness, and where social bonding traits co-evolve with the behavioral phenotype. We show that there is a tension between the evolution of social structure promoting cooperation and the evolution of cooperative behaviors themselves. I will discuss ways in which psychological and behavioral mechanisms can resolve this tension.

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Predicting ecological consequences of increasing temperature variability: matching data with theory

Increasing temperature variability is likely to be an important biological disturbance over the next few decades, as it increases the risk that species' tolerance limits will be exceeded. In response to thermal stress, many organisms exhibit characteristic physiological changes that increase tolerance to subsequent high temperatures. The activation of this so-called "heat shock response" requires, however, a significant energetic investment. In addition to positive effects on survival, heat shock responses may involve large sublethal effects that include reduced growth or reproduction due to energetic trade-offs between competing life history traits. Although there is growing recognition that stress may have important implications for population persistence and species interactions in the face of global climate change, we still lack a general framework for understanding how increasing temperature variation will influence the relative size of sublethal versus lethal thermal effects in natural ecosystems. That said, theoretical approaches that have worked in other ecological contexts (e.g., optimal behavioral and morphological prey responses to predator risk) might be successfully modified to provide predictions about thermal stress as well. We present one such model, highlighting its potential to guide the development of rigorous hypotheses and associated predictions for how organisms might respond to increasing environmental temperatures.

10-1 ALFARO, ME*; RABOSKY, DL; CHANG, J; TITLE, P; VENZON, M; ALFARO, Michae; Univ. of California, Los Angeles, Univ. of Michigan; *michaelalfaro@ucla.edu*
Global patterns of diversification across the ray-finned fish tree of life

A strong latitudinal gradient in species richness characterizes diversity patterns across most terrestrial vertebrates. Spatial diversity patterns across ray-finned fishes are more poorly understood. Here we assemble the largest phylogeny of ray-finned fishes to date, comprising more than 12,000 species. We use this framework to study spatial patterns of marine ray-finned fish diversity by integrating tip data from this tree with georeferenced occurrence data. Our results reveal a strong latitudinal gradient in species richness across actinopterygians. Surprisingly, high species richness at low latitudes is not explained by differential rates of diversification. Tropical communities with high concentrations of species richness also exhibit low average rates of speciation while the most temperate communities with low richness also possess the highest rates of speciation. Clade-level analyses confirms this result: the most species rich low latitude marine lineages possess low to moderate rates of speciation while some of the highest rates of speciation across all fishes are found in high-latitude lineages. Our results are consistent with patterns reported for terrestrial birds and mammals and suggest that differential rates of origination are insufficient to explain latitudinal gradients in vertebrate species richness.

81-4 ALLIGOOD, KS*; LESCAK, EA; BASSHAM, SL; CATCHEN, JM; VON HIPPEL, FA; CRESKO, WA; University of Oregon, Eugene, University of Alaska, Anchorage, University of Illinois, Urbana-Champaign; *kristin.alligood@gmail.com*
Linking Phenotypic and Genomic Evolution in Very Young Populations of Threespine Stickleback

Rapid change in head and body shape has accompanied the repeated and independent invasion of oceanic threespine stickleback into freshwater habitats in regions deglaciated approximately 13,000 years ago. Recent research has made clear that phenotypic and genetic divergence can occur in decades. A remaining challenge is to link stickleback genomic architecture to causal genes that underlie shape evolution. To address this we used natural populations of stickleback that colonized freshwater ponds created by the 1964 Alaska earthquake on islands in the Gulf of Alaska and Prince William Sound. These very young populations already show phenotypic and genotypic divergence from their marine ancestors. We used a large dataset of single nucleotide polymorphisms (SNPs) generated via RAD-seq to determine patterns of linkage disequilibrium (LD) in a network analysis of loci across the genome. We compared these genomic patterns with loci found to be associated with phenotypic variation identified with a genome wide association (GWA) approach. These analyses uncover several unique clusters of loci in LD which suggests that multiple evolutionary phenomena, i.e. chromosomal inversions, selection, admixture or epistatic fitness interactions, create local and widespread LD patterns in the stickleback genome. Furthermore, the LD patterns help to interpret our GWA findings and suggest that rapid phenotypic evolution may be underlain by many loci across the genome but that these loci significantly covary because of LD. The young stickleback populations present a rare opportunity to link rapid phenotypic evolution and the genomic architecture that shapes it in a natural context.

28-4 ALTIMIRAS, J.*; GARITANO-ZAVALA, A.; Univ. of Linköping, Sweden, Universidad Mayor de San Andrés, Bolivia; jordi.altimiras@liu.se

Heart size limits metabolic scope in tinamous, the most primitive flying birds

Together with ratites, the tinamous are the most primitive extant birds (clade Palaeognathae). Unlike ratites though, tinamous can fly. The tinamous have the smallest heart size among all existing birds, which is expected to limit aerobic scope. Our aim was to characterize heart morphometry and to measure metabolic and cardiovascular function in two species of the genus *Nothoprocta*, the Ornate Tinamou OT, a highland species and the Chilean Tinamou CT, a lowland species. Relative heart size was 0.24% for OT and 0.28% for CT, significantly smaller than high and lowland chickens (0.54% and 0.42% respectively). Resting metabolic rate is 31% lower in OT than in highland chickens. When exhausted, OT and CT had elevated glucose and lactate levels suggesting a severe oxygen debt, and OT also showed limited capacity to maintain body temperature with a significant and persistent drop in body temperature (over 2h) after the exhaustive bout. Heart rate running on a treadmill at 3 km h⁻¹ was 5% lower in OT, indicating that OT cannot compensate for the reduction in heart size with a faster heart rate. In anesthetized birds, cardiac output and stroke volume of OT was 40% of the cardiac output of chickens in identical conditions. Blood pressure was significantly higher in OT. Altogether, we provide evidence that heart size is a phylogenetically conserved trait among tinamous and that OT cannot compensate aerobically for its small heart. Instead, it relies on anaerobic metabolism incurring in a large oxygen debt while exhausted.

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The stress of parenthood: how brood size interacts with corticosterone and testosterone in eastern bluebirds (*Sialia sialis*)

In socially monogamous birds, the hormone testosterone typically facilitates territorial aggression and nest defense, but in doing so, can suppress parental care. However, some species do not follow this pattern and it is unclear why, in these species, we do not see the predicted relationship between testosterone and behavior. One hypothesis is that the stress hormone, corticosterone can dampen activity of the hypothalamic-pituitary-gonadal axis and lower testosterone production. One potential stressor for adult birds is increased parental care. In our study population of eastern bluebirds (*Sialia sialis*), both males and females contribute to parental care, but parental behavior is not related to individual levels of testosterone in either sex. In 2014, we conducted a brood size manipulation from which we found that adults provided more parental care to enlarged broods. When the nestlings were 5-7 days old, we conducted parental care observations. When nestlings were 7-9 days old, we used a live house sparrow (*Passer domesticus*) to conduct a simulated territorial intrusion. Following each of these behavioral trials, we conducted gonadotropin-releasing hormone (GnRH) challenges on adults to quantify testosterone production capability. We measured both testosterone and the stress hormone, corticosterone, in blood samples, and related levels of these hormones to adult behavior and brood size. Testosterone is thought to mediate the trade-off between parental care and aggression, but not for all species. Studying how other hormones and life history traits interact with testosterone will help to uncover why some species seem to have become "behaviorally insensitive" to testosterone.

73-7 AMARPURI, G.*; CHEN, Y.; BLACKLEDGE, T.A.; DHINOJWALA, A.; Univ. of Akron, Ohio; ga25@zips.uakron.edu
Modulation of spider glue's humidity responsive adhesion using surface energy and surface charge density.

Modern orb-web spiders use micron sized glue droplet to capture and retain prey. Spider glue is a unique biological adhesive which is humidity responsive such that the adhesion continues to increase upto 100% relative humidity (RH) for some species. This is unlike synthetic adhesives that significantly drop in adhesion with an increase in humidity. However, most of adhesion data reported in literature have used clean hydrophilic glass substrate, unlike the hydrophobic, and charged insect cuticle surface that adheres to spider glue in nature. Here, we vary the surface energy and surface charge of the substrate to test the change in *Larinioides cornutus* spider glue adhesion with humidity. We find that an increase in both surface energy and surface charge density increases the droplet spreading and there exists an optimum droplet contact area where adhesion is maximized. Moreover, spider glue droplets act as reusable adhesive for low energy hydrophobic surface at the optimum humidity. These results explain why certain prey are caught more efficiently by spiders in their habitat. The mechanism by which spider species tune its glue adhesion for local prey capture can inspire new generation smart adhesives.

3-6 ANDERSON, C.V.*; JAIN, S.S.; PARK, N.R.; ROBERTS, T.J.; Brown University, Providence; Christopher_V_Anderson@brown.edu

Locomotor and feeding muscles in *Anolis* lizards are tuned to different functional demands

Muscle, the biological motor of movement in animals, is used to perform a diverse range of tasks. For instance, muscles can be employed to produce the mechanical energy used to power a movement, or can act as a sink to dissipate that energy. Some muscle contractile properties, such as shortening speed and twitch time, vary among muscles, and it is reasonable to expect that such properties are matched to the demands of the task. Sprinting, for example, is a rapid, cyclical movement that may be limited by the twitch time of muscles. Biting, on the other hand, is a more episodic movement that may not be as dependent on cycling rate. We examined the contractile physiology of a locomotor and a feeding muscle in *Anolis* lizards to test the hypothesis that the mechanical properties of these muscles vary according to their functional demands. We found that twitch times were on average 1.7 times faster in locomotor muscles than feeding muscles. Further, we found that passive tension tended to develop at lower normalized muscle lengths in locomotor muscles than in feeding muscles. These findings suggest that locomotor muscles are tuned to allow for the very rapid force generating events during sprinting. The observation that feeding muscles develop passive tension at longer lengths compared with locomotor muscles may be related to a reduced risk of active lengthening in jaw muscles, if passive forces serve as mechanical protection against potential muscle damage during active lengthening. These results show that the mechanical properties of muscles may be closely linked to their different functional demands. This research was supported by NSF grant IOS 1354620.

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Song as a signal of cognitive ability: effects of early developmental stress on problem solving and song learning in the zebra finch
Song may serve as a reliable signal of cognitive abilities in songbirds because the development and expression of these traits require learning and share dependence on brain function. Specifically, developmental stressors could constrain both song learning and aspects of cognition to generate a correlation between these traits. The negative effects of early stress on song learning are well established and recent work also has shown relationships between song and problem solving in several species. Here we test the hypothesis that developmental stress underlies correlations between song and cognition by examining the effects of early nutritional stress on song and problem solving in the zebra finch. Treatment affected growth: finches from experimentally enlarged broods (stressed) were lighter (d 23 mass) than birds from smaller broods (controls). Treatment affected adult song: control males copied tutor songs more accurately than did stressed males, and control males sang songs that were more stereotyped. Additionally, when both male and female subjects were examined, treatment had mixed effects on cognitive performance: controls learned a spatial task more quickly than stressed birds, while stressed birds performed better in a motor task and a test of inhibitory control (a predictive measure of general problem solving ability). Our results are in line with studies showing negative effects of developmental stressors on growth, song development, and spatial cognition. We find mixed effects of this type of stress on adult cognitive performance, however, leaving questions about the mechanisms that might link song and other cognitive abilities.

38-3 ANDERSON, F.E.*; WILLIAMS, B.W.; HORN, K.M.; ERSEUS, C.; JAMES, S.W.; Southern Illinois University, North Carolina Museum of Natural Sciences, University of Gothenburg, University of Iowa; feander@siu.edu

Earthworms are polychaetes, too: phylogenomic analyses of relationships within Crassicitellata

In many terrestrial ecosystems, earthworms (Crassicitellata) constitute the main component of animal biomass, serve as critical links in food webs and play a vital role as soil ecosystem engineers. Unfortunately, the relative simplicity of the earthworm body plan has made morphology-based inference of crassicitellate phylogeny difficult. Recent molecular analyses using PCR-amplified loci have yielded key insights, but to date, genome-scale data have not been used to study crassicitellate phylogeny. To bring more loci to bear on the remaining challenges in crassicitellate systematics, we generated transcriptomes for members of ~40 crassicitellate genera representing fifteen families as well as six outgroups and implemented a progressive approach to infer orthology and test possible sources of bias. Our trees are broadly congruent with previously published molecular phylogenies we recovered two major crassicitellate clades, one comprising Criodrilidae, Hormogastridae, Lumbricidae and Lutodrilidae, and the other comprising Microchaetidae and all other crassicitellates in our data set. However, there are also several differences we found strong support for the hypothesis that Crassicitellata is a subgroup of a paraphyletic Haplotaxidae, and uncertainty remains regarding the position of Moniligastridae, possibly rendering Crassicitellata paraphyletic. While confirming the main nodes obtained with smaller datasets, our results indicate that we need to look more closely at relationships in the crown group Megascolecoidea, the basal branches of Crassicitellata, and the relationship of earthworms to other clitellates.

113-1 ANDERSON, P*.; LACOSSE, J.; Univ. of Illinois, Urbana-Champaign, Charles E. Jordan HS, Durham, NC; rody01@yahoo.com

Point of Impact: The dynamics and energetics of ballistic puncture
Jellyfish using their nematocysts to inject venom, mantis shrimp harpooning passing fish, and hunters shooting with bow and arrows are all examples of a common prey-capture strategy: ballistic puncture. Across seven orders of magnitude, these disparate systems are unified by a predator's weapon (nematocyst, spine, arrow, etc.) delivering energy to prey in order to cause damage and even death. The commonality of these systems offers an opportunity to explore how organisms at different scales and with different materials, morphologies, and kinematics utilize energy to perform ballistic puncture. In order to establish a framework for exploring puncture mechanics across biological scales, we examined the effects of size and velocity in a controlled ballistic puncture system. Arrows of identical tip shape but varying in mass and flight speed were shot into cubes of ballistic gelatin. Observations from high-speed videography of impacts suggest that when arrow speed exceeds the speed that stress waves propagate through the gelatin, puncture can occur with minimal deformation to the gelatin. By varying the mass and speed of the arrows, we examined how the kinematics and energetics of the projectile affected puncture mechanics. Depth of penetration (a measure of the effectiveness of puncture) is closely correlated with the kinetic energy of arrows during flight, more so than either momentum or velocity. These results demonstrate the important role energy plays in ballistic puncture mechanics. By expanding the scale of analyses in future work, we hope to establish a common ground for comparing ballistic puncture behaviors across biological scales, opening the door to exploring the evolution of biomechanical systems across major clades.

53-4 ANDERSON, R.A.; Western Washington University; Roger.Anderson@wwu.edu

Consequences of annual variation in ant availability and use by the Desert Horned Lizard

Given low primary productivity and the constraints of high heat and predators in deserts, then maximizing energy intake when foraging is presumed to be an imperative for desert lizards. Ants are the primary prey of the Desert Horned Lizard, *Phrynosoma platyrhinos* in a northern portion of the Great Basin desert scrub. The largest and most abundant ant species in the studied locale is the harvester ant *Pogonomyrmex californicus*, but this local ant species uniquely harbors a putatively harmful nematode parasite of *P. platyrhinos*. Hence, one could reasonably predict that energetics may not be the only factor in diet choice in this lizard. Moreover, reduced proportions of *P. californicus* in *P. platyrhinos* diets are expected in food-lean years relative to food-rich years because expansion of the diet to energetically less-preferred ants is expected in food-lean years. The foregoing ideas were examined using a variety of data sets over a 10 year period. These data sets included several methods of assessing spatiotemporal patterns of ant availability and analyses of the diet of *P. platyrhinos*, along with such outcomes as individual lizard body condition and annual recruitment into the lizard population.

44-2 ANDRIKOU, C.*; RUIZ-SANTIESTEBAN, A.J.; HEJNOL, A.; Sars International Centre for Marine Molecular Biology, Bergen; *carmen.andrikou@uib.no*
Tracing the origin of nephridia by characterizing excretion related gene complement in Xenacoelomorpha.

Excretion is the process of eliminating metabolic waste products from the system of the organism and can occur through passive or active transport. Active transport often takes place by ultrafiltration through specialized organs, named nephridia. The homology of nephridia is unsolved: although they show a great variation in morphology and development across bilaterians, recent studies have shown that the same orthologous developmental and structural genes are expressed in the nephridia of planarians and vertebrates. The phylogenetic position of the Xenacoelomorpha (comprised of the groups of Xenoturbellida, Nemertodermatida and Acoela), as possible sister group of all remaining bilaterians, and their lack of excretory structures make them a key group to study for understanding the evolutionary origin of nephridia. We investigated the putative role of candidate excretory genes by characterizing their expression patterns in two representatives of Xenacoelomorpha, the nemertodermatid *Meara stichopi* and the acoel *Isodiametra pulchra*, that differ in the morphology of their digestive tract. We focused on genes that either have a conserved role in nephridia development (e.g. *Sall*) or structure (e.g. *Neph*) in vertebrates and planarians. We also studied genes related to ammonia excretion (e.g. *Rh*) in crustaceans, planarians, nematodes and vertebrates. Our results show that in nemertodermatids and acoels all excretion related genes are mainly expressed in components of the reproductive and digestive systems as well as in individual - yet uncharacterized - cells. Our results hint at the presence of a not yet described excretory mechanism in Xenacoelomorpha, which could function as an early active transport system.

120-4 APANOVITCH, E.K.*; RIDDELL, E.A.; SEARS, M.W.; Clemson University, Clemson University; *eapanov@clemson.edu*
Stressed to the limit: Implications of geographic variation of stress across the range limit of a lungless salamander, *Plethodon metcalfi*
 Integration of physiological mechanism and the timescales over which they act can improve our ecological predictions under warming scenarios. The timescale over which stressors are experienced and the duration of the stress response they produce, influence the ecological capacities of an organism through alteration in energy allocation regimes. Organisms face challenges from warming, drying, variable temperatures, and fluctuations in vapor pressure deficits. Yet, interactions between these factors are often ignored. The natural gradients of temperature and humidity in the Southern Appalachian Mountains allow for the use of space for time substitutions to study to effect of climate on terrestrial salamander stress responses. To test for geographic variation of stress, we collected woodland salamanders from the latitudinal and elevational extent of their range. We obtained blood and fecal samples from each individual and analyzed leukocyte ratios and fecal corticosterone levels as metrics of stress. We compared findings to fine-scale environmental data over varying timescales. Leukocyte ratios indicated greater stress with drier air for all individuals, and with warmer temperatures for small individuals. Fecal corticosterone levels do not correlate to leukocyte ratios, suggesting the time course over which stressors interact are important to the physiological response. *Plethodon* species may mount in response to changes in climate. These findings indicate geographic areas where range contractions may occur due to increases in both the mean and the frequency of abiotic stressors.

59-6 ANGELI, N. F.*; FITZGERALD, L. A.; Texas A&M University; *nangeli@tamu.edu*

Heat tolerance lability in Caribbean lizards

Species may respond to climate change through adaptation, phenotypic plasticity, or the cumulative ability of individuals to acclimatize. Species with limited capacity to exploit changing environments should decline more often than species with the capacity to adjust. These two responses, persistence and decline, may be buffered by life history and physiological traits, or other mechanisms like behavior. In accordance with the climatic variability hypothesis, we predicted that more widespread species would have more capacity to respond to extreme heat under experimental conditions and in predicted climate scenarios. Ground lizards (*Ameiva spp.*) are widely distributed habitat generalists that live in warm heterogeneous environments. Thermal lability across populations may offer insights into heat tolerance. We measured morphological and physiological traits at 17 geographically isolated sites across the Puerto Rican Bank for more than 120 individuals among the 3 species of ground lizards in the *Exsul* Group: the widespread and persistent *Ameiva exsul*, the coastal forest restricted and declining *Ameiva wetmorei*, and the offshore island restricted and critically endangered *Ameiva polops*. Experimentally, population means for the widespread *Ameiva exsul* as well as the range-restricted *Ameiva (wetmorei and polops)* diverged for heat tolerance and preferred temperature. Demonstrating population-level differences in heat tolerance within species currently restricted to single types of macrohabitat was contrary to our predictions. We speculate that microhabitat refugia and evolutionary history may be important drivers of thermal trait lability. We calculate the warming tolerance (heat tolerance ~ climate scenarios) to draw conclusions about whether adaptive capacity is a potential buffering agent to consider when predicting species responses to global warming.

56-2 ARMENDARIZ PEAVY, AJ; Humboldt State University; *aja511@humboldt.edu*

New data on effects of Sea Star Wasting Disease - SSWD

Mortality from disease may play a critical role in food web dynamics of the intertidal zone. The sea star, *Pisaster ochraceus*, is a keystone species in the intertidal zone and are currently being affected by Sea Star Wasting Disease (SSWD). We have noticed a drastic decrease in populations of sea stars on the north coast of the rocky intertidal since 2013. If the numbers of *P. ochraceus* are on the decline due to SSWD, then we might predict increasing populations of their prey population, which include chiton, limpets and other snail species. This could potentially result in an increased food supply for other Asteroids. Since July of 2014 we have sampled 4 transect bands, each 3 x 30 m. running from onshore to offshore on four different sites in Northern California. For each transect band we have recorded the number of stars and the following for each individual: disease status, radius, and location in the intertidal zone. Every 5 meters along each transect band we have also recorded the mobile invertebrate species within a 0.25m² quadrat. I predict that I will find increasing populations of snails, limpets, and chitons associated with declining populations of *P. ochraceus*. If my prediction is correct and the current population of stars is no longer able to maintain a steady-state population of their invertebrate prey, a new opportunity may develop for another predator in the intertidal zone.

511-2 ARMSTRONG, E.J.*; STILLMAN, J.H.; San Francisco State Univ.; UC Berkeley; armstrong@berkeley.edu

Transcriptomic response to environmental stress in porcelain crabs.

The intertidal zone is a dynamic environment where species zonate as a consequence of their relative tolerances to abiotic stress. In order to assess stress responsiveness among intertidal species, we utilized comparative next-generation sequencing to investigate the transcriptomic responses of two, differentially sensitive, intertidal species of porcelain crab (genus *Petrolisthes*) to natural variability in temperature and pH. Congeners were exposed to either a low-variability, ambient control or a high-variability stress treatment where temperature and pH were spiked, mimicking natural diel fluctuations. Gill tissue was collected from crabs exposed to a single temperature/pH cycle (naïve response) and from those exposed to several cycles over two-weeks (acclimated response). Genes strongly differentially expressed included those involved in acid-base regulation (VHAs) and stress recovery (HSPs), and patterns of expression differed significantly between species in ecologically relevant ways. Although *P. manimaculus* exhibited a greater degree of expression change, nearly five times more genes were differentially expressed in *P. cinctipes*. In addition, for *P. manimaculus*, expression changes at a given exposure did not differ significantly between stress and ambient treatments whereas both naïve and acclimated individuals of *P. cinctipes* showed strong, stress-specific alteration in expression of acid-base regulatory genes. These results suggest that *P. manimaculus*' sensitivity to abiotic stress may be a result of a reduced stress response generally, and a limited capacity to alter expression of acid-base regulatory proteins in particular. This reduced responsiveness may be a consistent feature among species susceptible to environmental stress, setting modern habitat limits and potentially acting as a primary determinant of winners and losers under future climate change.

74-1 BABONIS, L.S.*; MARTINDALE, M.Q.; Univ of Florida, Whitney Lab; babonis@whitney.ufl.edu

Seeing without eyes: Opsins and the evolution of photodetection in basal metazoans

Opsins are photosensitive proteins that mediate the detection of light in photoreceptive tissues. Although they were originally thought to be restricted to the eye, opsins are now known to be expressed in numerous extraocular tissues across animal taxa. *Nematostella vectensis* (the starlet sea anemone) is eyeless yet exhibits two demonstrable light-sensitive behaviors: larval phototaxis and photoinducible spawning. The genome of *N. vectensis* encodes over 20 unique opsin genes; whether they play a role in mediating either larval or adult photosensitive behaviors is unknown. We combined molecular techniques with behavioral assays to characterize photosensitivity in *N. vectensis*. Most of the opsins examined were expressed in the pharynx and/or mesenteries while others were dispersed in the body wall epithelium or localized to the distal tips of the tentacles. Interestingly, closely related opsins had dissimilar expression patterns, suggesting that duplication and functional divergence have been important mediators of opsin diversification in this lineage. To investigate the role of opsins in mediating light-sensitive behavior, we used morpholinos and pharmacological inhibitors of opsin signaling pathways to manipulate opsin function *in vivo*. Wild type larvae exhibit chaotic phototaxis, swimming up in the water column in response to light; knockdown of opsin function resulted in a reduced capacity for this behavior. Additionally, the normal photoinducible spawning response of adult female polyps was inhibited upon disruption of opsin signaling. Together, these data suggest a role for opsins in regulating diverse photosensitive behaviors in an eyeless organism.

80-6 ASTLEY, H.C.*; MCINROE, B.; GONG, C.; KAWANO, S.; BLOB, R.; CHOSET, H.; GOLDMAN, D. I.; Georgia Institute of Technology, Univ. of California, Berkeley, Carnegie Mellon University, National Institute for Mathematical and Biological Synthesis, Clemson University, Carnegie Mellon University; henry.astley@physics.gatech.edu

Crucial advantages of tail use in the evolution of vertebrate terrestrial locomotion.

In the invasion of terrestrial environment, the first tetrapods faced the challenge of locomotion on complex, flowable substrates (e.g. sand and mud), sometimes oriented at inclines. Although the morphology of many early tetrapods is known from fossils, robotic studies have revealed that effective locomotion on these substrates also depends strongly upon kinematics; slight differences in movements of the same appendage can lead to success or failure. Using a model organism (the mudskipper) and a robotic physical model, we demonstrate how muscular tails provided critical locomotor advantages on granular substrates that the first invaders of land likely encountered. Mudskippers use their tails for additional propulsion with increasing frequency as the slope of the granular material increases, and the decline in locomotor performance with slope is shallower when the tail is used. Experiments with a robotic model of the mudskipper showed that, while the tail did not always provide a benefit to locomotion, use of the tail made the robot's performance more robust, achieving effective locomotion on a wider range of slopes, limb postures and foot placements than without tail use. These results suggest that, rather than simply being an inert appendage, the tails of early tetrapods were vital to their first forays into terrestrial habitats, even if limb use was limited.

100-3 BADGER, MA*; WANG, H; DUDLEY, R; Univ. of California, Berkeley, Nanjing Univ. of Aeronautics & Astronautics; badger@berkeley.edu

Avoiding topsy-turvy: how Anna's Hummingbirds (*Calypte anna*) fly through upward gusts

Hummingbirds are stable fliers under a diversity of challenging environmental conditions. In turbulent flow, hummingbirds adjust their wing kinematics on a stroke-by-stroke basis and both incline and fan their tails to improve stability. To better understand how hummingbirds modify their wing and tail motions in response to individual gusts, we filmed Anna's Hummingbirds as they negotiated an upwards jet of air moving at 10 m/s. As birds entered, flew within, and then exited the gust, they demonstrated a sequence of pitch-up, upwards, and pitch-down motions, respectively. Together, these perturbations frequently caused a dramatic decrease in body angle (i.e., a nose dive) as birds exited the gust. Birds exhibited large variation in average wing elevation, tail pitch, and tail fan angles among trials as they repeatedly negotiated the same gust. After extracting three-dimensional kinematic parameters, we identified those circumstances under which birds used different techniques to negotiate the gust, and determined the effect of each technique on the subsequent trajectory. Finally, we demonstrate that a hummingbird-sized glider with a bio-inspired and passively deflectable tail can successfully negotiate the same gust.

85-6 BAGGE, LE*; KINSEY, ST; JOHNSEN, S; Duke Univ., Univ. of North Carolina Wilmington; laura.bagge@duke.edu

The limits of an invisibility cloak: transparent shrimp become opaque after multiple tail-flipping escapes

Whole-body transparency, an apparently effective camouflage strategy in many aquatic species, can be disrupted by environmental/physiological stressors. In this study, we found that tail-flip escape responses temporarily disrupt the transparency of the anemone shrimp *Ancylomenes pedersoni*. After as few as three tail-flips, the previously transparent muscle fiber bundles within certain regions of the shrimps' abdomens become visibly opaque. Eliciting additional tail flips to the point of exhaustion (16 ± 3 SD; $n=23$) resulted in further increases in opacity, though the original transparency returned after approximately three hours of recovery. We hypothesize that increased perfusion, or an increase in blood volume between muscle fibers, can disrupt the normal organization of tissue, creating regions of low refractive index fluid between high refractive index fibers, resulting in increased light scattering. Our study measures pre- and post-contraction perfusion via (1) the injection of Alexa Fluor 594-labeled wheat germ agglutinin (WGA) that labels the sarcolemmal areas in contact with hemolymph, and (2) the injection of 0.2 μ m fluorescent microspheres that remain in the smallest perfused spaces. Additionally, we use transmission electron microscopy to quantify ultrastructural changes in the muscle tissue that becomes opaque after exertion. Comparing sections of opaque and transparent muscle tissue from this transparent shrimp species, as well as comparing the shrimp tissues that become opaque after exertion with tissues from a previously studied, non-transparent shrimp species, will help us understand how transparency can be disrupted.

71-4 BAHLMAN, J*; ALTSHULER, D; University of British Columbia; batman@zoology.ubc.ca

Kinematics used to modulate lift production in zebra finches

Birds naturally perform many behaviors that require modulation of their aerodynamic force production via changes in wing kinematics. Although considerable work has been done on wingbeat kinematics used to vary flight speed, a proxy for modulating thrust, comparatively less work has been done on how birds modulate lift, other than in hummingbirds. To examine this in forward flight, we trained zebra finches (*Taeniopygia guttata*) to fly carrying varying amounts of weight, up to 75% body mass, which required birds to generate corresponding magnitudes of lift. We examined two types of kinematics: kinematics that could affect aerodynamic force through increasing wing velocity (amplitude, frequency, downstroke ratio); and kinematics that affect force through changing wing shape (wing folding). For the kinematics that affect wing velocity, we found that birds increase wing velocity with increased weight through increasing wingbeat amplitude but not wingbeat frequency. Although, these parameters both have an equal effect on wing velocity and therefore force production, the preference for increasing amplitude and not frequency implies an energetic difference between the two. This hypothesis was confirmed with a work loop preparation. Downstroke ratio decreased with increasing weight, indicating the birds used a shorter and faster downstroke to generate greater downstroke velocity and lift. For kinematics that affect wing shape, birds folded their wings to a greater extent during upstroke as they carried increasing weight. Upstroke naturally produces counterproductive forces, i.e., negative lift, and folding reduces the negative lift thereby increasing net lift. Overall, birds increase net lift production with kinematics that produce a combination of increasing positive lift during downstroke and decreasing negative lift during upstroke.

19-1 BAGGETT, C.L.*; ANTHONY, C.D.; HICKERSON, C.A.M.; FELDHOFF, R.C.; John Carroll University, University Heights, OH, University of Louisville, KY; cbaggett17@jcu.edu

The Role of Pheromone Differences in Lineage Maintenance

Protein pheromones are undergoing rapid directional selection in salamanders of the genus *Plethodon*. Variation in mate recognition components, such as the sex-specific pheromones used by plethodontid salamanders may play a role in sexual incompatibility and therefore the maintenance of isolated, genetically distinct populations. Recent studies suggest that multiple, distinct lineages of *Plethodon cinereus* are present throughout their range. Three of these lineages are represented in northern Ohio, located along the southern shore of Lake Erie. This distribution creates a unique opportunity to study differences within species and across populations. The three goals of this study were to (1) determine if the ability of males to recognize potential mates is equal within and between lineages, (2) characterize the pheromone profile of *P. cinereus* and interpret this in the context of pheromone delivery evolution and (3) make a comparison of pheromone profiles across populations of the three distinct lineages within *P. cinereus* in Ohio. Male *P. cinereus* were collected from 9 localities across northern Ohio (3 populations from each lineage). To test the ability of animals in each lineage to recognize potential mates, males were exposed to the odors of both sympatric and allopatric females, as well as an odorless control. Recognition of these scents was quantified using the number of nose taps performed by the male during a 15 minute observational trial. Pooled samples of male courtship pheromones from each population were biochemically characterized and relative ratios of specific pheromone isoforms were compared across groups.

57-6 BAIER, D*; MORITZ, S; CARNEY, R; GARRITY, B; Providence College, Brown University; dbaier@providence.edu

Alligator (*Alligator mississippiensis*) shoulder girdle motion during walking

Alligators have played a significant role in evolutionary studies of archosaurs. Given that several major shifts in forelimb function (including 2 of the 3 origins of vertebrate flight) occur within this group, living crocodylian forelimb movements are of particular importance in assessing archosaur locomotor transitions. Previous X-ray investigations of walking alligators revealed substantial movement of the shoulder girdle, but since the sternal cartilages do not show up in X-ray, the source of the mobility could not be conclusively determined. Scapulocoracoid movement was interpreted to indicate independent sliding of each coracoid at the coracosternal joint; however, rotations of the entire shoulder girdle (both sternal cartilages + interclavicle) could also produce a similar outcome. Here, we present new data employing marker-based XROMM (X-ray Reconstruction of Moving Morphology) wherein simultaneous biplanar X-ray video and surgically implanted radio-opaque markers permit clear measurement of the vertebral axis, sternum and coracoid in walking alligators. We found that rotations of the sternum and coracosternal joint movement both contribute to shoulder girdle mobility. The few studies on coracosternal movement relevant to archosaurs were limited to either single X-ray views or standard light cameras and revealed conflicting data in lepidosaurs. Thus, mobility of the shoulder girdle in ancestral archosaurs remains unresolved. However, the loss of the clavicle in Crocodylomorpha may explain the increased mobility in the alligator shoulder girdle, suggesting that the degree of mobility may be unique to this group.

63-2 BAKER, EM*; HESSEL, AL; NISHIKAWA, KC; Northern Arizona University; emb324@nau.edu

Effects of Titin and Age on Muscle Stiffness

The property of muscle stiffness, though extensively studied, is poorly understood. Past experiments have described the stiffness in whole muscles, muscle tendon units, and individual muscle fibers. Muscle stiffness plays a role in stabilizing muscles during force production and reducing energy costs. In this study, the effects of titin and age on both active and passive muscle stiffness were tested using an eccentric workloop technique. The soleus and extensor digitorum longus muscles from wildtype, muscular dystrophy with myositis (mdm), and aged mice were extracted to determine how titin and age affect whole muscle stiffness. The stiffness of the muscle was assessed calculating effective Young's Modulus. The effects of age, genotype, and stimulation were analyzed using 3-way ANOVA and ANCOVA tests comparing age, genotype, and stimulation. Wildtype mice had a larger active stiffness for both EDL and soleus than mutants ($p < 0.0001$). For passive muscle, the mutant EDL was significantly stiffer than other muscles ($p < 0.0001$). The EDL increased in stiffness up to 250 days ($p = 0.0009$) before it dropped by almost 50% at 400 days. In the soleus, the stiffness was still increasing at 400 days ($p = 0.0013$), but at a slower rate than 30-250 days. The genotype data show that a deletion in the N2A region of titin significantly affects muscle properties like stiffness, though the mechanism by which this happens is yet unexplained. With age, the rise in muscle stiffness may also be due to an increase in connective tissues such as collagen, with the disparity seen between the two muscle types attributable to either differing muscle fiber types, titin isoforms, or both. Overall, this study opens the way to further investigation of the effects of titin on muscle stiffness and the mechanism responsible for enhanced muscle properties in healthy muscles.

42-6 BALAKRISHNAN, CN*; BERGLAND, AO; WARREN, WC; GONSER, RA; TUTTLE, EM; East Carolina University, Stanford University, Washington University, Indiana State University; chrisbala10@gmail.com

Divergence and degradation of a polymorphic supergene

Chromosomal inversions are thought to contribute to adaptation and speciation as they reduce recombination, protecting favorable combinations of alleles. White-throated sparrows *Zonotrichia albicollis* are a remarkable species in which a large inversion on chromosome two is perfectly associated with a suite of behavioral and morphological characteristics that define two "morphs" within the species. This polymorphic inversion, in combination with disassortative mating, leads to the stable maintenance of the two morphs within the species. Among the behavioral traits that vary predictably by morph are key aspects of social behavior including levels of aggression and parental care in both sexes. The unique features of this system have made white-throated sparrows a model system for the study of social behavior. With this in mind, we sequenced and assembled the genome of this species. Doing so, in combination with pooled whole genome resequencing and phylogenomic approaches, enabled us to resolve the evolutionary and demographic history of the inversion. As expected, we find high levels of divergence between the two chromosomal morphs including divergence in multiple candidate genes for behavioral variation. Because one of the two alleles exists in a perpetually non-recombining state, we also find evidence of degradation, akin to Y and W sex chromosomes. Lastly, we find dramatically reduced polymorphism across the inverted chromosomes, a pattern likely attributed to enhanced purifying selection.

3-2 BALABAN, JP*; AZIZI, E; Univ. of California, Irvine; jbalaban@uci.edu

Reduced metabolic rate mitigates muscle atrophy in western fence lizards

Hibernating mammals can resist muscle atrophy despite months of inactivity by lowering their body temperature and activating novel physiological pathways. However, since they employ both strategies simultaneously, the effects of the two mechanisms cannot be separated. In this study, we use the western fence lizard, *Sceloporus occidentalis*, as an ectothermic model to determine whether a reduction in metabolic rate is sufficient to resist muscle atrophy. To induce atrophy, we severed the sciatic nerve to prevent contraction of the gastrocnemius muscle and housed experimental and control lizards at either 15° or 30°C for 6-7 weeks on a 12/12 light/dark cycle. After treatment, we dissected out the muscles and used muscle ergometry to measure maximum isometric force (P_0), the force-velocity relationship, and contractile dynamics. We weighed and fixed the muscles at their optimal length for morphological measurements, and flash froze a subset, which we stained for NADH and ATPase to characterize fiber types. At 30°C, denervated muscles have a 20% reduction in muscle mass and a 12% reduction in P_0 , but no differences were seen at 15°C. In both treatments, no differences were detected between groups in muscle stress, shortening velocity or most contractile parameters. Although muscle atrophy in mammals is often associated with a shift from slow to fast fiber types, we found no difference in the percentage of SO, FG, or FOG fibers between treatment groups. We conclude that low metabolic rate is sufficient to prevent muscle atrophy in western fence lizards, and that atrophy in the lizard gastrocnemius is not associated with a change in fiber type composition or contractile dynamics. This work suggests that ectothermic vertebrates may have an intrinsic mechanism to resist muscle atrophy during seasonal periods of inactivity.

88-4 BALENGER, SL*; BASTIAANS, E; ZUK, M; Univ. of Minnesota, SUNY, Oneonta; sbalenge@umn.edu

Acoustic experience and social exposure during development alter adult reproductive tactics but not immune response in a field cricket

When sexual signals are perceived during growth and development they can provide information regarding the social conditions likely to be encountered as an adult. Perception of cues related to the presence and density of future mates and competitors can trigger plastic developmental mechanisms which result in adaptive phenotypes. Previous studies have shown that adult male *Teleogryllus oceanicus* field crickets from the island of Kauai, Hawaii reared alone and without hearing conspecific song are both strongly phonotactic, engaging in satellite behaviors when they hear a calling male, as well as reducing investment in body size and immunity. Such behavioral and physiological plasticity in response to the acoustic environment is particularly relevant for this particular population of *T. oceanicus* because a wing mutation has recently evolved there that renders >90% of males incapable of singing. Here we examined whether another source of population density information, i.e., the presence of other males, affects behavior, size, and immunity. Specifically, we examined satellite behavior, body condition residuals, and immune response by males reared singly and in groups in the presence or absence of conspecific song. Immune response did not vary with acoustic environment or rearing density; we therefore found no evidence for density-dependent prophylaxis. We did find, however, that males reared without song were significantly more phonotactic than those reared with song regardless of whether other individuals were present during their development or not. This finding suggests that song may be a special signal during development conferring information about adult mating competition, and that male crickets on the island of Kauai are likely engaging in adaptive satellite behavior regardless of population density.

510-7 BALIGA, Vikram B*; MEHTA, Rita S; Univ. of California, Santa Cruz; vbaliga@ucsc.edu

The Ontogeny of Cleaning in Fishes: Scaling Patterns Underlie Shifts in Feeding Strategy.

Body shape plays a crucial role in the movement of organisms. In the aquatic environment, body shape and the underlying axial skeleton components reflect the ability of organisms to propel and maneuver through water. Ontogenetic shifts in ecology (e.g. changes in habitat or feeding mode) may coincide with significant changes in body shape allometry. We use the evolution of cleaning behavior in the Labridae (wrasses & parrotfishes) as a case study. Cleaner fishes are species that remove and consume ectoparasites from other organisms. In many cases, cleaning involves a high degree of maneuverability, as cleaners on the hunt for parasites may continuously dart around the body of their clients. In the Labridae, at least 58 species are known to clean. Over two-thirds of these species, however, clean predominately as juveniles, exhibiting an ontogenetic shift away from cleaning as they enter adulthood. We examine features of the axial skeleton and pectoral fins in 31 species of labrids to assess how scaling patterns in these systems are associated with the ontogeny of cleaning behavior.

59-3 BANET, A.I.*; KUNKEL, K.E.; HINCH, S.G.; California State University, Chico, University of British Columbia; abanet@csuchico.edu

Maternal effects of stress: the influence of cortisol exposure and temperature on Sockeye salmon embryos

In recent years, many species have experienced environmental stressors that fall outside of the range they have historically experienced. In addition to direct effects on individuals, these stressors have the potential to influence the next generation via hormonally-mediated parental effects. In this study we examine how exposure to the stress hormone cortisol at fertilization influences the development rate and survival of Sockeye salmon embryos when incubated at a range of temperatures. To do this we collected eggs from female Sockeye salmon at the end of migration and exposed a subset of eggs from each female to cortisol baths to simulate high levels of maternal stress. We then incubated the eggs at two temperature treatments, one of which represents the upper bound of what the population has historically experienced. We discuss the effects of cortisol, temperature, and the interaction between the two on development rate and survival to hatch.

64-3 BAN, Y*; SMITH, B.E.; MALTBY, R; CONNOLLY, C; MARKHAM, M.R.; University of Oklahoma, University of Oklahoma, Health Science Center; yueban@ou.edu
Spatial uncoupling between sodium activated potassium channels and voltage gated sodium channels in electrocytes of the weakly electric fish *Eigenmannia virescens*

Weakly electric fish generate electric organ discharges (EODs) to navigate and communicate. The EOD waveform is determined by the morphology and subcellular localization of ion channels in the electric organ cells (electrocytes). To understand the role of electrocyte morphology and ion channel localization in shaping the EOD waveform, we used two-photon confocal microscopy to image electrocytes and immunohistochemistry to localize ion channels, ion transporters and Na⁺/K⁺ ATPases in *Eigenmannia virescens*. We found that electrocytes are highly polarized cylindrical cells ~1 mm in length and ~600 μm in diameter. The posterior face is deeply invaginated and vascularized with dense layers of vesicles beneath the membrane, while the main body and anterior face are relatively smooth. These cells initiate the AP with cholinergic receptors and voltage-gated sodium (Nav) channels localized only on the posterior face, and terminate the AP with sodium activated potassium (K_{Na}) channels which are restricted to the anterior face. The extreme compartmentalization of K_{Na} channels and Nav channels observed here is very different from mammalian neurons where K_{Na} channels are closely clustered with Na⁺ channels in microdomains. Computational simulations of electrocyte AP and sodium dynamics suggest that K_{Na} channels might be activated by lower Na⁺ concentrations than in mammalian neurons. To determine whether electrocyte K_{Na} channels have higher sensitivity to Na⁺ ions, we cloned the slack gene which encodes the K_{Na} channel in electrocytes. Alignment of amino acid sequences of the slack channels expressed among *E. virescens* electrocytes and mammalian neurons shows amino acid substitutions in the sodium regulatory sites in electrocytes.

57-3 BANJANIN, B*; BURDEN, SA; MOORE, TY; REVZEN, S; FULL, RJ; University of Washington, Seattle, Harvard University, University of Michigan, Ann Arbor, University of California, Berkeley; sburden@uw.edu

Estimating predictive dynamical models of legged locomotion from data

We seek dynamical models of legged locomotion that provide quantitative predictions for the response to novel perturbations and experimental treatments. Purely data-driven models cannot provide predictions for behaviors not included in the training dataset. Analytical reduced-order models crafted to study steady-state behaviors may give poor predictions following perturbations that induce transient behavior. We propose a method that mediates between these two extremes by estimating parameters for a family of spring-mass models directly from data. To test the proposed method, we made use of an experimental dataset involving large lateral perturbations and inertial load treatments applied to running cockroaches (*Blaberus discoidalis*), where kinematics of body and limbs were measured and dynamic quantities (velocities and accelerations) were estimated using a tuned Kalman filter. By fitting parameters for a potential energy function using an ensemble of stepwise acceleration time series, we estimate a predictive model that is piecewise-Hamiltonian, a piecewise-defined dynamical system that switches between conservative subsystems at step transitions. The resulting dynamical model provides better agreement with population-level average kinematic measurements and dynamic estimates observed in our dataset than existing analytical models. In future work, we will compare the estimated model's response to the measured perturbation and experimental treatment. More broadly, parametric models fit to empirical data provide an intermediary between data and analysis, enabling the experimentalist to generate new testable hypotheses and the analyst to reject inconsistent model mechanisms.

53-11 BARBER, Iain*; MACNAB, Vicki; ISMAIL, Zalina; University of Leicester, UK; ib50@le.ac.uk

Effects of changing temperatures on the host-parasite interactions of an ecologically important aquatic parasite

Global environmental change can influence the interactions between hosts and parasites, with consequences for parasite development, transmission and life cycle completion rates. Here we present results from recent experimental studies examining how increased temperature alters host-parasite interactions across the life cycle of the parasitic cestode *Schistocephalus solidus*. The effects of temperature on the growth of larval parasites in stickleback hosts were dramatic. Over a 16-week post-infection period, a 5°C temperature increase generated a fourfold increase in plerocercoid growth rate in experimentally infected fish, with all parasites reared in fish held at 20°C developing infective worms, compared to none held at 15°C. Furthermore, infected fish exhibited behavioural preferences for warmer temperatures, potentially generating a feedback loop accelerating parasite growth. Following the in vitro culture of adult worms, individual copepods (the 1st intermediate hosts of the parasite) were exposed to a controlled dose of *S. solidus* parasites and held under controlled temperatures. Infectivity of the parasite was quantified, and the subsequent growth rates of proceroids in host copepods was tracked over 6 weeks post-infection. Our results provide detailed information on the role of temperature dependent development of key developmental life stages of this parasite life cycle, and give insight into how life cycle completion rates might be altered under environmental warming. Our studies on this experimentally amenable model system demonstrate that anthropogenic global changes have considerable potential to influence the outcome of host-parasite interactions, with significant consequences for disease phenotypes and for life cycle completion rates under perturbed environments.

6-3 BAROUDI, RH*; PELINI, SL; Bowling Green State University; rbaroud@bgsu.edu

Interactive Effects of Litter Quality and Macro-Invertebrates on Litter Decomposition Rates Across a Successional Gradient

Disturbance in patches of Northern hardwood forests by periodic burns can lead to sequences of succession in which microbial and soil/litter dwelling invertebrate communities may vary in response to changes in tree and plant communities. The presence of many invertebrates, in particular detritivores, can drastically alter leaf decomposition as they make leaf material more readily available to microbes, which may result in varying decomposition rates depending on the stage of succession. This is significant as heterotrophic respiration during decomposition is a major input of carbon dioxide into the atmosphere, and the effects of invertebrates are often overlooked. Our study took place in Northern Michigan, along an experimental burn chronosequence consisting of 6 plots ranging in age from 20 to 100 years old. To examine the differences in decomposition along this successional gradient, we set out 3 treatments of litter bags in each plot, with each of the treatments being a composite mixture of leaves from either the oldest growth forest, mid-growth forest, or earliest growth forest. Two sets of replicates, one with a fine mesh and one with a course mesh, were created to illuminate the effects of invertebrate presence vs. invertebrate absence. We find that due to variation in plant and invertebrate communities, along with varying micro-climates, rates of litter decomposition vary across the sequence, with older plots showing accelerated rates of decomposition. The invertebrate-present replicates displayed accelerated rates of decomposition as expected. We also find that the litter mixtures most similar to their plot of origin decompose more efficiently, potentially due to home-field advantage effects of the microbial communities.

81-3 BARFIELD, SJ*; MATZ, MV; Univ. of Texas, Austin; sbarfield@utexas.edu

Genomic signatures of selection and gene expression divergence across thermal gradients in corals from the Great Barrier Reef

The Great Barrier Reef (GBR) extends across 15 degrees of latitude, corresponding to 3°C mean sea surface temperature difference between its northernmost and southernmost locations. Thermal gradients also exist within latitudes across the continental shelf, with inshore reefs experience up to 20°C higher midsummer temperatures than offshore reefs. Previous studies have shown that populations of the coral *Acropora millepora* exhibit differences in heat tolerance with respect to both latitudinal and cross-shelf (inshore-offshore) temperature gradients. However, no study to date has correlated genetic variation and gene expression across these temperature gradients. Here, we characterize population genomic signatures of selection in six *A. millepora* populations throughout the GBR, representing inshore and offshore locations, and examine the extent of gene expression divergence between coral populations from the warm low-latitude Wilkie Island and the cooler mid-GBR Orpheus Island. Our results highlight key physiological processes and regulatory mutations that may confer selective benefits on *A. millepora* populations, depending on the local thermal regime.

127-4 BASU, C*; HUTCHINSON, JR; WILSON, AM; Royal Veterinary College, University of London; cbasu@rvc.ac.uk

Walking kinetics and kinematics of the giraffe (*Giraffa camelopardalis*)

Giraffes (*Giraffa camelopardalis*) are ruminant artiodactyls whose large body mass combined with long, gracile limb and neck proportions render them highly derived in comparison to sister taxa. Neck and limb elongation is predicted to have functional consequences with respect to locomotion in giraffes. Previous studies have been confined to describing kinematics from a small number of trials, usually with single individuals. We have measured ground reaction forces and simultaneous 2D kinematics from three adult giraffes, from over 100 walking trials. Data were gathered over several days in an outdoor zoo enclosure. Giraffes were encouraged to walk over a forceplate array at their preferred speeds. We describe basic kinematic parameters (including stride length, stride frequency, duty factor and preferred speed), and relate these to peak vertical and horizontal forces. The three adults of similar size demonstrated a singlefoot in lateral sequence gait, using a preferred speed of 1.2m/s. At this velocity, the mean (of forelimb and hindlimb) duty factor was 0.67, peak forelimb vertical ground reaction force was 0.76x body weight, and peak hindlimb vertical force 0.4x body weight. Mean stride length was 2.3m, and mean stride frequency 0.5 Hz. Changes in walking speed were achieved both with an increase in stride length, and to a lesser extent an increase in stride frequency. The long neck of giraffes surely provides a high moment of inertia, which may in turn influence the acceleration and deceleration forces of the forelimb. We hypothesize that oscillations in neck angle are linked to the forelimbs' horizontal forces, and find that the peak neck flexion coincides with peak braking force in early stance, but is disconnected from peak propulsive force.

S4-7 BATTELLE, B-A; University of Florida, Whitney Laboratory; battelle@whitney.ufl.edu

Ocular and extraocular photosensitivity and opsin expression in the American horseshoe crab *Limulus polyphemus*, a chelicerate arthropod.

Limulus has been a favorite preparation for vision scientists since the 1930's; therefore much is known about its photosensitivity. More recently, the opsin repertoire and expression pattern in *Limulus* have been characterized. These data indicate that photosensitivity in *Limulus* is distributed widely and is complex. *Limulus* has a pair of image-forming lateral compound eyes (LE) and two types of "simple eyes": a pair of median ocelli (ME), and three pair of larval eyes (lateral, median and ventral) that persist in the adult. It also has photosensitive cells in its segmental ganglia and tail. A recent assembly of the *Limulus* genome revealed 18 opsin genes, many more than anticipated, and 17 are expressed. Ten, which are expressed in the eyes, have been characterized in detail. Some of these and additional opsins were detected in PCR screens of cDNA from segmental ganglia and tail, consistent with the presence of photosensitive cells in these tissues. However, *in situ* hybridization assays of segmental ganglia for opsin transcripts yielded negative results, suggesting opsin transcript levels are low in this tissue and preventing identification of opsin-expressing cells. There is one exception, however. *In situ* hybridization assays detected transcripts for peropsin1/RGR throughout the CNS, and immunocytochemical assays confirmed the expression of the protein in cells surrounding neurons. Some functions for the simple ME and larval eyes and photosensitive tail in *Limulus* have been identified. The relevance of photosensitive cells in the CNS of dark-shelled adult animals is unclear. However, for several years, at least, juvenile *Limulus* are largely transparent, and light stimuli may easily penetrate directly to photoreceptors in its CNS to influence behavior.

26-4 BAUER, C.M.*; KETTERSON, E.D.; GREIVES, T.J.; North Dakota State University, Indiana University; carolyn.marie.bauer@gmail.com

Reproductive development during vernal migratory preparation is not suppressed by the endocrine stress response in the Dark-eyed Junco (*Junco hyemalis*)

Birds use both photoperiodic and supplemental cues to time reproduction. For migrants, however, reproductive development must be temporarily halted until migration has been completed. Final transition into the breeding life history stage may be modified by the endocrine stress response, as the hypothalamic-pituitary-adrenal (HPA) axis has well-known suppressive effects on the hypothalamic-pituitary-gonadal (HPG) axis. We hypothesized that greater HPA-axis activity in migrants may act as a "brake" on the development of the HPG-axis. We predicted that prior to migratory departure, migrant birds would have elevated HPA-axis activity (also associated with hyperphagia and fattening) compared to resident birds. To test this prediction, we sampled baseline corticosterone (CORT), stress-induced CORT, and negative feedback efficacy of Dark-eyed Juncos (*Junco hyemalis*) in an overwintering population that included both migratory (*J.h. hyemalis*) and resident (*J.h. carolinensis*) individuals. Juncos were sampled in western Virginia in early March, which was about 2-4 weeks before peak migratory departure for migrants and 4-6 weeks before first clutch initiation for residents. Contrary to our prediction, we found that migrants had lower baseline and stress-induced CORT compared to residents. These results suggest that delayed breeding in migrants is affected by other physiological mechanisms. Additionally, our findings also suggest baseline CORT does not permissively enhance pre-migratory fattening, as migrants had lower baseline CORT and were fatter than residents.

91-1 BATZEL, G*; NEDVED, B.T.; HADFIELD, M.G.; University of Hawaii at Manoa; batzelg@hawaii.edu

Presence and Localization of Carbonic Anhydrase Genes in *Hydroides elegans*

Carbonic anhydrase (CA) is a metalloenzyme responsible for catalyzing the reversible hydration of carbon dioxide into bicarbonate. The CA-gene superfamily consists of five unique families (that arose independently from one another), with vertebrate and invertebrate lineages occupying the alpha-CA family. Although the original function of alpha-CAs appears to have been as a pH regulator, due to its ability to regulate bicarbonate production, it has also been co-opted for biomineralization processes in calcifying animals. Until now, no study has tested for the presence or expression of alpha-CAs in a calcifying marine annelid. The tube building polychaete, *Hydroides elegans*, is an ideal candidate for studying calcification, because it forms a calcium carbonate tube that adheres tightly to submerged marine surfaces. We have identified ten unique alpha-CA transcripts in transcriptomes from *H. elegans*, consistent with the eleven total isoforms found in a non-calcifying polychaete, *Capitella teleta*. Furthermore, we report the successful cloning, expression, and localization of a secreted and a cytosolic CA isoform, HeCA1 and HeCA2 in *H. elegans*. Transcripts of both genes were localized in the calcifying collar segment of competent larvae and juveniles, suggesting that a combination of externally and internally mediated calcification may be occurring. Finally, we constructed a model for protein evolution that supports extensive gene duplication events that took place within the alpha-CA family.

132-4 BAUMER, A.*; LEFTWICH, M.C. ; KATIJA, K. ; The George Washington University, Monterey Bay Aquarium Research Institute; abaumer@gwmail.gwu.edu

Larvacean locomotion: a kinematic investigation using ROV-sampled, high-definition videos

Larvaceans, a free-swimming tunicate, are found throughout the world's oceans. They filter their food (e.g. small plankton, detritus, particulates) by secreting complex house structures made of mucus. Once the filtration structures become clogged, larvaceans abandon the house and swim freely to another location before generating another mucus house. Estimates indicate that discarded mucus houses, which are abandoned by larvaceans once they become clogged, are responsible for one-third of the particulate transported to the bottom of Monterey Bay in Central California. Here we conduct a study of an undescribed larvacean, *Bathocordaeus sp.* (Tunicata: Larvacea), to examine their free-swimming and in-house behavior, and how changes in their body kinematics may alter fluid interactions. High-definition videos captured by remotely operated vehicles (ROVs) in Monterey Bay from 2003 to present were analyzed to extract the kinematics of larvacean tail motion during these two distinct behaviors. Using in-house Matlab algorithms, we reveal significant differences in stroke dynamics as traveling waves propagate along the larvacean tail. These kinematic differences may have important implications for swimming performance and fluid filtration rates through larvacean mucus houses.

33-4 BAYER, S.R.*; WAHLE, R.A.; BRADY, D.C.; JUMARS, P.A.; University of Maine; skylarrb@gmail.com
First in situ measurements of fertilization success and the influence of population density in the giant sea scallop
 Fishing down sedentary broadcast spawners challenges their reproductive success by depleting natural aggregations that are thought to promote high rates of fertilization. Here I present the first field experiments on fertilization success in the giant sea scallop, *Placopecten magellanicus*, a commercially valuable sedentary broadcast spawner in the Northwest Atlantic. Building on previous laboratory studies we (1) developed and tested a Nitex mesh chamber to measure relative rates of fertilization success *in situ*, and (2) assessed fertilization over a range of population densities using 24-h time integrated fertilization assays progressing from dockside field manipulations to natural population in a coastal estuary. Notwithstanding fertilization chamber artifacts, dockside results suggested that density effects might be detectable in more natural populations on the seabed. However, in both manipulated and natural populations spanning 10-fold differences or less, we could not detect a significant effect of density or nearest-neighbor distance on fertilization. We suspect that scallops in the field populations were not spawning synchronously on any given 24-h fertilization trial. If true, differences in fertilization may only be detectable across population density gradients in the event of mass, synchronous, spawning, or across more dramatic differences in population density that we could only produce in dockside manipulations.

45-6 BEECHKO, A/N*; GHOSSEIN, N; HORNER, A; GARLAND, T; AZIZI, M; California State University, San Bernardino, University of California, Riverside, University of California, Irvine; beechkoa@gmail.com
Effects of aging and exercise on musculoskeletal performance in two genetic strains of the house mouse, Mus musculus domesticus
 Mammalian muscles are extremely plastic, rapidly remodeling in response to exercise, disuse, or aging. Aging is associated with decline in muscle performance, whereas exercise results in mechanical or energetic changes that enhance performance. We aim to understand how exposures to regular exercise, and the genetic propensity for exercise, counteract age-related declines in muscle performance. Although numerous studies have documented age-related changes to muscle and locomotor performance, our understanding of how genetics and exercise alter the normal pattern of muscle ageing is limited. We use mice from two genetic lines (control and selected for over 70 generations for high wheel running) that were divided into four cohorts (Control/wheel access, control/no wheel access, HWR/wheel access, HWR/no wheel access) to test effects of exercise and genotype on muscle aging. We use muscle force-velocity relationships *in situ* for plantarflexor muscles to compare contractile performance in our cohorts. We predict that mice with genetic propensity for endurance running will have more slow fibers with higher endurance capabilities, resulting in slow contractile speed. We also predict that maximum shortening velocity of muscle fibers across both lines will decrease with age. Finally, we predict that mice from the young control group will have higher contractile velocity than HWR mice. Results of this study will serve as an important step in understanding how endurance training and age affect muscle performance. In addition, this study may provide insight into relative contributions of genotypic selection and phenotypic plasticity as mechanisms that determine muscle variation and performance.

31-4 BECKER, DJ*; ALTIZER, S; BENTZ, AB; CZIRJAK, GA; STREICKER, DG; University of Georgia, Leibniz Institute for Zoo & Wildlife Research, University of Glasgow; dbecker@uga.edu
Livestock-dense habitat functions as an ecological trap for vampire bats: immunological evidence
 Urbanization and agriculture cause declines for many wildlife, but some species benefit from human-provided food. The abundance and predictability of these provisioned resources can affect wildlife behavior and physiology and in turn alter infectious disease dynamics. Specifically, host condition and immune defense responses to resource shifts are key to understanding whether provisioning amplifies or dampens pathogen transmission. We here tested relationships between provisioning, host condition, and immunity through a cross-sectional study of vampire bats (*Desmodus rotundus*) in Peru and Belize. This hematophagous species has potentially benefited from intensification of livestock rearing, which could reduce starvation stress and energy spent during foraging, allowing bats to invest more in immunity. We predicted that bats captured in sites of high livestock density would be in better body condition, display less chronic stress and inflammation, and have higher investment in humoral immunity. Contrary to this prediction, however, we found increasing livestock density was associated with poorer condition, greater levels of stress and inflammation, and lower IgG, and that these negative health impacts were more severe in reproductively active bats. We also found that although livestock intensification was associated with impaired bat health, capture success increased with livestock density. Together these results suggest livestock-dense habitats could function as ecological traps by producing source populations of immunologically impaired vampire bats. Increasing the relative abundance of such habitat could have profound impacts on bat susceptibility to zoonotic pathogens and the spatial spread of infections.

S2-9 BEINART, Roxanne A.*; GIRGUIS, Peter G.; Woods Hole Oceanographic Institution, Harvard University; rbeinart@whoi.edu
Linking symbiont physiology to the ecology of chemoautotrophic symbioses
 Symbioses between prokaryotes and eukaryotes are ubiquitous in our biosphere, yet we still know little about the role that symbionts play in ecological and ecosystem processes. At deep-sea vents worldwide, dense populations of invertebrates host chemoautotrophic bacterial symbionts that use vent-derived reductants (e.g., H₂S) as energy sources for carbon fixation and provide primary nutrition for their host animals. However, despite the predominance of prokaryote-eukaryote symbioses in vent ecosystems, the ecological and biogeochemical effects of symbiont activity are poorly understood. Here, I present evidence that symbiont metabolism plays a substantive role in habitat use by vent symbioses. By pairing a regional-scale survey of vent symbioses in the context of their habitats with analysis of *in situ* gene expression, we discovered structured habitat partitioning that is consistent with the physiological tendencies of specific symbiont phylotypes. Additionally, experimental manipulations allying assessment of productivity, sulfur metabolism and gene expression demonstrated specific interactions with the environment. Through the metabolic activity of their microbial symbionts, vent symbioses are likely to both influence and be influenced by their abiotic and biotic environment. Thus, symbiont physiology may prove key to understanding the structure of vent communities, as well as local biogeochemical cycles.

119-2 BELANGER, RM*; MOONEY, LM; NGUYEN, HM; ABRAHAM, NK; PETERS, TJ; KANA, MA; MAY, LA; University of Detroit Mercy; belangra@udmercy.edu
Examining chemosensory recovery post-atrazine exposure in the crayfish (*Orconectes virilis*)

Environmental contaminants, such as atrazine, are known to have a negative impact on olfactory-mediated behaviors in aquatic animals. Previous research in our lab has shown that an acute atrazine exposure has harmful effects on olfactory-mediated behavioral responses to both food odors in crayfish *O. rusticus*; however recovery of chemosensory abilities has not been examined. In this study, we determined if recovery of chemosensory abilities after exposure to sub-lethal, environmentally-relevant concentrations of atrazine was possible. Atrazine-treated crayfish (*Orconectes virilis*; N=13) were exposed to 80 ppb atrazine for 96 hours. We then analyzed the ability of the control and atrazine-treated crayfish to locate a food source using a Y-maze. We used Noldus Ethovision to compare the time spent in the food arm of the Y-maze, near the food source, as well as moving and walking speed of control and atrazine-treated crayfish. We also compared the number of crayfish that handled the food source and the amount of food consumed. Following 24, 48 and 72-hour recovery periods in fresh water, behavioral trials were repeated to determine if there was any observable recovery of chemosensory-mediated behaviors. Overall, we found that crayfish are not able to recover chemosensory abilities 72 hours post-atrazine exposure. Because crayfish are a keystone species and rely heavily on their chemosensory abilities to acquire food, long-lasting impacts on chemoreception post-atrazine exposure could impact fitness and population size.

128-4 BENOIT, J. B. *; MICHALKOVA, V.; SZUTER, E. M.; MEDLOCK, J.; BAUMANN, A. A. ; ATTARDO, G. M. ; AKSOY, S.; University of Cincinnati, Slovak Academy of Sciences, Oregon State University, University of Tennessee, Yale University; joshua.benoit@uc.edu

Rapid autophagic involution of the tsetse fly milk gland is critical to the efficiency of lactation and population growth

Lactation in tsetse flies requires a dramatic increase in the expression and synthesis of milk proteins to nourish developing intrauterine progeny. In the recovery period following progeny birth, tsetse cease milk production and the milk gland undergoes involution within 24 hours. In this study, we examined the role that autophagy plays during milk gland involution. Autophagy genes show elevated expression in the milk gland immediately before or within two hours post-parturition, which decline within 24-48h post-parturition. This expression pattern is inversely correlated with that of the *milk gland proteins* (lactation-specific protein coding genes) and the autophagy inhibitor *FK506-bp1*. Increased expression of *Drosophila inhibitor of apoptosis 1, diap1*, was observed in the milk gland during involution, which likely prevents apoptosis of milk gland cells. RNAi-mediated knockdown of *autophagy related gene 8a (atg8a)* prevented rapid milk gland autophagy during involution, which prolongs gestation and reduces fecundity in the subsequent gonotrophic cycle. In addition, *atg8a* knockdown reduced the recovery of stored lipids during the non-lactating periods by 15-20%. Population modeling revealed that a delay in involution due to the suppression of autophagy yields a negative population growth rate. This study indicates that periods of autophagy in the milk gland during involution are critical to restore nutrient reserves and allow efficient lactation in subsequent pregnancy cycles.

70-2 BENHAM, P.M.*; CHEVIRON, Z.A.; University of Montana; phred.benham@umontana.edu

Genetic divergence predicts the degree of divergence in renal traits of salt marsh Savannah Sparrows

Studying the process of local adaptation is key to understanding population response to environmental change. Although differential selective pressures drive adaptive divergence, the degree to which populations are able to move toward local adaptive optima can be hampered by demographic processes, such as gene flow among populations, fluctuations in population size, and colonization history. Savannah Sparrows occupy salt marsh habitats along the Pacific coast, but phylogeographic analyses indicate salt marsh populations in California and Mexico differ in their degree of isolation from inland counterparts. Analyzing traits associated with osmoregulation within this phylogeographic framework provides a strong approach for inferring the role of demographic factors in shaping adaptive outcomes. Given that young populations experiencing more gene flow should exhibit reduced adaptive divergence, we predicted that California salt marsh sparrows, which are genetically similar to interior birds, would exhibit less divergence in traits linked to osmoregulatory performance than Mexican populations, which exhibit a longer history of isolation. To address this we collected data on kidney morphology (mass, medulla area, nephron number) and function (plasma and urine osmolality) from Mexican salt marsh, California salt marsh, and interior populations. We found an increase in the size and number of kidney traits as well as the plasma and urine osmolality of all salt marsh populations relative to interior birds. California populations, however, were less divergent from interior populations compared to the Mexican populations, suggesting that the lack of genetic divergence in California salt marsh populations has impeded adaptive differentiation to salt marsh environments.

30-3 BENTZ, AB*; BECKER, DJ; NAVARA, KJ; University of Georgia; abbentz@uga.edu

Species-specific traits shape patterns of yolk testosterone allocation in response to competition: a meta-analysis

Competitive interactions between females can result in permanent behavioral and physiological programming of offspring via hormone-mediated maternal effects. For birds, exposure to increased competition generally causes greater deposition of testosterone into their egg yolks. Increased yolk testosterone programs offspring to grow faster and be more aggressive, traits that appear beneficial for high-competition environments. Nevertheless, not all studies show a positive relationship between competition and yolk testosterone, and these studies are generally labeled as anomalies. However, if we address these studies from a species-specific context, rather than assuming a uniform "ideal" phenotype for a given environment, we may find that alternative allocation patterns of yolk testosterone in response to competition create phenotypes that are likewise beneficial. Transient changes in competition (e.g., breeding density) may elicit a hormonal response, but there are also other inherent, species-specific traits (e.g., solitary vs colonial breeders) that generate differences in competition and likely provide selection pressures that shape this response. To test this idea, we performed a meta-analysis using effect size of yolk testosterone allocation in response to competition. We used species-specific traits to account for inter-specific variation in yolk testosterone response and found that effect size was significantly moderated by several traits, in particular, coloniality. Applying a species-specific perspective helps contextualize studies that show little or negative response of yolk testosterone to competition and improves our understanding of how variation in this response evolved.

60-5 BERGMANN, P.J.; Clark University; pbergmann@clarku.edu
Pathways of convergence of snake-like body shapes in squamate reptiles

Snake-like body shapes have evolved convergently many times in all major clades of vertebrates. Although these species superficially look similar, it is unknown whether they have arrived at this convergent body shape through similar patterns of evolution of their body parts. Several clades of lizards have evolved snake-like body shapes and have multiple intermediate phenotypes between short-bodies with pentadactyl limbs and elongate bodies without limbs. The pathways of body part evolution were studied here for seven such clades of lizards: *Bachia*, *Brachymeles*, *Chalcides*, *Hemiergis*, two clades of *Lerista*, and *Scelotes*. Patterns of digit gain and loss, the integration of body parts, the occurrence of threshold relationships between body parts, and phylomorphospace occupation were compared among these clades to test whether they evolved their body parts following convergent pathways. On the one hand, clades had similar patterns of digit gain and loss evolution and integration of body parts. On the other hand, different clades had different pairs of traits related by threshold-like versus gradual relationships. Results from the phylomorphospace gave a complex picture of body shape evolution, but suggested that most clades evolved differently. These findings showed that although all seven clades have evolved similar snake-like body shapes, the evolutionary pathways that they followed to arrive at these body shapes differ, suggesting a lack of constraint in how body shapes can evolve.

121-1 BERTOLATUS, D.*; BARBER, L.B.; VAJDA, A.; University of Colorado - Denver, United States Geological Society;
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Transcriptome profiling in fathead minnow following exposure to complex chemical mixtures

Many chemicals including pesticides, pharmaceuticals, surfactants, and plasticizers have been detected in surface waters. Several of these chemicals of emerging concern [CECs] have been shown to cause adverse outcomes in aquatic organisms. Although a large body of research exists documenting the effects of exposure to single chemicals in laboratory settings, aquatic organisms are exposed to complex mixtures of chemicals that vary in time and space. A better understanding of the biological consequences propagated by exposure to environmentally relevant, complex mixtures of CECs is needed for effective regulation and management of ecosystems. Transcription profiling provides information on a wide range of physiological processes that are potentially affected by exposure. To characterize effects caused by contaminant mixtures, we exposed cultured fathead minnows (*Pimephales promelas*) to water from 4 different rivers in flow-through mobile laboratories in the fall of 2014. The exposure locations were chosen to capture unique landuse types, including agricultural, urban, mixed-use, and forested, thus presenting with different contamination profiles. We will measure genome-wide transcript abundance using microarrays in the livers of males exposed for 6 days. A hypothesis-driven approach will be used to test for changes in a subset of genes known to be sensitive to CECs, e.g. hormone receptors, steroidogenic enzymes, and xenobiotic receptors. We will use a systems approach to identify differentially expressed genes across all 60,000 microarray features. The DEG lists will be analyzed for enrichment of genes associated with specific cellular pathways and biological processes using GSEA and SNEA.

58-1 BERNARDO, M.A.*; SINGER, M.S.; Wesleyan University, Wesleyan University; mbernarado@wesleyan.edu

Nutrient-mediated manipulation of host feeding behavior by a parasitoid

Parasites often manipulate the physiology and behavior of their hosts in ways that benefit parasite fitness. Host feeding behavior represents a potentially powerful target of parasite manipulation because host diet is likely to have strong effects on parasite fitness. Here we investigate how a parasite's manipulation of its host's nutrient intake benefits the parasite. The parasitoid wasp *Cotesia nr. phobetria* specifically attacks the grazing caterpillar *Grammia incorrupta*. Previous work by others shows that *Cotesia* wasps manipulate extensively the biochemistry and physiology of their hosts. In our study system, we found that wasp-parasitized caterpillars consistently selected a carbohydrate-biased diet, which increased the body size of the developing wasps. This result provides evidence for adaptive parasite manipulation of host feeding behavior. We further hypothesized alternative mechanisms for this benefit to parasitoids: maximizing the nutrient supply to host tissue (fat body) that serves as a critical food source for parasitoid growth, and/or limiting nutrients required for maximal recovery of host immune function. In the latter case, we reasoned that the feeding duration of parasitoids might be limited by the rate at which the host's immune response recovers to full strength. We analyzed total lipid content as a proxy for fat body as well as immune function of parasitized and unparasitized caterpillars. Our preliminary results show quantitatively more lipid in hosts on the carbohydrate-biased diet after wasp emergence. We also found changes in the immunological melanization response of parasitized caterpillars over time on different diets. These results show how parasite manipulation of host nutrient intake can accrue multiple physiological benefits to the parasite.

127-7 BERTRAM, J.E.A.*; HASANEINI, S.J.; Univ. of Calgary; jbertram@ucalgary.ca

A focus on pendulums and springs leads walking and running analysis astray

For the last several decades the field of comparative locomotion mechanics has been dominated by analyses directed at documenting and assessing mechanisms of energy exchange (transduction) that occur within a stride. It has been thought logical that legged animals will benefit from reusing energy available from one portion of the stride in another portion of the stride. Increases and decreases of energy corresponding to patterns expected for pendulum-like and spring-like exchange do indeed occur. However, demonstration of such patterns does not indicate their value to the dynamics of legged locomotion. In order to evaluate the potential role of pendular and spring exchange in bipedal locomotion we use a dynamic optimization model to predict movement strategies that require the least energetic investment. Predictions of the model operating under specified circumstances are then compared with the spontaneous movement patterns of humans in the same circumstances. Successful prediction by the optimization strategy then allows detailed analysis of the model and the identification of the factors that determine cost optimization. It is found that spring-like leg motion is energetically favorable even if no energy exchange takes place (where cost of the motion has to be actively provided by positive and negative work). It is also found that the inverted pendulum is a favorable motion pattern for slower (walking) speeds, but the value of this strategy is dependent on limiting the energetic loss at transition between support limbs, rather than transferring energy from one portion of the stride to another. Identification of the factors involved in effective legged locomotion will allow the interpretation of the morphological and behavioral strategies implemented by legged organisms.

107-7 BERTRAM, R.S.; SCHOENFUSS, H.L.; LAGARDE, R.; PONTON, D.; DIAMOND, K.M.; OFFERLE, T.; BLOB, R.W.*; St. Cloud State Univ., Hydrom Réunion, UMR Entropie, Clemson Univ.; rblob@clemson.edu

Waterfall-climbing performance of gobiid fishes from La Réunion: how conservative are novel functional behaviors?

Several species of gobiid fishes from oceanic islands have evolved the ability to climb tall waterfalls. This behavior is most common among juveniles that are returning to adult stream habitats after completing a marine larval phase, and is facilitated by the fusion of the pelvic fins (in all gobies) into a ventral sucker. Previous observations identified two distinct modes of climbing. "Powerbursting" is found in many species and is likely the ancestral mode, with climbing powered by brief bouts of axial undulation between periods of attachment to the substrate. In contrast, "inching" is known only in the genus *Sicyopterus*, and is executed through alternating attachment of the pelvic sucker and a novel oral sucker. Comparisons among powerbursting species from Hawai'i and the Caribbean have shown a wide range of performance within this climbing mode; however, inching performance has only been measured in one species, *S. stimpsoni* from Hawai'i. To evaluate whether inching species might show less diversity in performance than powerburst climbers due to the more recent evolution of inching, or the demands of oral-pelvic coordination, we filmed climbing by two additional species from the Indian Ocean island of La Réunion: the inching climber *S. lagocephalus*, and the powerburst climber *Cotylopus acutipinnis*. For inching *S. lagocephalus*, climbing speed and the percentage of time spent moving closely matched previous results from *S. stimpsoni*; however, *C. acutipinnis* showed reduced climbing performance that differed from that measured in other powerburst species. Thus, the novel evolution of inching may restrict gobies to a more conservative range of climbing performance than powerburst mechanics.

S10-9 BHULLAR, B.-A.S.; Yale University; bhart-anjan.bhullar@yale.edu

Bird jaws and the origin of Aves

The avian body plan is profoundly modified compared to its distant reptilian antecedents. In the trunk, a series of transformations associated with flight are an obvious driving force behind this modification. However, the bird head is also dramatically different from that of other reptiles. Here I provide an overview of the steps leading from the early divergences of reptilia to the base of Aves, with a particular focus on the beak. There is now considerable evidence that the basic plan of the avian head is that of a juvenalized or paedomorphic theropod dinosaur. A dramatic reduction of the facial region ordinarily would lead to a very short rostrum, save that the avian premaxilla became hugely enlarged in compensation, to form the upper beak. At least a part of this transformation was enabled by the simple addition of a median zone of gene expression and proliferation early in the embryonic patterning of the face. Previously we published on the expression of two genes, *Fgf8* and *Lef1*, indicating signaling at two different embryonic time points; additional expression data support the general pattern. Moreover, the fossil record indicates that, as the premaxillae enlarged, the maxillae became concomitantly smaller. I will present some preliminary evidence that this occurred through a reduction of anterior proliferation and thus ossification in the maxillary primordia. Finally, I will show that new data from fossil taxa support a dramatic and sudden transformation of both the upper rostral and the palatal skeleton near the crown clade aves, perhaps suggesting a discrete developmental shift. I will then review the limited data on the possible function of the beak at its origin, and will cautiously speculate about its role as a prehensile organ replacing the hands.

119-7 BEVAN, E*; WIBBELS, T.; NAVARRO, E.; ROSAS, M.; NAJERA, B.; SARTI, L.; ILLESCAS, F.; MONTANO, J.; PENA, L.; BURCHFIELD, P.; University of Alabama at Birmingham, 1300 University Boulevard, Gladys Porter Zoo, 500 E Ringgold St, Brownsville, Texas, Gladys Porter Zoo, 500 E Ringgold St, Brownsville, Texas, CONANP, Nicolas Bravo 35, Ciudad Victoria, Tamaulipas, Mexico, Gladys Porter Zoo & CDEN, SC Calle Simon Castro, Ciudad Madero, Tamaulipas, Mexico, Gladys Porter Zoo; libby84@uab.edu

Using Unmanned Aerial Vehicle (UAVs) Technology for Locating, Identifying, and Monitoring Courtship and Mating Behavior in the Green Sea Turtle (*Chelonia mydas*)

The rapidly advancing field of unmanned aerial system (UAS) technology is becoming more widely used in wildlife biology and conservation. UAS technology provides many benefits that enhance the collection of data from a variety of study areas, including remote areas that are difficult to access. In particular, unmanned aerial vehicles (UAVs) are highly applicable platforms for identifying and monitoring sea turtles in their in-water habitat. This technology can facilitate ecological and behavioral studies of courtship and mating activities in sea turtles since these behaviors often occur in nearshore areas adjacent to nesting beaches, near or at the water's surface, and these behaviors can occur for long periods of time. In the current study, the courtship and mating behavior of green sea turtles off a nesting beach at Rancho Nuevo, Mexico, were recorded using a commercially available UAV. A variety of behaviors were observed including some novel behaviors, and some that have been previously described for green turtles. Further, the results exemplify the applicability of UAS technology for studies of adult green sea turtles in nearshore waters.

S8-5 BINFORD, GJ*; ZOBEL-THROPP, PA; BINFORD, Greta; Lewis and Clark College; binford@lclark.edu

How the brown recluse got its bite: evolutionary assembly of the unique venoms of sciarid spiders

Venoms are complex phenotypes with a large and diverse set of interacting molecular components. Spider venoms have deep evolutionary histories, and are strikingly complex. There are many phylogenetically widespread toxin lineages in spiders, however some have narrow distributions and reflect rare recruitment events of new venom toxin activities. The sciarid spider family includes the brown recluse and over 100 congeners in the genus *Loxosceles*. These are generalists living in dry habitats and caves. Brown recluse bites cause dermonecrosis in mammals. A toxin gene family with phospholipase activity (*SicTox*) causes these lesions. Comparative analyses indicate *SicTox* expression in venoms is limited to sciarids, consistent with recruitment of the gene family before the most recent common ancestor of this taxon. We address the hypothesis that with the evolutionary recruitment of new bioactive toxins in venoms, other lineages will undergo changes as part of the changing molecular functional complex. We predict that, coincident with recruitment of *SicTox* proteins, other toxin lineages have changed in presence, abundance, or adaptive evolution of function. We present comparative venomomic data that integrate HiSeq transcriptomes of venom glands, and Orbitrap proteomic analyses that identify and compare gene families contributing to venom proteomes. We also present results of comparative analyses of evolutionary dynamics of these gene family lineages. Our dataset includes sampling across representatives of diverse sciarids with common ancestry spanning ~10 - 120 million years, and a range of non-sciarid haplogynous spiders including three taxa in their sister lineage (*Drymusa*, *Periogops*, and *Scytodes*) and other haplogynes including pholcids and plectreuids.

37-5 BLOUIN, N.A.*; SALOMAKI, E.D.; LANE, C.E.; University of Rhode Island; nblouin@uri.edu

My brother's keeper: Adelphoparasitism in red seaweeds

By far, the largest numbers of formerly photosynthetic parasites are found among the red algae. Nearly half the floridiophyte orders in the red algae contain parasitic taxa and there appear to be nearly a hundred independent parasite lineages within the group. Because there are so many independent evolutionary events of parasitism in the red algae and it appears that parasites have most often evolved from a common ancestor of their hosts, this is an intriguing group to explore the evolutionary changes concomitant with a transition from a free-living to parasitic lifestyle. For much of their life history many red algal parasites exist as a nucleus and a collection of mitochondria freely intermingling with the host's organelles and cytoplasm within host cells. As the first step in understanding how the parasite relationship has repeatedly evolved in the red algae and why parasites are so well tolerated as intracellular guests, we have sequenced the genome of the free-living red seaweed *Gracilariopsis andersonii* and *Gracilariophila oryzoides*, its obligate parasite with a combination of Illumina and PacBio sequencing. Their gene repertoire and synteny suggests that successful parasitic association among red algae results from similarity rather than evading host detection as is common among most other parasitic lineages.

49-1 BOCKUS, A.B.*; SEIBEL, B.A.; University of Rhode Island; abockus@my.uri.edu

Trimethylamine oxide accumulation as a function of depth in Hawaiian midwater fishes

Trimethylamine oxide (TMAO) is a common osmolyte and counteracting solute. It is believed to combat the stress induced by hydrostatic pressure as some deep-sea animals contain higher TMAO levels than their shallow water counterparts. It has also been proposed that TMAO may accumulate passively during lipid storage, a hypothesis that has not been directly tested. Previous research showed that lipid content decreased with depth in a population of Hawaiian fishes presenting a novel test of these competing hypotheses. We found that TMAO is positively correlated with habitat depth (hydrostatic pressure). We further showed using phylogenetic independent contrasts that this relationship was not influenced by the evolutionary relatedness of these 27 species. Interestingly, we found that lipid content increased with depth, in direct contrast to previous studies. TMAO is thus also positively correlated with lipid content. While we are unable to distinguish between these hypotheses, we show that TMAO is strongly correlated with depth in midwater fishes.

118-6 BOARDMAN, L.*; SORENSEN, JG; KOSTAL, V; SIMEK, P; TERBLANCHE, JS; University of Florida, Gainesville, Aarhus University, Denmark, Biology Centre of the Czech Academy of Sciences, Czech Republic, Biology Centre of the Czech Academy of Sciences, Czech Republic, Stellenbosch University, South Africa; boardman.leigh@gmail.com

Metabolomic profiling of hypoxia responses at low temperatures in a chill susceptible insect

Insect chill tolerance depends on the ability to withstand alterations in cellular homeostasis caused by low temperature exposure. Decreased oxygen availability (hypoxia) is known to interact with low temperature stress resistance, often improving insect survival. Here, we investigated whether the low temperature tolerance of larvae of a Lepidopteran chill susceptible pest, *Thaumatotibia leucotreta*, is affected by oxygen availability by measuring metabolic rate, critical thermal minimum (CTmin), supercooling point (SCP) and changes in 43 metabolites under varying oxygen conditions. The critical oxygen partial pressure (Pcrit) was determined to be 4.5 kPa, below which metabolic rate was suppressed. Altering the oxygen availability did not affect CTmin nor lethal SCP (=body freezing). Metabolomic profiling revealed the upregulation of some anaerobic metabolites and alterations in concentrations of citric acid cycle intermediates during and after chilling exposure. Hypoxia exacerbated the anaerobic metabolite responses. These results suggest that the chilling tolerance of *T. leucotreta* larvae is not oxygen limited, in keeping with the handful of other studies of tracheate arthropods that have investigated low temperature responses under altered oxygen levels. This study also presents clear evidence of some scope for anaerobic metabolism in *T. leucotreta*, which likely contributes to their ability to survive in necrotic fruit.

114-7 BODENSTEINER, B.L.*; WARNER, D.A.; IVERSON, J.B.; MILNE-ZELMAN, C.; MITCHELL, T.S.; REFSNIDER, J.M.; JANZEN, F.J; Iowa State University, Auburn University, Earlham College, Aurora University, The University of Toledo, Iowa State University; bodenbro@iastate.edu

Geographic variation in thermal sensitivity of early life-history traits in a widespread reptile

Organisms with large geographic distributions may experience a great diversity of climatic conditions. Therefore many of these organisms must locally adapt or exhibit phenotypic plasticity. These processes are of particular interest in organisms with traits that are intrinsically connected to temperature, including embryonic development. To examine potentially adaptive spatial patterns in a widespread vertebrate, we quantified early life-history traits of the painted turtle (*Chrysemys picta*) from seven distinct populations across its geographic range (Kansas, Illinois, New Mexico, Oregon, Minnesota, Idaho, and Nebraska). Eggs from these populations were incubated under constant conditions across a range of environmentally relevant temperatures. We measured incubation duration, hatchling body size and condition, and morphological abnormalities to quantify differences in phenotypic reaction norms across these populations. We hypothesized that incubation duration at a given temperature would vary among populations. Secondly, we predicted that northern populations would be more sensitive to thermal variation due to shorter seasons and more variable temperatures in nature. Better understanding spatial variation in key traits of these organisms will provide insights into current adaptations to local climatic variation and potentially into future phenotypic responses to projected global climate change.

50-4 BOGANTES, V.E.*; MAHON, A.R.; HALANYCH, K.M.; Auburn University, Central Michigan University; veb0007@auburn.edu

Genetic structure of *Polyeunoa laevis* (Annelida: Polynoidae) between Southeastern Argentinean waters and the Southern Ocean
The polychaete *Polyeunoa laevis* is a scale worm, often associated with gorgonians. This species shows a range of morphological variation; however, previous studies argued that two characters are useful for identification, shape of the neuropodial acicular lobe and most neurochaete being unidentate. Based on morphological studies, *P. laevis* is reported to be widely distributed in the southwest Atlantic, sub-Antarctic, and Antarctic regions. To assess if traditional morphological characters are useful in species identification, 93 individuals were sequenced for the mitochondrial marker COI. Sampling sites include Southeastern Argentina (SEA), West Antarctic Peninsula, Northeast Antarctic Peninsula, Weddell, Bellingshausen, Amundsen and Ross Seas. Preliminary molecular phylogenetic analyses recover 3 clades. One corresponds to the SEA region, a second clade includes most of the samples from east Antarctica and the Ross Sea, and the third clade includes most of the samples from west Antarctica. The two clades recovered from the southern ocean correspond to differences in the temperature of water masses. This study suggests some connectivity between the two clades found in the Southern Ocean, but genetic differentiation between the SEA and Southern Ocean. Open ocean barriers might be limiting the dispersal ability of this species and consequently impeding gene flow. Specimens from the SEA were also morphologically different suggesting a possible unrecognized species level diversity. More sampling sites with focus on the Argentinean waters and the East region of the Antarctic, combined with a more detailed morphological study, will help to elucidate the current taxonomic status and the genetic connectivity of these organisms.

103-4 BOLLA, R.*; PETERSON, A.; SUMMERS, A.P.; PAIG-TRAN, E.W.M.*; California State University, Fullerton, University of California, Irvine, University of Washington; rbolla@csu.fullerton.edu

First Evidence of Cyclonic Filtration in Mobulid and Manta Ray Filter Feeders

Mobulids, mantas and devil rays, use filter feeding to capture zooplankton prey that can be smaller than the pore size of their gill rakers. Filtering structure inside their dorso-ventrally compressed oral cavity consists of five branchial arches with each epi- and ceratobranchial surface containing two mirrored arrays of gill rakers. Crossflow filtration is the primary mechanism of particle entrapment, funneling particles toward the esophagus by way of tangential shearing between the flattened filter lobes and the parallel flow stream. Prior experiments with four fold enlarged 3D models of mobulid filter lobes have shown that a secondary mechanism, cyclonic filtration, acts to resuspend small particles that enter filter pore back into the flow stream. We studied the flow dynamics of mobulid gill raker models at actual size and in four fold enlarged models while varying flow velocity, gill raker orientation, angle of attack and secondary structures commonly found on filter lobes. We induced cyclonic filtration in actual sized models that mimicked the filter morphology of mobulid filter feeders by suspending models in a flow chamber with a die stream aimed at the filter lobes. Vorticity in the filter pore did not vary with scale, however the number of vortices increased with the flow velocity and decreased with increasing angle of attack. At smaller angles of attack the vortices stayed continuous within the pores, but extended in the lateral direction at steeper angles. This complex behavior of the vortices further strengthens the assertion that vortex filtration must play a significant role in the filter feeding mechanics of Mobulids.

54-8 BOK, M.J.*; PORTER, M.L.; NILSSON, D.-E.; Lund University, Sweden, University of Hawaii at Manoa, USA; mikebok@gmail.com

Looking with gills: The function and evolution of fan worm branchial photoreceptors

Fan worms (Sabellida) possess some of the strangest eyes in nature. Their eponymous fans are composed of two sets of radiolar tentacles that project up out of the worm's protective tube into the water column. Primarily used for respiration and feeding, these radioles are also often involved in photoreception. They express a surprising diversity of eyelets of varying levels of sophistication, ranging from scattered single ocelli to compound eyes with up to 1,000 facets. These photoreceptors are probably a relatively recent evolutionary development to cope with a sessile, tube-dwelling lifestyle, and the ancestral cerebral eyes (haplessly positioned within the tube) have degenerated to minute pigment cups with scant visual potential. The branchial radiolar ocelli on the other hand, appear to function as visual burglar alarms for detecting the silhouettes of looming predators and eliciting a startle response for the worm to rapidly retreat within its fortified tube. Despite sometimes resembling arthropod compound eyes, the branchial photoreceptors have ciliary membrane elaborations and hyperpolarize in response to light. Considering the unusual and apparently recently-evolved nature of the fan worm branchial photoreceptors, these animals are an excellent case for examining the emergence of novel visual systems and the development of rudimentary visually guided behaviors. Here we present molecular, anatomical and neurobiological investigations aimed at discerning the origins of branchial eyes in this group. We find a fascinating case of evolutionary pragmatism; a novel visual circuit likely emerging from preexisting components not previously implicated in visual systems.

32-5 BOND, S.R.*; BAXEVANIS, A.D.; National Human Genome Research Institute, NIH; steve.bond@nih.gov

A BLAST-free clustering method for classifying orthogroups

Inferred orthology (i.e., homology via speciation events) between or among genes is commonly used as a predictor of gene product function. Orthology is also a crucial consideration when classifying genes coherently and consistently across taxa, but the granularity of many popular ortholog prediction tools can be too coarse to properly resolve multiple clusters of closely related sequences in large gene families. Thus, classification is often at the discretion of curators following manual inspection of gene trees. In this work, we present a new effort to automate the classification of orthogroups from predefined sets of homologous sequences. In contrast to common ortholog prediction methods, AlignMe scores have replaced BLASTP E-values as the similarity metric between pairs of sequences. This provides a more refined input for Markov clustering (MCL), which is a popular method for grouping genes into orthogroups via weighted random walks through an all-by-all similarity graph. An issue with MCL, however, is its sensitivity to user-defined parameters. It is difficult to know *a priori* which parameters to apply and, if different groups of genes have undergone varying degrees of evolution, it may not be possible to select appropriate parameters for the entire dataset. To overcome this we have devised an MCL scoring method, which allows parameter optimization. Furthermore, recursive analysis of clusters by subsequent rounds of parameter optimization accounts for varying evolutionary rates among groups of genes. Our new approach has been named Recursive Dynamic Markov Clustering (RD-MCL), and it shows improved performance over established methods. RD-MCL will be of particular interest to those studying gene family expansion, as it provides an easy and objective mechanism for classifying likely orthogroups.

65-2 BONKA, AN*; HERNANDEZ, MH; ILLESCAS, FM; NAJERA, BM; MARTINEZ, LS; PENA, LJ; BURCHFIELD, PM; WIBBELS, TR; Univ. of Alabama at Birmingham, Gladys Porter Zoo, Brownsville TX, CDEN, Tamaulipas, Mexico, CONANP Ciudad Victoria, Mexico, CONANP Mexico City, Mexico, Univ. of Alabama at Birmingham ; abonka@uab.edu
Horizon Regime and Light Intensity Affect Sea-finding Orientation in Hatchling Kemp's Ridley (*Lepidochelys kempii*) Sea Turtles
 Sea-finding orientation in hatchling sea turtles represents a critical early life history event. The behavioral and physiological basis of this event has significant implications for the ecology, evolution, and conservation of sea turtles. In the current study, sea-finding orientation of hatchling Kemp's ridley (*Lepidochelys kempii*) sea turtles was investigated under two different naturally occurring horizon regimes (distinctive landward and open silhouettes) and under varying light intensity (5am, 6am, 7am). Hatchlings were monitored using time-lapse wildlife cameras and photos were reviewed immediately following trials. Results indicated sun position and horizon silhouettes represent major orientation cues affecting hatchling orientation. The results also provide insight for optimizing conservation strategies for programs that relocate nests. Nests relocated to areas with distinctly contrasting silhouettes between the landward and seaward direction reduces the amount of time hatchlings spend exposed to predators and/or desiccation on the beach during sea-finding. Finally, the results suggest that beach characteristics that enhance the efficiency of sea finding could represent a selective evolutionary pressure that contributes to the selection of optimal nesting beaches by sea turtles.

46-3 BORGMANS, G*; VAN DAMME, R; Department of Biology, University of Antwerp, Universiteitsplein 1, 2610 Antwerp, Belgium; glenn.borgmans@uantwerpen.be
Stress on the job: a case study of *Anolis carolinensis*
 Stress is known to affect the endocrinology, physiology and behaviour of a wide variety of animals. These responses may confound the results of scientific experiments or observations on captive study animals. The last few decades there has been an increased awareness of the importance of animal welfare and numerous studies have investigated stress and how to avoid it in model species such as small mammals, birds and even fish. Although many reptilian species are used as model species in various branches of biology, little is known on how they react to the stress induced by housing conditions or experimental treatments. One of the reasons for this neglect could be that it is difficult to assess stress levels in reptiles in an objective manner. In this study, we evaluated several methods of assessing stress in green anoles (*Anolis carolinensis*) and investigate how captive conditions influence these levels. Stress levels were gauged via behavioural and physiological measurements. Behaviour was scored via direct observations and time budgets were calculated. Physiological measurements included assessments of fecal corticosterone level, body condition, reflectance of the skin using photospectrometry and heterophil:lymphocyte ratio in the blood. We examined changes in response to three potential stressors: manipulation frequency, level of environmental enrichment and cage size. We hypothesize that a higher manipulation frequency, a lower level of enrichment and a smaller cage size will all lead to increased stress levels and concordant changes in behavioural and physiological indices.

18-1 BORCHERT, JD*; ANGILLETTA, MA; Arizona State University; jdborche@asu.edu

The effects of temperature and density on the fitness and behavioral choices of flies

The current theory of thermoregulation does not adequately predict how organisms thermoregulate in nature. One reason the theory fails is because it does not account for ways that an organism interacts with other organisms in its environment. To account these biotic interactions, we used game theory to predict how fruit flies, *Drosophila melanogaster*, should select sites when laying eggs. To determine how flies should optimally behave, we examined the fitness of flies at treatment types that varied in density, temperature, food quality, and available space. To calculate fitness we used flies which had experienced different temperatures either in the lab or in the wild and tracked their survivorship and fecundity under different treatment types. To look at how the flies actually behave, we observed where flies chose to lay eggs under various densities of competing females. In each trial, 4 or 15 flies were placed within a thermal arena containing a choice of two oviposition sites, one at a preferred temperature (25 C) and another at a lower temperature (20 C). We found that flies changed their behavior as density changed and how they changed their behavior depended on the other treatment variables. We then compared the choices these flies made to their calculated fitness's under each treatment type to determine if the flies were behaving optimally. By drawing on game theory to make quantitative predictions, this research builds on previous empirical studies of competition between thermoregulating animals.

10-6 BORSTEIN, S.R.*; WAINWRIGHT, P.C.; MCGEE, M.D.; University of Tennessee, Knoxville, University of California, Davis, EAWAG; sborstei@vols.utk.edu

Trophic shifts drive morphological diversification on reefs

The role of ecological specialization and the impacts it has on diversification is a necessity to better understand biological patterns associated with diversity. Coral reefs are some of the most complex and nutrient rich habitats in the world and harbor one of the most diverse communities of fishes. Here we investigate if trophic specialization drives rates morphological evolution in coral reef fishes. We gathered volumetric diet data from the literature and measured seven functional traits from lateral photographs of 318 species of coral reef acanthomorph fishes from the West Indies, Okinawa Island, Japan, and Kona, Hawaii. Dietary items were categorized into five different prey functional groups: evasive prey, planktonic prey, durophagous prey, attached prey, and plant matter. To determine if certain dietary specialists had faster rates of morphological evolution than others, we used the *r* package geomorph to calculate the multivariate rate of morphological evolution across the phylogeny. We performed three different versions of this analysis using different prey volume cutoffs for consideration of dietary specialization at 50%, 66%, and 75% consumption of a functional prey type. The main axis of morphological variation of the coral reef fishes in our data set is head elongation and depth, accounting for 49.8% of the variation. The extensiveness of the fork in the caudal fin and caudal peduncle length accounted for 14.5% and 11.1% respectively. When comparing rates of multivariate morphological evolution we find that fishes that specialize on evasive prey items have significantly higher rates of morphological evolution than other specialists and non-specialists across all three volumetric dietary cutoffs. Our results indicate that dietary specialization can be a major driver of morphological evolution in coral reef fishes.

42-1 BOSTWICK, CJ*; YANG, Q; KOHN, AB; HAWKINS, RD; MOROZ, LL; Univ of Florida, Gainesville, FL, Columbia Univ, New York, NY; cbostwick87@gmail.com

Genomic deciphering of memory-forming circuits in *Aplysia californica* at single-neuron resolution

Aplysia californica is a valuable model organism for the cellular analysis of behavior, including learning and memory. The neural circuits controlling the defensive withdrawal reflexes of this organism have been analyzed extensively, to the level of individual, functionally identified neurons. These circuits are capable of several forms of learning, including sensitization, habituation, and classical conditioning. We utilized single-cell RNA-seq to profile individual sensory and motor neurons known to control both the tail-withdrawal reflex (TWR) and siphon/gill-withdrawal reflex (S/GWR). We discovered a multitude of transcripts to be differentially expressed between the pleural ventrocaudal (VC) sensory neurons of the TWR and the abdominal LE sensory neurons of the S/GWR. These included transcripts encoding glutathione S-transferase, zinc-finger containing proteins, RNA-binding and processing proteins, a ribonucleoprotein, a 5-hydroxymethylcytosine-binding protein, and multiple uncharacterized transcripts (among others). We also analyzed differential expression between the LFs motor neurons contributing to siphon withdrawal of the S/GWR and the L7 motor neurons contributing to the gill withdrawal component of the S/GWR. Several transcripts were found to be differentially expressed including those encoding kinesin heavy chain, a G protein coupled receptor kinase, an NFX1-type zinc finger protein, a polyadenylate-binding protein, and uncharacterized transcripts. These differentially expressed transcripts may help us to distinguish between functionally similar neurons involved in defensive withdrawal reflexes and highlight the unique repertoire of molecules utilized by each circuit. Supported by NSF and NIH.

103-2 BOULLIART, M; DE MEYER, J; VAN WASSENBERGH, S; DE KEGEL, B; ADRIAENS, D*; ADRIAENS, Domini; Ghent University; dominique.adriaens@ugent.be

Potentials and limitations of modelling bite forces: implications of simplifying real life musculoskeletal systems to simplified 3D and 2D models

In case the bite force of an organism can't be measured in vivo, it can be estimated mathematically using static-state equilibrium models. However, these models represent different levels of simplifications of the reality. To investigate the impact of such simplifications of the musculoskeletal topography and the parameters describing muscle function, three different models are compared in this study. The first model describes the topography using 3D-coordinates and calculates muscle contraction force by using a series of parameters (including the muscle's origin and insertion, fiber and tendon lengths and pennation angle). As the lower jaw becomes depressed, this model accounts for changes in muscle physiology parameters according to this movement. The second model uses the same 3D-coordinates, but calculates muscle force based on the physiological cross section area (PCSA) of the muscle. In this model, the muscle force is a theoretical maximal isometric force that remains constant throughout the simulation of different gape angles. The third model projects lever arms and the muscle's line of action to the midsagittal plane and uses the PCSA (as measured in 3D) to infer muscle force. Input-data for these models is obtained from the European eel (*Anguilla anguilla*). Several isometric- and allometric-scaled morphs are deduced from a yellow eel specimen and implemented in the models. These results are compared, and validated against in vivo bite force data of yellow eels. Bite force calculations of earlier life stages (leptocephali and glass eels) were also simulated using the same models. These comparisons therefore allow defining constraints on the predictive power of different models generally used to calculate bite forces.

102-2 BOTTON-DIVET, L*; CORNETTE, R; HERREL, A; FABRE, A-C; HOUSSAYE, A; UMR 7179 MNHN/CNRS, Paris, UMR 7205 CNRS/MNHN/UPMC/EPHE, Paris, UMR 7179 MNHN/CNRS, Paris / Ghent Univ., Ghent, Duke Univ., Durham; lbottondivet@mnhn.fr

Is the forelimb of semi-aquatic mustelids adapted to locomotion in different environments? A morphometric study

The evolution of the locomotor apparatus is driven by the phylogenetic heritage of organism, the medium in which it moves and locomotor habits. Mustelids display various locomotor modes ranging from arboreal locomotion to swimming and burrowing. Their evolutionary history shows several returns to an aquatic lifestyle. As semi-aquatic species move both on land and in water, their locomotor apparatus is submitted to the functional constraints of both media. Because the less aquatic forms swim mainly using forelimb paddling we hypothesize functional adaptations of the forelimb, conversely, the more aquatic forms that swim using hind limbs and body undulation should present locomotor adaptations at the level of the hind limbs. We performed 3D scans of the long bones of 87 specimens of 20 mustelid species covering all sub-families. Using traditional landmark-based geometric morphometrics as well as sliding semi-landmarks we quantified the form of both diaphysis and articular surfaces of forelimb long bones. Using this morphometric dataset, we investigate the influence of locomotor behavior while taking phylogeny and body size into account. Preliminary results suggest that aquatic species show morphological differences in forelimb long bone shape compared to other species. Moreover, the most aquatic species appear highly specialized and show morphological differences in both limb pairs. Although these results suggest adaptive differences in the limbs of semi-aquatic mustelids further studies investigating forelimb-hindlimb shape covariation, the musculature and kinematics of locomotion are needed.

S7-9 BOULINIER, Thierry*; KADA, Sarah; DUPRAZ, Marlene; PONCHON, Aurore; CHAMBERT, Thierry; GARNIER, Romain; MCCOY, Karen; CEFE CNRS - Univ Montpellier, MIVEGEC CNRS - IRD - Univ Montpellier, ISPA, Lisboa, PennState College, Princeton University, MIVEGEC CNRS - IRD - Univ Montpellier; thierry.boulinier@cefe.cnrs.fr

Migration, prospecting, dispersal? What types of host movement matter for the circulation of infectious disease agents?

Spatial disease ecology is emerging as a new field that requires the integration of complementary approaches to address how the distribution and movements of hosts and parasites may condition the dynamics of their interactions. In this context, migration, the seasonal movement of animals to different zones of their distribution, is assumed to play a key role in the spread of parasites and pathogens. Nevertheless, migration is not the only type of host movement that can influence the spatial dynamics of infectious diseases. Dispersal has attracted attention as another important type of movement. Host dispersal has notably been identified as a key factor for the evolution of host-parasite interactions as it implies gene flow among local host populations and thus a specific potential for coevolution with infectious agents. But not all movements between host populations lead to dispersal *per se*. Prospecting, i.e. movements targeted at selecting and securing habitat for future breeding, may also play a role in parasite spread. Prospecting movements, studied in detail in certain social species, could result in the dispersal of infectious agents among different host populations without necessarily involving host dispersal. Here, we review how these various types of host movements might influence the circulation of infectious disease agents and discuss methodological approaches that could be used to assess their importance. Overall, we highlight that a detailed consideration of the behavioral and population ecology of hosts and parasites is required to disentangle the relative role of different types of movements for the spread of infectious diseases.

94-7 BOURDEAU, P.E.*; HULL, W.; JONES, A.; MCINTIRE, L.; ROCHE, J.; ALLEN, B.J.; Humboldt State University, California State University Long Beach; peb112@humboldt.edu

Potential effects of ocean acidification and thermal stress on intertidal communities in the field

Increasing atmospheric CO₂ in recent decades has caused increases in global temperatures and a reduction in seawater pH, so-called ocean acidification (OA). Physiological costs of responding to OA when the tide is in may compromise the ability of rocky shore organisms to mount effective thermal defenses when the tide is out, or may increase their susceptibility to other risk factors (e.g., reduced shell thickness can lead to increased threat of predation). Predicted changes in air and sea surface temperatures and ocean carbon chemistry over the next century are therefore expected to have dramatic effects on population dynamics, species interactions, and the structure of ecological communities. Our ability to effectively predict the consequences of co-occurring stressors on local community structure and associated ecosystem functions hinges on the development of realistic models of organismal responses to these perturbations, particularly models based on studies done in natural systems. During bouts of strong upwelling, nearshore and shallow intertidal areas in northern California can experience extended periods of acidified and hypoxic waters due to a relatively narrow continental shelf. To assess the potential effects of OA and thermal stress on intertidal communities in the field, we examined individual- and population-level changes of key calcifying species and their predators at multiple study sites along a 360 km section of coast that vary in their exposure to upwelling events and high temperature stress. Our data suggest that energetic subsidies associated with upwelling events in the field may currently overwhelm potential negative OA and temperature effects predicted from laboratory studies.

26-5 BOYER, A.C.*; MACDOUGALL-SHACKLETON, S.A.; University of Western Ontario, Advanced Facility for Avian Research, London, ON, Canada; abooyer@uwo.ca

Effects of Recurrent Inclement Winter Weather Cues on White-Throated Sparrows, *Zonotrichia albicollis*

Climate change has been linked to an increasing frequency of inclement weather and winter storms. As such, it is important to understand the effects changing weather patterns have on birds. We investigated the effects of experimental recurrent inclement winter weather cues on body composition, glucocorticoid hormones, and behaviour of white-throated sparrows, *Zonotrichia albicollis*. We used a hypobaric climatic wind tunnel to simulate storms by altering barometric pressure and temperature accordingly, and measured behavioural responses, body composition, and baseline corticosterone levels in birds exposed, or not exposed, to weekly simulated storms over a three month period. Experimental birds developed significantly higher fat and lean masses. Baseline corticosterone levels decreased over time in both groups, and time spent at food cups increased over time in both groups, however there was no effect of experimental treatment. Thus, although manipulations did not have a detectable effect on baseline corticosterone, it did affect body composition. This research provides novel experimental evidence that birds detect changing weather patterns and respond appropriately, and indicates that repeated exposure to inclement weather cues directly affects birds' energy reserves.

123-5 BOYCE, A.J.*; WOLF, B.O.; MARTIN, T.E.; University of Montana, University of New Mexico, USGS; MT Coop Wildlife Res. Unit; andrew1.boyce@umontana.edu

Resting metabolic rate explains variation in adult survival probability within but not across latitudes

Tropical birds are typically longer lived than temperate counterparts. This slow "pace of life" is thought to be associated with reduced metabolic rates via mechanisms such as reduced oxidative stress and/or reduced cost of reproduction. Initial studies of avian metabolic rates failed to find significant differences among latitudes, but recent work has found lower metabolic rates in tropical species, fitting the pattern predicted by the pace of life hypothesis. However, latitude is merely a proxy for a variety of factors that may influence both adult survival probability and metabolic rate thus latitudinal patterns in metabolic rate do not explicitly link metabolism to variation in longevity. While tropical species are consistently longer-lived than temperate counterparts, extensive variation exists within latitudes. This unexplained variation provides the opportunity to determine the independent influence of metabolic rate on longevity independent of additional factors correlated with latitude such as temperature or seasonality. We measured resting metabolic rates (RMR) of Passerine birds via an open-flow respirometry system at tropical (Sabah, Malaysia, 6°N), and temperate (AZ, USA, 35°N) field sites. We estimated adult survival probability based on 21 (AZ), and 7 (MY) years of banding/resighting at the same sites where metabolic measurements were undertaken. Based on phylogenetic least-squares analyses, we found that metabolic rate explained variation in adult survival within but not among latitudes. Within sites, long-lived species had lower metabolic rates than would be predicted by mass and phylogenetic relationships alone. Additionally, tropical species were longer lived than temperate species, even after controlling for differences in metabolic rate. Our results support the pace of life hypothesis in that, within latitudes, species with high adult survival probability had low metabolic rates. However, our results also suggest that there is an additional effect of latitude on adult survival probability independent of variation in metabolic rate.

92-6 BOYER, S.L.*; MARKLE, T.M.; BAKER, C.M.; LUXBACHER, A.M.; KOZAK, K.H.; Macalester College, University of Minnesota, Harvard University; boyer@macalester.edu

Historical refugia have shaped the geographic distribution of diversity in dispersal-limited arachnids endemic to the Australian Wet Tropics

How did Pleistocene glacial cycling affect the diversity of rainforest life? Over the past several decades, biologists have tested the hypothesis that forest contraction and fragmentation drove speciation in rainforest animals, concluding that in most cases species-level divergences predate the Pleistocene. Consequently, focus has turned to the role of Pleistocene refugia in preserving lineages, effectively acting as "museums" of biodiversity. We tested this model in a lineage of tiny dispersal-limited arachnids distributed throughout in the rainforests of the Australian Wet Tropics. We generated a model of habitat suitability for the dispersal-limited mite harvestman genus *Austropurcellia* (Arachnida, Opiliones, Cyphophthalmi, Pettalidae) and projected it onto paleoclimate data layers dating back to the Last Glacial Maximum (LGM). We compared the power of present-day and past distribution of suitable climatic conditions to the predict present-day distribution of diversity across subregions of the Wet Tropics. We found that the distribution of suitable climatic conditions during the LGM is the best predictor of both number of species and phylogenetic diversity in our study system, outperforming current distribution of suitable climatic conditions. This finding is consistent with a model in which historical refugia have played a significant role in shaping present-day biogeographic patterns.

55-4 BOYLE, K. S.*; HERREL, A.; Muséum National d'Histoire Naturelle, Muséum National d'Histoire Naturelle/Centre national de la recherche scientifique; kboyle@mnhn.fr

Morphology of the Weberian apparatus and otoliths of serrasalmid fishes in relation to feeding ecology

The Weberian apparatus is a synapomorphy for the diverse (>7,900 spp.) clade of otophysan fishes. This feature involves a chain of three bilateral vertebral elements (Weberian ossicles) that transduce sound pressure oscillations of the swim bladder to fluid motion in the saccule of the ear. The Weberian apparatus and inner ear modifications confer acute hearing and a wider auditory bandwidth that are hypothesized to have facilitated radiation of otophysans. Acute hearing may be an adaptation of otophysans used to assess the acoustic environment and locate food, however, this hypothesis remains speculative. Neotropical Serrasalminae (piranhas, pacus, tambaqui, pirapatinga, silver dollars) include species that feed on falling fruits and seeds, consume small fish, eat scales and fins, and rheophilic species that feed on macrophytes in noisy rapids. We used μ CT scans to examine the Weberian ossicles, vertebrae 1-4, neurocranium, otoliths, and swim bladders of 50 specimens from 19 species of serrasalmids. Initial results indicate allometry between volumes of Weberian ossicles and otoliths and body length. On average, rheophilic species displayed the smallest relative Weberian ossicle and otolith sizes and least size variation of the tripus, scaphium, and lagenar and utricular otoliths. Species that feed on whole fish, fins, or scales showed the largest relative tripus and scaphium sizes and were most variable in Weberian ossicle and otolith sizes. Fruit and seed eating species showed the largest intercalarium and otolith sizes. Observed differences are predicted to impact hearing sensitivities and be associated with noise environments and targeted prey sounds. Shape and phylogenetic comparative analyses will be used to examine relationships further.

117-7 BRAINERD, E.L.; Brown University; ebrainerd@brown.edu
X-ray reconstruction of moving morphology (XROMM) and Video reconstruction of moving morphology (VROMM) enable dynamic arthrology

Dynamic arthrology is the study of both structure and motion of joints. XROMM makes it possible to visualize and measure 3D shape and 3D motion within joints, both in living animals performing natural behaviors and *in situ* specimen preparations. Marker-based XROMM relies on radiopaque markers implanted into bones that then move rigidly with the bones. These markers are tracked in 3D from biplanar videofluoroscopy images, and combined with static bone morphology from a CT scan into highly precise and accurate reconstructions of bone shape and motion. From XROMM animations, 6 degree-of-freedom motion at joints can be quantified, and centers of rotation identified. Marker-based XROMM requires biplanar X-ray imaging, but in some cases, markers can be attached rigidly to bones but still visualized externally with standard video cameras. An example are the superficial bones in the heads of ray-finned fishes. Several of the skeletal linkages for suction feeding are visible externally, and miniature bone pins can be attached to the bones and tracked externally. A CT scan then yields bone shape and marker placement, and 3D bones can be animated as in XROMM. This new method, video reconstruction of moving morphology (VROMM), only works for superficial bones, but it provides all the same information about morphology and motion at joints. VROMM may also be applicable to the study of exoskeletal joints in some arthropods. Both VROMM and XROMM have the potential to yield high-precision joint motion, but a precision study with a frozen specimen should be undertaken as part of every XROMM or VROMM project. New, open-source software developed at Brown, the XMA Portal online data management system and XMA Lab marker-tracking software, are greatly increasing the speed and accessibility of XROMM and VROMM.

125-3 BRADLEY, P. W.*; BRAWNER, M.D.; RAFFEL, T.R.; ROHR, J.R.; OLSON, D.H.; BLAUSTEIN, A.R.; Oregon State University, Corvallis, OR, Oakland University, Rochester, MI, University of South Florida, Tampa, FL, USDA Forest Service, Pacific Northwest Research Station;

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Effect of temperature on chytridiomycosis in larval amphibians

Climate models predict changes in the frequency and magnitude temperature fluctuations, with potential implications for infectious disease. Prior studies of *Batrachochytrium dendrobatidis* (Bd) infection in adult amphibians support the hypothesis that temperature variability increases disease susceptibility in ectotherms. Using 40 independently controlled temperature chambers, we experimentally tested whether a temperature shift (from warm to cold or from cold to warm) would alter larval susceptibility to Bd infection in red legged frogs (*Rana aurora*) and western toads (*Anaxyrus boreas*). Both host species responded to temperature similarly. Both harbored elevated Bd infection intensities under the constant cold (15° C) temperature in comparison to the constant warm (20° C) temperature. Additionally, both species experienced an increase in Bd abundance when shifted to 20° C compared to a constant 20° C, but they experienced a decrease in Bd when shifted to 15° C compared to a constant 15° C, resulting in a strong shift-by-exposure temperature interaction. These results support the "lag effect" hypothesis, which predicts that shifts from cold to warm and from warm to cold might increase and decrease amphibian susceptibility to pathogens, respectively.

74-7 BRANDLEY, N*; CAVES, E; JOHNSEN, S; Colorado College, Duke University; nicholas.brandley@coloradocollege.edu
Do warning signals exploit an evolutionary constraint on insect visual acuity?

Insects often have refined color and polarization vision, however their compound eyes have poor visual acuity because the small lens of individual ommatidia are diffraction-limited. In contrast, the camera-type eyes of vertebrates do not suffer from diffraction to the same degree because they have larger apertures; the net result is diurnal vertebrates often have visual acuities that are orders of magnitude finer than insects. While many studies have discussed the role of color and polarization in private communication channels, none have examined if signals exploit the evolutionary constraint on visual acuity in the compound eyes of insects. Here we examine if warning signals ---especially in species that prey on insects --- have spatial characteristics that are obvious to their potential predators (*e.g.* birds) but not to their insect prey. We model the appearance of three types of signals to both birds and insects: 1) warning signals from species that prey on insects, 2) warning signals from species that do not prey on insects, and 3) intraspecific signals between insects. Because compound eyes are diffraction-limited, evolving a compound eye with visual acuity comparable to that provided by the camera-type eyes of diurnal vertebrates would require huge changes in lens size, and therefore physically unlikely changes in eye size. We suggest that taxon-specific constraints on visual acuity are in certain cases more rigid than constraints on color discrimination (which can change with a single amino acid substitution), making them a more reliable way to achieve private communication when the signaler would suffer from detection by insects.

29-7 BRANNOCK, PM*; ORTMANN, AC; MOSS, AG; HALANYCH, KM; Auburn University, University of South Alabama, Auburn University; pmb0010@auburn.edu
Temporal and spatial variation in pelagic micro-eukaryotes assemblages in Mobile Bay and along the Alabama coast

To compare seasonal diversity patterns of planktonic eukaryotes, a 2.5 year study sampling surface water in Mobile Bay and along the Alabama coast was conducted. Four locations along a transect were sampled bi-monthly from July 2009 to December 2011. To better understand the variation within these communities, high-throughput Illumina amplicon sequencing targeting the eukaryotic specific hypervariable V9 region of the small subunit ribosomal RNA gene was employed. Prior to sequencing, water samples were prefiltered using a 150 µm nitex screen and planktonic eukaryotes were collected using a 142 mm diameter 0.7 µm glass fiber filter. There was a significant difference in pelagic micro-eukaryote community composition both spatially (Bay vs. Shelf) and temporally. Community composition changed was correlated with DIN, temperature, salinity, DO, and prokaryote abundance. However, OTUs are being replaced with close relatives. The Bay had significantly lower temperature, lower salinity, and higher nutrients within the winter and spring season in comparison to the other seasons. This corresponded with higher abundance of diatoms in the Bay in the winter and spring. The Shelf on the other hand did not show a significant difference in environmental factors in reference to season and was heavily dominated by copepods during late spring to summer. Time points of large copepod abundance appeared to be correlated with lower dinoflagellate abundance. Furthermore, sampling for this project was conducted before, during, and after the *Deepwater Horizon* oil spill. Unfortunately, no hydrocarbon analyses were conducted, even though oil was reported to have reached both shelf locations, especially in June 2010. However, no visible shifts in community composition were observed when oil sheens were present.

107-3 BRESSMAN, NR*; GIBB, AC; FARINA, SC; Cornell University, Northern Arizona University, Harvard University; nrb66@cornell.edu

A comparative analysis of the novel terrestrial locomotion of the tide pool sculpin, *Oligocottus maculosus*

Tide pool sculpins (*Oligocottus maculosus*) are intertidal fish that use terrestrial locomotion to move across land when stranded above the tideline. Our goals were to describe the kinematics of the terrestrial locomotion of *O. maculosus* and compare their terrestrial locomotion to their aquatic locomotion, the terrestrial locomotion of subtidal sculpin species (*Leptocottus armatus* and *Icelinus borealis*), and the terrestrial locomotion of walking catfishes (*Clarias* spp.). We used high-speed video to record locomotion on terrestrial platforms and in water and landmark tracking software in MATLAB to analyze their body movements. *O. maculosus* use a previously undescribed form of axial-appendage-based locomotion, driven by lateral oscillations of the tail fin, synchronized with alternating body rotation about the base of the pectoral fins, which resembles a human "army crawl". The terrestrial army crawl may originate from a modified series of aquatic fast starts (lateral bends), performed in a terrestrial environment. However, *O. maculosus* use axial undulation of the body during aquatic locomotion, whereas they appear to use axial oscillation in combination with their pectoral fins during terrestrial locomotion. In contrast, with *O. maculosus*, the subtidal sculpin species oscillate the tail from side to side, but do not make effective contact between the pectoral fins and the substrate. Because of this, they are able to move very slowly (if at all) when stranded on land. We note that *O. maculosus* have only subtle differences in morphology when compared with many subtidal species, which suggests that few morphological changes are necessary to produce effective terrestrial movements in this major lineage of teleosts.

S5-8 BRENNAN, PLR; Mount Holyoke College; pbrennan@mtholyoke.edu

THE ROLE OF GENITAL COEVOLUTION IN INTROMITTENT ORGAN MORPHOLOGY. The Role of Genital Coevolution in Intromittent Organ Morphology

Male intromittent organs are exceedingly diverse, yet we know comparatively very little about female genital diversity. Previously it has been suggested that female genitalia are not very variable, and therefore little effort was dedicated to their study. However, the most direct mechanical interaction between males and females occurs during copulation, and therefore genital coevolution is expected to be widespread. Recent studies that have used more modern morphological and morphometric approaches have found that female genitalia can indeed be quite variable, and female genital adaptations, have been reported in many taxa. These adaptations can be very dramatic, for example in waterfowl, where an evolutionary arms race resulting from sexual conflict over mating has resulted in very obvious morphological changes in female vaginas. Female adaptations can also be subtle and involve physiology and behavior, such as in garter snakes, where females body roll and squeeze their vagina to limit copulation duration and copulatory plug formation. Though studying female genital morphology and function is undeniably challenging, knowledge of female genital morphology and function are absolutely crucial to our understanding of diversity in morphology of the male intromittent organ.

12-4 BRIGGS, D*; KUO, C; CROSBY, A; IRSCHICK, D; University of Massachusetts at Amherst; drbriggs@umass.edu

Form and function of gecko toepads in relation to body angle: A comparative study

We investigated how the toepads of various gecko species were employed in relation to body posture, such as when geckos were hanging upside down, rightside up, or were positioned sideways. We investigated the angles between the toes on each foot (fore and hind). We calculated toe angles for each individual by taking photos of the body oriented up, down, and sideways. We hypothesized that because different gecko species have differing toepad areas, and also differ in the relative shape and even the number of functional toes, that they would differ in how they use their toes. For example, the genus *Phelsuma* has primarily 4 functional toes, whereas other geckos, such as tokay geckos employ five. Our study thus provides vital insight into the mechanics of how animals that vary in size from several grams to close to 100 grams are able to adhere to surfaces in an effective way. This work could also inform new synthetic technologies on the best methods for adhering to structures in different orientations.

110-3 BRODER, ED*; GHALAMBOR, CK; ANGELONI, LM;
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Authentic science with live organisms can transform evolution education

The majority of the US public rejects evolution, yet evolutionary approaches grow increasingly important in solving the world's most pressing problems such as global food security, curing and preventing diseases, coping with climate change, and preserving ecosystems. One of the major challenges in teaching evolution is overcoming preset beliefs that are held even in the face of conflicting evidence. People are more receptive to information that opposes existing beliefs when asked to make their own conclusions based on explanatory evidence, a process inherent in the scientific process. Authentic science is a pedagogic approach in which students conduct the scientific process as if they were practicing scientists, but it is not used to teach evolution because of the time and resources required to observe evolution. We worked with local seventh-grade teachers to develop an authentic science program using live Trinidadian guppies from populations with different evolutionary histories, which allowed students to observe the end points of evolution rather than the process. We implemented this weeklong program in two Northern Colorado schools for two consecutive years reaching over 600 students. In the second year, we administered pre- and post-assessments that showed significant increases in both knowledge and acceptance of evolution in program participants as compared to a control group. Mounting evidence suggests that empirical evidence alone is ineffective at teaching evolution and must be paired with content on the nature of science. As suggested by the success of our program, authentic science may be the tool that allows us to overcome preset beliefs, transforming evolution education in the US.

87-1 BROTHERS, C.J.*; MCCLINTOCK, J.B.; Univ. of Alabama, Birmingham; brotce@uab.edu
The effects of ocean warming on feeding and growth in the sea urchin *Lytechinus variegatus*

A number of common and ecologically important marine invertebrates including the sea urchin *Lytechinus variegatus* inhabit enclosed shallow bays at the northern end of their biogeographic distribution in the Gulf of Mexico. Seasonal high temperature events in these enclosed bays are already capable of inducing physiological stress, and geography prevents this sea urchin from gaining a thermal refuge by migrating northward. Accordingly, it is important to evaluate whether predicted near-future seawater temperatures may induce sub-lethal impacts on feeding and growth that may ultimately reduce the fitness of *L. variegatus*. Sea urchins were chronically exposed in the laboratory to two temperature treatments, a current ambient temperature (26°C) and a predicted near-future temperature (30°C) (n=12 per temperature treatment) for a total period of 60 days. Sea urchins were fed an *ad libitum* diet composed of field-collected blades of the seagrass *Thalassia testudinum* every other day. Feeding and fecal production rates of sea urchins were measured every other day and averaged over 10 day periods. In addition, organismal growth was evaluated by recording wet weights for all individuals every 30 days. During the first 60 days of the temperature exposure experiment, there were no significant differences in feeding rates, fecal production rates, or growth of sea urchins held at either 26 or 30°C. However, there was a modest trend that suggested that individuals exposed to 30°C were beginning to lose weight by day 60. Accordingly, the experiment was prolonged and the results of continued exposure will be presented. The findings so far indicate that *L. variegatus* is able to feed efficiently and sustain growth in the face of chronic near-future elevated seawater temperature for a period of at least two months.

8-6 BROOKS, CAC*; GUMM, JM; Southern Illinois University, Stephen F. Austin State University; cbrooks@siu.edu
TERRITORIALITY AND HETEROSPECIFIC 'DEAR ENEMY' RECOGNITION IN TWO FRESHWATER FISHES (GENUS *Cyprinodon*)

Territorial aggression can vary based on species or the identity of the competitor. Some species exhibit 'dear enemy' recognition; where lower levels of aggression are directed toward neighboring, territorial individuals. *Cyprinodon variegatus* has been shown to outcompete closely related species due to high levels of aggression and territorial males exhibit dear enemy recognition. Recently, *C. variegatus* has been introduced into the home range of *Cyprinodon rubrofluvialis*, leading to hybridization. We examined territorial establishment and maintenance between heterospecific neighbors and evaluated if heterospecific neighbors express dear enemy recognition. We also tested the hypothesis that territorial males of each species differ in their expression of dear enemy recognition. We found that territorial male *C. rubrofluvialis* and *C. variegatus* in conspecific and heterospecific groups do show more aggression towards non-territorial males. Change in aggressive behaviors over time depends upon the behavior, the identity of the individual, and community structure. Energetically expensive aggressive acts towards territorial neighbors decreased after territory establishment while aggression towards non-territorials did not change. Less energetically expensive behaviors increased towards territorial males while no displays were directed towards non-territorials. *C. rubrofluvialis* established territories faster, more often and reduced aggression more over time when compared to *C. variegatus*. When aggression is decreased towards invasive species, hybridization may increase, leading to introgression. This is the first study to show heterospecific dear enemy recognition between vertebrate species and to compare the expression of dear enemy recognition between closely related species.

56-3 BROUGHTON, HM*; JOLLES, A; GOVENDER, D; SHIKWAMBANA, P; Oregon State University, South African National Park Services, South African National Park Services; broughth@onid.orst.edu

Parasite and pathogen communities in African lions (*Panthera leo*): The role of Feline Immunodeficiency Virus for structuring disease dynamics

Wildlife conservation, including the conservation of large carnivores, is increasingly a disease-mediated task as disease emergence, population fragmentation, and restriction of wildlife to reduced and degraded habitat may potentiate disease impacts in already vulnerable populations. However, while this phenomenon is now widely recognized by wildlife management officials, coinfecting pathogens may confound sound disease management strategy. Coinfections, through various mechanisms, may lower the threshold for pathogen invasion, increase the likelihood of pathogen maintenance, or alter the coevolution of pathogens within and between their host, thus contributing to unforeseen consequences for host and population health. This presentation examines the role of one such pathogen, Feline Immunodeficiency Virus (FIV), in structuring pathogen and parasite communities within African lions (*Panthera leo*) living in Kruger National Park, South Africa. As an immunosuppressive lentivirus of domestic and wild felids, FIV may impose subtle, but significant costs on the host population by facilitating the transmission and maintenance of native and non-native pathogens. Therefore, this presentation will investigate the impacts of FIV for other pathogens within the system, as well as the epidemiology of and associations between other significant pathogens and parasites.

99-7 BROWN, H.M.*; RUBEGA, M.; University of Connecticut;
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Do herons mitigate glare by adjusting body orientation during cross-media foraging?

As visual predators, day herons face several challenges while hunting across the air-water interface. One potential challenge is that sun glint off of a reflective water surface, which can cause the visual phenomenon we refer to as glare, may reduce visibility of a terrestrial predator's aquatic prey. Therefore, we might expect that day herons have evolved behavioral, morphological, and/or physiological adaptations to reduce the likelihood of experiencing glare. One possible behavioral mechanism for reducing the amount of sun glint in a visual field is by orienting away from the sun while foraging. However, at an orientation of 180 degrees to the sun, the heron will cast a shadow directly over its strike zone, and risk alerting the target prey. Thus, we expected to see evidence of herons trading off their own visual needs against the problem of being detected by their prey. We tested the hypothesis that foraging herons orient themselves to the sun in a manner that maximally reduces sun glint while minimizing their own shadow in their strike zone. We recorded body orientations of free-living, foraging Great Blue Herons and Great Egrets (*Ardea herodias* and *Ardea alba*) in southern Florida, as well as sun position and sun visibility. Our results indicate that herons are orienting randomly with respect to the sun at all solar elevations, including the lowest ones, when the most sunlight is being reflected at the sea surface. These findings suggest that herons are not compensating for glare behaviorally, and other heron behaviors that are thought to be compensatory for glare may need to be reconsidered.

28-2 BRYCE, C.M.*; HOUGHTALING, P.; WILMERS, C.C.; WILLIAMS, T.M.; Univ. of California, Santa Cruz;
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Energetics and evasion dynamics of large predators and prey: pumas vs. hounds

Measuring fine-scale movement, performance, and energetics of large carnivores and their prey is critical for understanding the physiological underpinnings of trophic interactions. Yet our ability to describe the free-ranging dynamics between highly active carnivores is substantially impaired by the wide-ranging and cryptic behaviors of these large mammals. Advances in biologging sensor technology now make it possible to remotely quantify fine-scale movement patterns and energetics. Here we used calibrated SMART collars containing GPS and 3-axis accelerometers to monitor evasion and escape maneuvers and energetics during predator-prey chase sequences using trained scent hounds (*Canis familiaris*, avg. mass = 25.4 kg) pursuing pumas (*Puma concolor*, avg. mass = 60.3 kg) that were simultaneously instrumented. Reconstruction of chases reveals how pumas successfully used terrain (e.g., fleeing up steep, wooded hillsides) as well as evasive maneuvers (e.g., running in a figure-8 pattern) to increase their escape distance from the faster hounds (avg. 45% faster). These adaptive strategies were essential to successful escape in light of the 1.6-2.1x higher mass-specific energetic costs of the chase for pumas compared to hounds (avg. 1.08 vs. 0.593 kJ·kg⁻¹·min⁻¹, respectively). On average, escapes were exceptionally costly for pumas, requiring exercise at 89.7% of predicted VO_{2max} and consuming 26% more energy than typically spent for hunting activity. These results demonstrate the marked investment of energy for escape by a large mammal and the advantage of dynamic maneuvers to aid in reducing total chase time.

131-4 BROZEK, J.M. *; SCHNEIDER, J.E.; KEEN-RHINEHART, E.; Lehigh University, Susquehanna University;
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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 often studied in the context of human obesity, but may play a role in adaptive traits - especially plastic traits which may influence survival. Pregnant Syrian hamsters fail to increase food intake and lose ~40% of body lipid stores, so offspring may be highly susceptible to programming from the maternal environment. We hypothesized that variation in adult ingestive behaviors - intake and hoarding - may be due to programming effects that are not controlled for. To test the effects of maternal energy availability on offspring traits, pregnant hamsters were either fed *ad libitum* throughout gestation or limited to 90% of pre-pregnant daily intake for the final 2/3 of gestation. Postpartum maternal care and litter size can affect pup growth and development, so we attempted to control litter size and cross-fostered all pups to get 4 treatment groups. Based on the literature, we expected lowered birth weight, catch-up growth, and altered adult behaviors in restricted groups. Pilot studies showed significantly lowered birth weight; this effect was not replicated. Pups from restricted dams fostered to control dams exhibited catch-up growth and substantial sex differences in food hoarding as adults. The underlying neuroendocrine correlates of this effect will be discussed. We show that subtle differences in a pregnant mother's energy expenditure during food acquisition can have long term effects on offspring ingestive behaviors. Programming effects may lead to inter-individual differences in adult responses to energetic challenge in laboratory and wild populations.

S2-2 BUCKLEY, B.A.; Portland State University;
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CELLULAR RESPONSES TO HEAT STRESS IN ANTARCTIC FISHES

The extremely cold-adapted fishes of the Southern Ocean possess some of the lowest upper thermal thresholds of any species. These fishes have evolved in the sub-zero waters of Antarctica for millions of years and possess profoundly cold-dependent physiologies. Some species have lost the traditional heat shock response but they nevertheless can respond to heat via modification of the transcriptome. It is clear that stenothermal fishes and eurythermal fishes differ in their response to temperature at the transcriptomic level. Many of the genes that vary in expression during thermal stress in cold-adapted fishes are related to the broad cellular stress response, a set of stress-related processes potentially including cell cycle arrest and/or apoptosis. Here, molecular chaperoning capacity was quantified in heat-shocked Antarctic fishes with different thermal tolerances. In addition, pro-apoptotic proteins and markers of cell cycle progression were measured. Taken together, these studies indicate that even relatively mild heat exposures (2°C) can cause apoptosis in these cold-adapted and environmentally sensitive species. To our knowledge, this is the lowest upper thermal threshold for the initiation of apoptosis in any known species. The research was funded by the National Science Foundation's Office of Polar Programs.

S9-8 BUCKLEY, L.B.*; HUEY, R.B.; Univ. of Washington, Seattle; lbuckley@uw.edu

How extreme temperatures impact organisms and the evolution of their thermal tolerance

Understanding the biological impacts of extreme temperatures requires transducing meteorological estimates into organismal responses, but that transduction is complex. In general, the physiological stress induced by a given thermal extreme should increase with the extreme's magnitude and duration. However, organisms can differ strikingly in their exposure to and tolerance of extreme temperatures. Moreover, their sensitivity to extremes can vary during ontogeny, across seasons, and among species; and that sensitivity should be subject to selection. We use a simple quantitative genetic model and demonstrate that thermal extremes can substantially influence the evolution of thermal tolerance, particularly when the extremes cause mortality or persistent physiological damage, or when organisms are unable to use behavior to buffer extremes. Selection imposed by thermal extremes can drive organisms in temperate and tropical sites to have similar thermal tolerances despite major differences in mean temperatures. Indeed, the model correctly predicts that Australian *Drosophila* should have shallower latitudinal gradients in thermal tolerance than would be expected based only on gradients in mean conditions. Predicting responses to climate change requires understanding not only how past selection to tolerate thermal extremes has helped establish existing geographic gradients in thermal tolerances, but also how increasing the incidence of thermal extremes will alter geographic gradients in the future.

56-4 BURGAN, SC*; GERVASI, SS; MARTIN, LB; Univ. of South Florida; sarahburgan@mail.usf.edu

From Tolerance to Transmission: The Implications of Repeated West Nile Virus Exposure

Host immune responses can reduce parasite load (resistance) and/or mitigate damage caused by infection (tolerance). These defense strategies mediate the outcome of individual infections but also have implications for population-level processes. Hosts with high tolerance and low resistance maintain high performance despite high parasite burden, enabling these individuals to contribute disproportionately to transmission. Past exposure to parasites modifies the consequences of subsequent exposures for individuals, but how it impacts transmission is less clear. Antibody responses augment resistance upon parasite re-exposure, but whether re-exposures also impact tolerance has yet to be studied. Multiply exposed individuals may pose a greater risk to others in a population if they develop increased competence to transmit a parasite. We exposed wild-caught house sparrows (HOSP) 2x to West Nile virus (WNV) with exposures separated by a ten-day recovery period. We then quantified serum viremia and five forms of bird health and/or performance within and between exposures. We expected that both population-level resistance and tolerance would increase following a secondary exposure to WNV. Our initial findings show high variability among WNV-infected HOSP in viremia profiles and performance. In 90% of cases, viral loads exceeded the threshold for transmission to a vector. Despite a mortality rate of 70%, these individuals were infectious for between two and four days prior to death. We did not detect a significant relationship between infection intensity and performance. Further analysis will indicate whether survivors of primary infection develop increased tolerance and/or resistance to subsequent infection, and thus broadens our understanding of the role of individuals in disease dynamics in nature.

94-5 BUCKLEY, L.B.*; NUFIO, C.R.; KIRK, E.M.; KINGSOLVER, J.G.; Univ. of Washington, Seattle, Univ. of Colorado, Boulder, Univ. of North Carolina, Chapel Hill, Univ. of North Carolina, Chapel Hill; lbuckley@uw.edu

Elevational differences in developmental plasticity determine phenological responses of grasshoppers to recent climate warming
Annual species may increase reproduction by increasing adult body size through extended development, but risk being unable to complete development in seasonally limited environments. Synthetic reviews indicate that most, but not all, species have responded to recent climate warming by advancing the seasonal timing of adult emergence or reproduction. Here we show that 50 years of climate change have delayed development in high-elevation, season-limited grasshopper populations, but advanced development in populations at lower elevations. Developmental delays are most pronounced for early-season species, which might benefit most from delaying development when released from seasonal time constraints. Rearing experiments confirm that population, elevation and temperature interact to determine development time. Population differences in developmental plasticity may account for variability in phenological shifts among adults. An integrated consideration of the full life cycle that considers local adaptation and plasticity may be essential for understanding and predicting responses to climate change.

S3-1 BURGE, C.A.*; GRONER, M.L.; BUCCI, J.; STAUDIGEL, P.; COX, R.; WYLLIE-ESCHEVERRIA, S.; FRIEDMAN, C.S.; Univ. of Maryland, Baltimore County, Univ. of Prince Edward Island, Univ. of New Hampshire, Univ. of Miami, Univ. of Washington; colleenb@umbc.edu

Zostera marina and Crassostrea gigas as potential partners in an acidic ocean

Climate change is affecting the health of marine organisms. Our ability to mitigate climate change effects is an important step in limiting future impacts to ecosystems. Ocean acidification (OA), or the decrease in seawater pH caused by the dissociation of atmospheric CO₂ in seawater, is a threat to calcifying organisms such as the Pacific oyster, *Crassostrea gigas*. In contrast, photosynthesizing plants, such as eelgrass, *Zostera marina* may benefit in future OA environments due to increased dissolved inorganic carbon (DIC) available in the water. By removing excess DIC, these plants can create local areas of pH refugia. *C. gigas*, may improve the health of *Z. marina* by removing potential pathogens, in particular the causative agent of eelgrass wasting disease, *Labyrinthula zostera*. One potential mitigation strategy to improve the health of both *C. gigas* and *Z. marina* is co-culture. In order to test the potential benefits of an oyster-eelgrass partnership, a full-factorial laboratory study with monoculture (juvenile *C. gigas* or *Z. marina*) and co-culture (*C. gigas* and *Z. marina*) under three CO₂ conditions, 400, 1000, and 1600 ppm was conducted. Half the tanks containing *Z. marina* or co-culture were exposed to *L. zosterae*. Increased mass of *C. gigas* was measured in low pH conditions in co-culture. In low pH conditions, the proportion of diseased *Z. marina* leaves decreased as compared to high pH conditions. An isotopically labeled CO₂ tracer indicated that the eelgrass incorporated the lighter isotope (δ¹²C), suggesting a draw down of the carbon due to photosynthesis. In OA conditions, the health of *Z. marina* can improve, and co-culture of *Z. marina* and *C. gigas* may be a beneficial mitigation strategy.

95-6 BURNETT, N.P.*; KOEHL, M.A.R.; Univ. of California, Berkeley; burnetnp@berkeley.edu

Effects of herbivory on the biomechanics of kelp in wave-swept environments

Kelp are ecologically-important organisms in wave-swept coastal areas where they provide food and habitat for many other organisms. Previous studies have shown that wounds from herbivory can facilitate the breakage of kelp by waves and currents. We used the long, flexible kelp, *Egregia menziesii*, to study how herbivore wounds affect breakability of kelp fronds, how wounds interact with the twisting of fronds by waves to affect breakage, and how wound healing affects tissue mechanical properties as well as new frond growth after wounding. We found that the structure of *E. menziesii* fronds is fairly robust against the wounds caused by its most common amphipod herbivore: a hole that removed about 50% of the cross-sectional area of a frond only reduced the tensile breaking load by approximately 30%. The kelp also showed some ability to heal from wounds by strengthening the remaining tissue around a hole. Furthermore, new frond growth at the intercalary meristem was affected by herbivore damage. The supporting rachis of the new portion of the frond that grew after damage was thicker compared with rachis produced pre-damage, but the strength of the new tissue was not different. Twisting had no effect on the mechanics of intact frond tissue, despite our prediction that twisting would pre-stress the frond and cause breakage under weaker forces. However, twisting increased the breaking strength of wounded fronds, suggesting that wounded fronds can survive greater hydrodynamic forces if they become twisted by the ambient water flow. Our results reveal how the structure of *E. menziesii* fronds allows the kelp to survive in an environment with large hydrodynamic forces and strong grazing pressure, and that herbivores can have a big influence on the interaction of kelp with the surrounding fluid environment.

75-2 BUSEY, HA*; ZATTARA, EE; MOCZEK, AP; Indiana University, Bloomington; hbusey@indiana.edu

Getting a-head: Evolution and Development of Dorsal Head Patterning in Horned Beetles

The evolutionary origin of the insect head has been of longstanding interest in evolutionary biology. Much is known about the formation of the ventral head containing the mouthparts, yet dorsal head formation remains poorly understood, in particular during the transformation of larval to pupal/adult stages. This is particularly problematic as many insect groups have evolved diverse dorsal adult head morphologies as well as integrated novel and ecologically important structures such as shields, stalks, or horns, into dorsal adult head formation. We investigate the developmental origin of the adult dorsal head from larval precursor tissues, evaluate the evolutionary conservation of that process, and investigate the mechanisms underlying the integration of novel head structures - horns - within the context of head formation. Specifically, we use selective ablation of regions of the larval head epidermis to map the fate of this tissue during pupation in three species of horned *Onthophagus* beetles exhibiting species-specific differences in horn location and number. Here we present the first larval-to-adult fate map for the dorsal adult head of any holometabolous insect. We then show that while most components of this fate map are conserved across diverse *Onthophagus* species in terms of location, the exact phenotypic response to regional ablation vary as a function of species and sex, indicating species-specific differences in the developmental potential of homologous head regions. Lastly, we provide evidence suggesting that posterior head horns have become integrated into head formation by re-using the same positioning mechanism that generates head segment boundaries in embryos and larvae, while anterior head horns may have evolved their positioning mechanisms *de novo*, possibly explaining their relative rarity.

S5-2 BURNS, M.*; TSURUSAKI, N.; San Diego State University, Tottori University; mercedes.burns@gmail.com

Reproductive morphology under long-term demographic evolution in an arthropod

The intromittent organs of the harvestman or "daddy-longlegs" fauna are cuticular structures often running the full length of the body. Hydraulic pressure, as well as intrinsic and extrinsic muscle, evert and may subtly alter this cuticle's shape prior to copulation. Recent work on the North American leiobunine harvestmen taxa has suggested that aside from the primary inseminatory function, the penis may deliver a mechanical stimulus and/or provide leverage for coercive access to the female pregenital chamber. Accordingly, these organs are subject to morphological evolution guided by sexual selection and intersexual conflict, but it is unclear how the strength of these mechanisms of selection changes with demography, such as shifts in phenology or operational sex ratios. We studied the reproductive organs of males of five species of the Japanese *curvipalpe* group, collected from populations that varied in their breeding season length and observed male:female ratio. Although not all features with hypothesized utility in coercive mating were observed in species with strongly biased sex ratios, we found males of species with primarily female-biased populations had penises with reduced nuptial gift giving regions, as compared to males of species with more even operational sex ratios. Similarly, populations at high elevation or latitude tended to have males with larger intromittent structures. Even more dramatic was the morphological differentiation in secondary sex characteristics associated with these males. Ultimately our findings suggest phenology and long-term sex ratio bias are two of many factors with the potential to strongly influence evolution of primary and secondary reproductive morphology.

84-4 BUSTAMANTE, J.*; PANZARINO, J.F.; RUPERT, T.J.; LOUDON, C.; Univ. of California, Irvine; jorgebjr@uw.edu

Piercing mechanics of bed bug tarsi

The mechanical properties of bed bug (*Cimex lectularius* L.) tarsi were investigated in order to evaluate their vulnerability to piercing by plant trichomes (sharp microscopic hairs). This information will help inform development of physical methods for control of insect pests such as bed bugs. Nanoindentation was used to measure the force required to insert a sharp probe into the cuticle of the tarsi in different regions, as well as to determine reduced elastic moduli for the cuticle. Scanning electron microscopy was used to visualize the indents that had been generated by nanoindentation. The force required to insert a sharp object into the cuticle of the tarsus was determined for depths ranging from 1 to 9 microns at strain rates ranging from 0.003 to 0.5 s⁻¹. A force of approximately 0.5 mN was required to indent to a depth of 1 micron. Greater force was required to insert a sharp object at greater depth or at faster strain rates. A specific region of the pretarsal claws (membrane with microtrichia) was more frequently pierced by trichomes during bed bug locomotion, and was more easily pierced and had a lower reduced elastic modulus. The combination of these mechanical attributes, in addition to the presence of natural infoldings in the cuticle of this area, make the membrane with microtrichia of the pretarsal claws particularly vulnerable to piercing.

97-4 BUTCHER, MT*; THOMAS, DR; RISKIN, DK; MITCHELL, RM; HERMANSON, JW; Youngstown State University, Univ. of Toronto, Mississauga, Centers for Disease Control, Atlanta, Cornell University; mtbutcher@ysu.edu

Myosin fiber types in moles: Fast muscles make the slow burrower
Moles have modified forelimbs that allow them to apply remarkably high levels of force per gram body mass. To further understand the high force capabilities of moles, myosin heavy chain (MHC) fiber types were quantified in the star-nosed mole (*Condylura cristata*). Its hypertrophied pectoral girdle muscles have the advantage of mass for high force and power output, thus we hypothesize that slow MHC-1 and fast, oxidative MHC-2A fibers would best meet the metabolic requirements for locomotion under the surface. Fiber types were determined by protein gel electrophoresis (SDS-PAGE) and histo/immunohistochemical staining techniques, enabling identification of the MHC isoforms expressed. An abundance of fast MHC-2A, 2X, and 2B fibers are distributed in the major limb musculature of *C. cristata* (N=3), including mm. teres major, pectoralis profundus, triceps brachii, quadriceps femoris, and gastrocnemius. Small amounts of the slow isoform were resolved in the gels of each muscle studied; however, no clear evidence of MHC-1 fibers was determined by either acid-mATPase incubations or reactions with anti-slow antibodies. The findings do not agree with our hypothesis and indicate that contractile properties of fast MHC isoforms contribute to the high out-forces of mole forelimbs. Fast fiber types of moles are additionally found to be moderately oxidative, suggesting that prolonged contractile activity in fast-contracting muscles may be important to thermoregulation in small, burrowing mammals. This finding would also seem to suggest that expression of slow MHC-1 fibers may be derived in larger mammals.

51-7 BUTLER, M.W.; LUTZ, T.J.; STAHLSCHEMIDT, Z.R.*; Lafayette College, University of the Pacific; zstahlschmidt@pacific.edu

Eating increases oxidative damage

While consuming a meal has substantial benefits in terms of both nutrient and energy acquisition, there are physiological costs associated with digesting and metabolizing a meal. For centuries, these costs have primarily been documented in the context of energy expenditure while other physiological costs have been relatively ignored. Here, we tested whether the seemingly innocuous act of eating a meal affects either systemic oxidative damage or antioxidant capacity of corn snakes (*Pantherophis guttatus*) by collecting plasma during absorptive (peak increase in metabolic rate due to digestion of a meal) and post-absorptive (baseline) states. When individuals were digesting a meal, there was a minimal increase in antioxidant capacity relative to baseline (6%), but a substantial increase in oxidative damage (nearly 180%). This oxidative cost due to simply digesting a meal demonstrates the importance of investigating non-energetic costs associated with meal processing, and begs future work identifying the mechanism driving this increase. Because energetic costs associated with eating are taxonomically widespread, eating-induced oxidative damage may be similarly prevalent and, thus, an important factor in the evolution of life histories.

79-4 BUTLER, J.M.*; MARUSKA, K.P.; Louisiana State University; jbutl48@lsu.edu

The mechanosensory lateral line system activates socially relevant brain regions during territorial interactions in an African cichlid fish

Fish must integrate information from multiple senses during social interactions to make appropriate behavioral decisions. We recently demonstrated that the lateral line system is used by the African cichlid *Astatotilapia burtoni* to assess opponents and facilitate use of non-contact over contact behaviors when engaged in male-male territorial contests. It is unknown, however, where this socially-relevant mechanosensory information is processed in the brain to mediate these decisions. To examine which brain regions receive contextual mechanosensory information, we quantified expression of the immediate early gene *cfos* as a proxy for neural activation in sensory and socially-relevant brain regions from lateral line intact and ablated animals following territorial interactions. Lateral line ablated animals had fewer *cfos*-stained cells in lateral line processing regions and many nuclei implicated in social decisions. By correlating assessment and fight behaviors with *cfos* activation patterns, we demonstrate that regions of the social decision making network likely receive hydrodynamic cues that can be used to mediate behavioral choices such as when to fight or which type of aggressive behavior to perform. Use of water movement cues rather than more dangerous contact behaviors may serve as a self-preservation mechanism. Together these data indicate that the lateral line system provides relevant information to social brain regions during territorial interactions. To our knowledge, this is the first evidence in any species that conserved decision making nuclei also receive socially-relevant mechanosensory information. These results also highlight the importance of multimodal sensory input in mediating adaptive behaviors via the social decision making network.

6-1 CAHILL, AE*; AURELLE, D; BOISSIN, E; BOUZAZA, Z; DAVID, R; DUBOIS, S; DEJODE, A; EGEE, E; ERGA, Z; LEDOUX, J-B; MERIGOT, B; WEBER, A; Aix-Marseille Université, IMBE, Mostaganem University, Aix-Marseille Université, IMBE; CHENUIL, A; Aix-Marseille Université, IMBE; abigail.cahill@imbe.fr

Determinants of connectivity in the marine environment: a multispecies approach

In marine invertebrate species, adults are often sessile or sedentary and populations exchange individuals via dispersal of gametes and larvae. This leads to a general pattern where species that have a long larval period are expected to have more connected populations than those without larval dispersal. However, in the northwestern Mediterranean Sea, even species with relatively long-lived larvae and correspondingly high dispersal potential show a surprising number of genetic breaks over a small spatial scale. We compiled data on genetic patterns, habitat, and life history traits in ten species spanning six phyla, focusing on a 50 km area near Marseille, France. We hoped to understand what factors (e.g. life history, habitat) best explain the patterns of genetic differentiation in this region. By using data from a single area, we minimized the effects of sampling at different sites and instead focused on traits that may influence connectivity. We found that total genetic differentiation in the region varies with larval type, but not with habitat or other species traits. Additionally, genetic breaks around Marseille correspond to known patterns of circulation in the area. We also found that genetic diversity within species is weakly correlated with species diversity. Our results re-emphasize the importance of ocean circulation (i.e. physical connectivity) and larval dispersal in determining genetic connectivity in marine populations, and therefore many different ecological and evolutionary processes.

58-4 CALVETE, Juan J.; Instituto de Biomedicina de Valencia, CSIC; jcalvete@ibv.csic.es

Understanding venom variability: a challenge for the analytical chemist, an opportunity for the evolutionary biologist

Adaptive radiation involves the diversification of a lineage into species that differ in phenotypic traits used to exploit different resources. Ecological opportunities arise when new or previously inaccessible resources are encountered or are newly exploitable following the acquisition of a key evolutionary innovation. Venom is a polygenic complex adaptive trait. Inter- and intraspecific venom variability has long been appreciated by herpetologists and toxinologists. Changes in venom composition are inherited, so have a genetic background. However, venom variability among conspecific snakes from different populations and age is also a common phenomenon, so there are other factors at play. Although the molecular mechanisms that generate this diversity remain largely elusive, recent evidence indicate that genetic and postgenomic mechanisms contribute to venom composition variability. Phenotypic venom variation is shaped by a variety of evolutionary processes, historical flukes (genetic drift and founder effects), and ecological adaptations. Separating the effects of history and chance from adaptation is a significant challenge, but is experimentally tractable. One way to deal with this reality is the quantitative comparison of phenotypic variation of traits associated with fitness across the evolutionary history of a group of species. Recent comparative venom studies across a number of New World snake lineages, including *Agkistrodon*, *Sistrurus*, *Crotalus*, *Lachesis*, *Bothriechis*, and *Micrurus*, will illustrate how genus-wide venom proteomic analysis may aid in the identification of global evolutionary trends within and between genera, and nodes of venom phenotypic differentiation across the phylogeny of these clades.

114-2 CAMPBELL-STATON, SC*; CHEVIRON, ZA; BARE, A; LOSOS, JB; EDWARDS, SV; University of Illinois, Champaign-Urbana, University of Montana, Harvard University; shane.campbellstaton@gmail.com

Effects of local environment, acclimation, and extreme winter events on phenotypic and genomic variation of the green anole (*Anolis carolinensis*)

Temperature plays an important role in shaping the form and function of every species. Ectothermic organisms are particularly sensitive to fluctuations in their thermal environment. Their inability to produce appreciable amounts of heat through physiological mechanisms makes them vulnerable to thermal shifts, and a good system for the study of temperature-mediated evolution. Additionally, in a world of human-accelerated ecosystem change it is increasingly important to understand how temperature influences processes of adaptation and acclimation. The central goal of this work is to understand how temperature shapes the variation within terrestrial ectotherm species. Towards this aim we investigated the effects of cold temperatures on phenotypic and genomic variation of the green anole, *Anolis carolinensis*. After overwater dispersal from Cuba, the species has spread from Florida throughout the southeast to occupy a range of environments as far north as Tennessee and North Carolina and west into Texas and Oklahoma, where environments differ dramatically from that of its ancestral range - particularly during the winter months. We combine niche modeling, geographic surveys of thermal limits, common garden experiments, and several genomic techniques to gain a clearer understanding of how novel environments have shaped the evolutionary trajectory of this species after its colonization of the mainland. Additionally, we explore rapid evolutionary response to a single extreme winter storm (termed the "polar vortex"), which sent arctic winds and snowstorms through the southeast during the winter of 2013-2014.

80-1 CAMACHO, J.*; HEYDE, A.; BHULLAR, B.A.S.; HAELEWATERS, D.; SIMMONS, N.B.; ABZHANOV, A.; Harvard University, Yale University, American Museum of Natural History, Imperial College London; jamin.j.camacho@gmail.com

The evolution and development of diverse and adaptive skull shapes in New World leaf-nosed bats

The New World leaf-nosed bats (Phyllostomidae), arguably the most ecologically diverse clade of mammals, have evolved extraordinarily diverse faces and skulls adapted for many different food types, such as insects, fruit, nectar, other vertebrates, and blood. To understand the processes that generated this diversity, we employ a phylogenetically informed geometric morphometric approach analyzing the variability of 3D skull landmarks from developmental and adult data from several lineages. Our results demonstrate widespread peramorphosis in skull morphologies and reveal that their distinctive ecomorphologies are largely achieved through "terminal addition" as the evolutionarily more recent features in cranial morphology emerge later in bat development. Phyllostomids, thus, provide a real-world example of "ontogeny recapitulates phylogeny" with important implications for understanding the evolution of adaptive morphological diversity in vertebrate body form.

44-1 CANNON, J.T.; VELLUTINI, B.C.; SMITH III, J.; RONQUIST, F.; JONDELIUS, U.; HEJNOL, A.*; Naturhistoriska Riksmuseet, Stockholm, Sars International Centre for Marine Molecular Biology, Bergen, Winthrop University, South Carolina; andreas.hejmol@uib.no

Xenacoelomorpha is the sister group to Nephrozoa

Placement of Xenacoelomorpha in the tree of life remains a major unresolved question the study of deep animal relationships. Two conflicting hypotheses are under debate. Xenacoelomorpha either form a clade sister to all other animals with bilateral symmetry (=Nephrozoa, i.e. protostomes and deuterostomes) or a clade inside Deuterostomia. Xenacoelomorpha, comprised of Acoela, Nemertodermatida, and Xenoturbella, are bilaterally symmetrical marine worms that lack a number of features common to most other bilaterians, e.g. anus, intestinal lumen, excretory organs, and circulatory system. Thus, depending on the phylogenetic position of this clade, these animals are pivotal for understanding the initial acquisition of nephrozoan features, or they have undergone substantial secondary loss. Here, we have sequenced eleven novel xenacoelomorph transcriptomes, and show robust phylogenomic support for Xenacoelomorpha as the earliest branch of Bilateria. Systematic testing under different models of evolution, as well as 24 experimental datasets designed to address potential artifacts, such as long branch attraction, saturation, and missing data, all corroborate this result. Our phylogenomic analyses support previous hypotheses that the last common ancestor of bilaterians was a benthic acoelomate worm with a single gut opening and without nerve cords. Thus, common bilaterian features such as excretory organs, coelomic cavities, nerve cords and body segmentation were not present at the cnidarian-bilaterian split.

120-6 CARLO, M.A.*; SEARS, M.W.; Clemson University; mcarlo@clemson.edu

Warming nest temperatures impact survival and growth of Eastern fence lizards (*Sceloporus undulatus*)

Organismal responses to rapid climate change rely heavily on the plasticity of physiology and behavior. For instance, mobile animals can behaviorally thermoregulate to buffer effects of climate warming. Yet, animals in immobile life stages lack the capacity to alter behavior and therefore rely on physiology. When a female Eastern fence lizard (*Sceloporus undulatus*) chooses a nest site, she determines the conditions experienced by her embryos. Developing embryos are exposed to recurrent thermal stress in shallow nests with fluctuating temperatures. In Summer 2014, we conducted a laboratory experiment to evaluate the capacity for acclimation to the embryonic thermal environment. We reared *S. undulatus* embryos under three thermal regimes: a contemporary regime with a maximum daily temperature (T_{max}) of 32.1°C, and two regimes to simulate warming scenarios in which T_{max} was raised by 3.5°C and 7.0°C. Results showed embryos from warmer nests had lower survivorship and grew more slowly post-hatching. In Summer 2015, we conducted a field experiment on *S. undulatus* nests located using radio telemetry of gravid females. We experimentally warmed a random subset of the nests, then compared embryonic survival and hatchling phenotypes to that of the remaining unaltered nests. Results showed similar effects to the lab study: offspring from warmed nests survived less and grew more slowly. The lab results indicate that increased nest mortality and thermal constraints on the physiology of developing lizards may limit the persistence of the species under climate change. However, our field results suggest that existing variation in nest characteristics and nest site selection might buffer offspring to a changing environment.

121-3 CARTER, AW*; BOWDEN, RM; PAITZ, RT; Illinois State University; afwilso@ilstu.edu

Can yolk estrogens affect sex determination when incubation temperatures fluctuate in a species with TSD?

Reptiles with temperature-dependent sex determination (TSD) may be particularly susceptible to rapid climatic changes, which underscores the importance of investigating environmental and maternal effects on TSD. Numerous studies have demonstrated that estrogens can alter how temperature influences sex determination, such that the incubation temperature required to produce females is altered when exogenous estrogens are applied to the egg. Unfortunately, this phenomenon is almost exclusively studied using supraphysiological doses of estrogens and unnatural constant incubation temperatures. We used the red-eared slider turtle (*Trachemys scripta*) to examine how natural variation in yolk estrogens (estrogen levels are higher in late-season clutches) influences sex determination under more natural fluctuating incubation temperatures. First, we tested if the effect of temperature on sex determination changed across the nesting season when using fluctuating incubation temperatures. Eggs were incubated at one of three ecologically relevant regimes: 28.0±3, 28.5±3, 29.0±3, or at a constant 29.2 °C. Secondly, we tested if the seasonal increase in yolk estrogens is capable of altering the effect of incubation temperature on sex determination. We collected early season clutches and dosed eggs with either a sham (5 µl 70% ethanol) or a mixed estrogen dose (20 ng estradiol + 77.5 ng estrone sulfate/5 µl 70% ethanol), which simulated the seasonal increase in the yolk estrogens. Results from these studies will inform whether variation in yolk estrogens alters how temperature influences sex determination under more natural conditions, thereby providing a mechanistic approach to predicating how reptile species may respond to climatic changes.

106-6 CARRILLO, A.*; MCHENRY, M.J.; Univ. of California, Irvine; an.carrillo@yahoo.com

The role of the canal neuromasts in zebrafish foraging

Fish sense water flow with two types of receptor in the lateral line system. Although neurophysiological and biomechanical studies have demonstrated how these types differ in their sensitivity to flow, it remains unclear what roles these two submodalities play in behavior. We studied how the lateral line permits foraging in the dark in juvenile and adult zebrafish (*Danio rerio*). The lateral line of this species is similar to a broad diversity of fishes because it includes only superficial neuromasts in juveniles and then develops canal neuromasts by the adult stage. We learned that fish at both stages of growth strike at a vibrating sphere and this behavior ceased if the lateral line was compromised by exposure to neomycin sulfate. Juveniles exhibited the greatest probability of striking at the sphere when it was oscillating at a frequency between 28 and 60 Hz. Adults exhibited similar sensitivity, but were additionally responsive to higher frequencies, up to the 100 Hz permitted by our experimental setup. Therefore, changes in the lateral line permit zebrafish to respond to higher frequency signals as they grow. This suggests that the development of canal neuromasts extends the trophic niche available to a fish as it grows by detecting a more broad range of flow stimuli.

46-6 CASAGRANDE, S*; CRAMER, J; HAU, E; Max Planck Institute of Ornithology; scasagrande@orn.mpg.de

Glucocorticoid reaction norms across internal gradients in oxidative stress

Finding links between hormonal phenotypes and fitness has proven difficult because of considerable within- and among-individual variation in hormone concentrations. One valuable approach is to quantify within-individual hormonal flexibility along an environmental gradient and to relate the resulting reaction norm to fitness-related traits. In wild great tits (*Parus major*), we experimentally varied work load during the breeding season to manipulate cellular oxidative stress. We trapped 46 birds of both sexes when their nestlings were 7 days old. All birds were blood-sampled to determine baseline corticosterone levels, oxidative damage and antioxidant compounds. Before immediately releasing the birds, we symmetrically clipped three primary feathers of 13 males (11 males served as controls). Males with clipped primaries are known to decrease offspring provisioning rates, which induces a compensatory increase in work load in their female mates. When nestlings were 12 days old we re-trapped and re-sampled all focal adults. Provisioning rates were determined from video-recordings. We quantified proxies of reproductive success like lay date, clutch size, hatching success, fledging success, and fledgling body condition. The data will be analyzed using mixed effect models to test the following predictions: 1) individuals will differ in their glucocorticoid responses to increased work load, 2) parameters describing oxidative status will explain among-individual variation in glucocorticoid responses, 5) the interplay between oxidative status and glucocorticoid flexibility will be related to reproductive investment and to fitness.

86-3 CASS, AN*; ROBERTS, RB; North Carolina State University; amanda_cass@ncsu.edu

Molecular characterization of cryptic gut regionalization in trophically divergent cichlids from Lake Malawi

Cichlid fishes of the East African rift lakes are well known for their explosive speciation and dramatic phenotypic diversity. These radiations are characterized by a wide array of extreme trophic specializations. While the craniofacial modifications associated with dietary specialization have received significant attention, associated differences in gut morphology are not well understood. Understanding the morphological, developmental, and genetic changes correlated with dietary shifts will not only allow us to better understand how trophic diversity evolved in cichlids, but also broader patterns of vertebrate trophic specialization, and the interaction between diverse human gut phenotypes, dietary adaptation, and diet-related disease. Unlike tetrapods, gut regionalization in teleosts is often not easily visualized. The cichlid gut is a simple tapered tube, with no obvious distinction between small and large intestine. Using phylogenetically robust molecular markers of these regions, we have determined that both overall gut length, and the relative percentages of the adult gut expressing large and small intestinal markers follow broad vertebrate trends correlating gut morphology and dietary specialization. Additionally, we have characterized the emergence of these species-specific phenotypes through ontogeny from a generalized larval state. A separate large and small intestine have not previously been identified in cichlids, and our data are the first description of cichlid gut morphology from fishes raised in a common garden, demonstrating that identified differences are not the result of a plastic response to diet, but instead are heritable and species-specific.

85-3 CAVES, EM*; BRANDLEY, NC; JOHNSEN, S; Duke University, Colorado College; eleonor.caves@duke.edu

Visual acuity in fish: the effects of eye morphology, environment, and ecology

Fish use their visual systems for a variety of tasks (capturing prey, detecting predators, schooling, and courtship) that require them to resolve an image; however, spatial acuity (the ability to resolve detail) is highly variable across fish species. Eye size, ecology, and habitat (in particular depth) may potentially drive variation in spatial acuity. While prior studies have explored the effects of ontogeny, morphology, or environment within a single species or several related species, broad comparative analyses of the relationships between visual acuity, eye and body size, ecology, and depth in fish are currently lacking. We conducted a literature review of spatial acuity (measured behaviorally, morphologically, and electrophysiologically) in fish and elasmobranchs, and used phylogenetic comparative methods to explore these relationships in species from different families, ecologies, and environments. Fish are an excellent system for such a study, because fish eyes vary in size between species and across lifespan, in shape from spherical to oblong, and in various morphological specializations such as multiple lenses or lack of lenses altogether. Additionally, fish differ in ecology (i.e. diurnal/nocturnal, herbivore/predator) and habitat, occupying a variety of depth ranges. Such cross-species analyses help elucidate how visual capabilities may be adapted to an animal's visual needs; overall, identifying the factors that influence visual acuity will increase our understanding of sensory ecology in fishes as well as other organisms with camera type eyes.

104-4 CATES, C.D.*; WARNER, D.A.; Auburn University, Auburn University; coreydalecates@gmail.com

Long Term Effects of Incubation Moisture on Desiccation Rate in the Brown Anole Lizard (Anolis sagrei)

The interaction between a developing embryo and its environment can have significant effects on an individual's phenotypes. Developmental plasticity is considered adaptive when the environment induces phenotypes beneficial in that environment. However, because the environment can change throughout an individual's lifespan, understanding long-term effects of plastic responses during development is important. In this study, we use lab and field experiments to quantify the long-term effects of incubation moisture on desiccation rate in lizards (brown anole, *Anolis sagrei*). We have shown previously that incubation moisture has dramatic effects on desiccation rate of hatchling lizards, which in turn influences offspring survival in the field depending upon their post-hatching moisture environment. For example, egg incubation under dry conditions (-600 kPa) produces offspring with significantly lower rates of desiccation than does incubation under wet conditions (-30 kPa). Offspring from dry incubation conditions also have greater survival in dry post-hatching environments than do those from wet incubation conditions. Monitoring lizards via a mark-recapture study in the field, we continued to measure their desiccation rate up to about 1.5 years of age (well into adulthood). Preliminary observations suggest that lizards lose less overall body mass due to desiccation during adulthood than they do as hatchlings. Analysis of the survival and desiccation data (both as hatchlings and as adults) will allow us to assess selection on desiccation rates in the wild and assess the long term effects that incubation moisture has on desiccation rate. Upcoming results from this ongoing project will provide insights into how plasticity associated with incubation moisture changes over the course of a lifetime.

115-6 CERVENY, KL*; VALDIVIA, LE; LAMB, DB; TAFESSU, A; WILLIAMS, A; HORNER, W; WILSON, SW; Reed College, University College London; cervenyk@reed.edu

Controlling the timing of neurogenesis regulates eye size in zebrafish

Continuous neurogenesis in growing tissues requires a tight balance between progenitor cell proliferation and differentiation. In the zebrafish retina, neuronal differentiation proceeds in two stages with embryonic retinal progenitor cells (RPCs) of the central retina accounting for the first rounds of differentiation, and stem cells from the ciliary marginal zone (CMZ) being responsible for late neurogenesis and growth of the eye. Whether similar mechanisms regulate the transition from proliferation toward differentiation during both early and late stages of eye development is currently unknown. In this study, we analyse two small eye mutants that exhibit reduced CMZs and carry lesions in *gdf6a*, a BMP family member previously implicated in dorsal eye specification. We show that *gdf6a* mutant eyes exhibit expanded Retinoic Acid (RA) activity and go on to demonstrate that exogenous activation of this pathway in wild-type eyes inhibits retinal growth, generating small eyes with a reduced CMZ and fewer proliferating progenitors similar to *gdf6a* mutants. We provide evidence that RA encourages cell cycle exit and regulates the timing of RPC differentiation during both early and late neurogenesis, showing that over-activation of the RA pathway accelerates retinal neurogenesis whereas its inhibition in *gdf6a* mutants re-establishes appropriate timing of retinal neurogenesis and restores retinal stem and progenitor cell populations in the CMZ. Together, our results support a model by which dorsally expressed *Gdf6a* balances RA pathway activity during early and late neurogenesis to control the transition from proliferation toward differentiation in the growing eye.

89-1 CHABOKDAST, A*; WALKER, S; University of Oxford;
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Multibody dynamic modelling of the wing hinge in a blowfly

The flight motor of Diptera forms one of the most intricate biomechanical systems found in the nature. The alternating contractions of the two indirect power muscle groups results in cyclical deformations of the thorax exoskeleton, most noticeably, in the posterior known as the scutellum. These deformations of the thorax and scutellum are then amplified and transmitted to the wing by the multiple hardened cuticular components, called the axillary sclerites, which are manipulated by c.13 specialized accessory muscles. At every stage of a wingbeat cycle, activation levels of both power and accessory muscles and the relative position and orientation of the axillary sclerites can change. Although numerous different models of the wing hinge have been developed in an attempt to describe the inner workings of the hinge joint, they have failed to encapsulate the dynamic and three-dimensional nature of the wing hinge mechanism. This level of complexity can ideally be addressed using Multibody Dynamic Analysis (MDA), which is a computational technique originally developed for engineering applications. We have developed the first MDA model of the Dipteran wing hinge to investigate the function and kinematics of its different components. At this early stage of our modelling, we created an abstract 4-link model of the wing hinge of a blowfly, in which high quality micro-tomographic static scans were used to ensure realistic representation of the wing hinge components. Kinematic data of the thorax, obtained using time-resolved in vivo microtomography, were used to predict the 3D kinematics of the other wing hinge components in each step of a wing beat cycle. This was our initial step towards a more complex model formed by the inclusion of the wing hinge components as well as the power and accessory muscles to investigate the overall mechanism of the insect wing hinge.

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Effect of acclimation on physiological and behavioral responses of larval urchins to warming

Global climate change, in particular warming, is a major threat to marine biodiversity in the 21st century. Tropical species are believed to be especially vulnerable for they are living close to their upper thermal limits and thus have small thermal safety windows. Here, using the sea urchin *Lytechinus variegatus*, we explored phenotypic plasticity in a tropical species in the face of warming. Specifically, we tested the hypothesis that acclimation to warmer temperatures increase performance at elevated temperature, i.e., acclimation increases the pejus temperature. Larval urchins were reared at three temperatures (26, 29, and 32 °C), ranging from present day summer temperature to that predicted for Bocas del Toro at the end of this century. We used oxygen consumption and swimming speed as metrics of performance and compared larval performance at 4 different temperatures (the three rearing temperature and 35 °C). Swimming speed and oxygen consumption rate in general increased with increasing temperature for larval urchins regardless of acclimation history. However, at the highest temperature tested, larvae reared at 26 °C exhibit metabolic depression but not the others. Interestingly, the increase in oxygen consumption rate between the 3 °C increases was smaller for the warm acclimated individuals. The importance of acclimation in shaping thermal response imply that natural variation in thermal limits may be larger than previously expected. Increased performance at higher temperatures through acclimation highlights plasticity in tropical species and that they might have the potential to adapt to future climate scenario.

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Physical and physiological costs of reproduction in watersnakes

A key theory in life-history research predicts the existence of a trade-off between current and future reproductive success. Increases in the cost of each reproductive attempt theoretically reduce future reproductive ability. Additionally, the cost of a single reproductive attempt may shift with body size, altering the relationship between this trade-off. Historically, however, it has been difficult to experimentally quantify these costs in organisms. Squamate reptiles have proved a good model to measure reproductive costs as reduction in locomotor performance is easily quantified. As the burden of reproductive material increases, we predict a corresponding reduction in locomotor performance and thus a greater cost to reproduction. We measured the swimming speed of watersnakes during and immediately after pregnancy to estimate the loss of locomotor imposed by reproduction. Further, we correlated this loss of swimming speed with relative clutch mass (an estimate of reproductive effort) and body length. Female snakes swim slower during pregnancy than after. Increasing the relative clutch mass resulted in slower swimming speeds during pregnancy. Further, shorter individuals showed a greater change in swimming speed suggesting a greater cost of reproduction for smaller individuals. Lastly, we have demonstrated that additional costs to locomotor ability may be incurred by the dam due to weight loss during pregnancy from carrying the burden of reproductive material.

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Transcriptomic approach to identify sex determination genes in the male shrimp *Ferrenopenaeus merguensis*

Siuming Francis Chan Fisheries College, Guangdong Ocean University, PR China The recent use of RNA-Seq technique in the study of transcriptome of non-model animals has advanced our understanding in many research areas. As a newly developed aquaculture species, there is great interest in the monosex culture of *Ferrenopenaeus merguensis* in China. However, little information can be found on the control of male sex differentiation of this species. In this study, we have used an RNA-seq transcriptome analysis to identify candidate genes that may confer sexual development/sex determination of this shrimp. Global gene expression from spermatophore and testis was measured using Illumina reads from intact and unilateral eyestalk ablated males. Several sex-related genes including the Insulin-like androgenic gland hormone (IAG), Fem-1, female-lethal, and hatching enzyme have been identified. At least 5 different eyestalk CHH/MIH/GIH related neuropeptide transcripts have been found in the male reproductive tissues. Their expressions in intact and unilateral eyestalk ablated male are highly correlated with the process of male reproductive maturation. The results re-enforce the notion that the sinus-gland-androgenic gland axis is involved in the control of male sexual development. Transcripts that showed constitutive expression differences between the two groups have been selected for further validation analysis. In summary, this study provides a comprehensive comparison between the eyestalk ablated and intact male shrimp and the result is useful for future research in male sex development in shrimp.

S11-8 CHANDLER, J.C.*; AIZEN, J.; ELIZUR, A.; BATTAGLENE, S.C.; VENTURA, T.; University of the Sunshine Coast, University of Tasmania; tventura@usc.edu.au
Understanding a crustacean's masculinity: Transcriptomics of the Eastern rock lobster

In the Eastern spiny lobster, *Sagmariasus verreauxi*, commercial importance and growing potential in aquaculture drive a need to better understand sexual development. As a crustacean of the class *Malacostraca*, male sexual-differentiation is governed by the male-specific androgenic gland (AG), which secretes the masculinising insulin-like AG hormone (IAG) but from here little else is known. Thus, using the *de novo* assembled *S. verreauxi* transcriptome, we aim to uncover the male sexual-development pathway (SDP). Starting with the endocrinology of Sv-IAG, we have identified a binding protein (*Sv-IGFBP*) and additional insulin-like peptides (*Sv-ILP1*, *ILP2*) and investigated their binding *in silico*. Moreover, we have identified a tyrosine kinase insulin receptor (*Sv-TKIR*) and provided proof-of-function using a recombinant-IAG activation assay. Nevertheless, IAG is not a sex-determining factor, so we have also focused on identifying upstream elements of the SDP. Through the use of phylogenetic analyses we have identified a class of highly conserved sex-determining factors, the DM-domains (*Dmrt*s). With further investigation, one of the *Sv-Dmrt*s was found to have two genetic variants, one of which is male-specific, hence we have termed it *Sv-DMY*. Therefore, we have identified a sex-linked, putative sex-determining *Dmrt* which have been sparsely identified in only four of the higher vertebrates (Y-linked *DMY* in Medaka, Z-linked *Dmrt1* in chicken and flatfish and W-linked *DM-W* in frog). Moreover, this discovery has determined the chromosomal mechanism of sex-determination and provided a genomic sex-marker, both of which have significant application in aquaculture.

67-4 CHANG, J.*; ALFARO, M.E.; Univ. of California, Los Angeles; jonathan.chang@ucla.edu

The tempo of body shape evolution in ray-finned fishes: bringing morphology into the "phenomic era" with crowdsourced morphometrics

Recent advances in phylogenomics and next-generation sequencing technologies have made phylogenetic inference of large radiations of organisms possible. These comprehensive genomes and large phylogenies have been successfully used in conjunction with existing 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. 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 and Amazon workers, and use statistical methods to determine the accuracy of remote workers compared to morphologists. We show that the quality of Amazon workers' data are not significantly different from results collected via traditional sources. Furthermore, the ability to easily parallelize this pipeline allows data to be collected in hours, as opposed to days or weeks. We demonstrate this workflow by collecting body shape data across approximately 7,000 species of ray-finned fishes. We combine this data with a phylogeny of approximately 12,000 fishes and estimate the rates of phenotypic evolution and lineage origination. Our results suggest that the morphological diversification of ray-finned fishes predates the Cretaceous-Paleogene mass extinction event, and highlight the use of crowdsourced "phenomics" as a competitive method to bring phenotype data into the genomic era.

93-5 CHANG, J.J.*; CRALL, J.D; COMBES, S.A; Swarthmore College, Harvard University, Univ. of California, Davis; jjchang64@gmail.com

Bumblebees vary their landing strategy in the presence of wind

Landing is a critical component of insect flight. In nectivorous insects such as bumblebees (*Bombus impatiens*), landing must be performed hundreds to thousands of times daily, and thus represents a key component of foraging behavior. Previous studies have shown that the visual system triggers preparatory landing behaviors, such as deceleration and leg extension, and recent work suggests that landing is regulated by a simple, yet robust, universal control strategy, whereby the rate of image expansion is held constant to regulate flight speed during the approach. However, to our knowledge there has been no research investigating whether insects use this same strategy in the presence of wind, a ubiquitous challenge for insects flying in natural environments. We investigated the landing behavior of bumblebees in the presence and absence of wind, when landing on flowers that were aligned with or perpendicular to the flow. We filmed bees approaching and landing on real flowers in a wind tunnel using high-speed videography, and tracked body kinematics using a modified version of BEETag, an open-source image-based tracking system. Our results show that bees' approach paths to flowers vary highly in still air, but become more restricted in the presence of wind, irrespective of flower orientation. In still air, flight speed declines gradually during the approach, as predicted by previous studies. However, in the presence of wind, flight speed remains constant throughout the approach and landing, peak acceleration is higher at touchdown, and body stability is reduced. These findings suggest that wind has a strong influence on landing strategies in insects, with important implications for both the design of flying micro aerial vehicles and the ecomechanics of insect flight in natural environments.

41-3 CHAPPLE, TK*; GLEISS, AC; KANIVE, PE; JORGENSEN, SJ; CARLISLE, AB; BLOCK, BA; Stanford University, Stanford University/Univ. Western Australia, Montana State University, Monterey Bay Aquarium; tchapple@stanford.edu
Class Segregation in white sharks (*Carcharodon carcharias*) and the Underlying Mechanisms

Understanding the underlying mechanisms and function of sexual segregation can be critical to quantifying population characteristics and dynamics (Wearmouth & Sims 2008) and can help predict life-history strategies of cryptic species. Recent data show evidence of sexual segregation in white sharks (*Carcharodon carcharias*), but the underlying mechanisms remain largely unknown. We use electronic tagging data and visual observations of white sharks in central California to describe class segregation and explore the disparate underlying mechanisms and life history implications between the sexes. We found that females remain in warmer oligotrophic offshore waters while males simultaneously return to colder prey-rich waters, which is likely linked to unequal energy requirements for growth (sub-adults) and reproduction (adult). We consider these findings, in the context of other available data, to support theories of white shark life history strategies.

15-2 CHEESMAN, S.C.*; BAYANI, A.K.Y.; DONAHUE, M.L.; CARRUTH, L.L.; Georgia State University; lcarruth@gsu.edu
Early Life Cold Exposure Decreases Global Methylation Levels in Juveniles and Attenuates the Corticosterone Response After Restraint in Adult Zebra Finches (*Taeniopygia guttata*)

Cold exposure, especially early in life, can be stressful. We investigated if early-life cold exposure (first two weeks post-hatch) affects hypothalamic-pituitary-adrenal (HPA) axis sensitivity and global DNA methylation in the brain of juvenile and adult male and female Australian zebra finches (*Taeniopygia guttata*). Plasma corticosterone (Cort) levels after restraint was used to determine HPA axis sensitivity. Control birds showed the predicted elevation in plasma Cort after restraint stress in adulthood, however cold-exposed birds exhibited a blunted Cort response. The attenuated Cort response displayed by cold-exposed birds suggests that these birds are either maintaining higher baseline Cort levels to begin with or that they have an attenuated stress response. In adulthood, there was no significant difference in global DNA methylation levels between cold-exposed and control birds. Cold-exposed juveniles showed no significant difference between baseline and restraint plasma Cort levels, however these birds had significantly lower methylation levels. In parallel, we administered oral Cort for 10 days post hatch and measured global methylation patterns in juvenile and adult male finches to see if the similar results were observed. The results of both experiments were consistent, juvenile birds displayed a significant reduction in global DNA methylation but the adult birds did not. These studies suggest that hypomethylation on a global scale can occur after adverse early life events, however it is not known if these treatments resulted in hypermethylation of any specific gene sequences.

13-6 CHEN, R.*; REN, J.; GE, S.Q.; HU, D.; CHEN, Rui; Georgia Institute of Technology, Institute of Zoology, CAS; chenrui@gatech.edu

Beetle wings are inflatable origami

Beetles keep their wings folded and protected under a hard shell. In times of danger, they must unfold them rapidly in order for them to fly to escape. Moreover, they must do so across a range of body mass, from 1 mg to 10 grams. How can they unfold their wings so quickly? We use high-speed videography to record wing unfolding times, which we relate to the geometry of the network of blood vessels in the wing. Larger beetles have longer unfolding times. Modeling of the flow of blood through the veins successfully accounts for the wing unfolding speed of large beetles. However, smaller beetles have anomalously short unfolding times, suggesting they have lower blood viscosity or higher driving pressure. The use of hydraulics to unfold complex objects may have implications in the design of micro-flying air vehicles.

119-5 CHEJANOVSKI, Z.A.*; LAPIEDRA, O.; KOLBE, J.J.; Univ. of Rhode Island, Harvard Univ.; zchejanovski@gmail.com
Lizard foraging behavior in response to urbanized environments and associated predation risk.

A fundamental question in behavioral ecology is whether and how animals are able to cope with human-induced rapid environmental changes. For example, urbanization is a global phenomenon that causes declines in biodiversity and habitat fragmentation. In such disturbed environments, foraging animals are likely to experience an array of novel conditions, such as predators, parasites, food resources and artificial substrates. Theory states that animals may be able to increase their fitness by adjusting their foraging decisions to match current environmental conditions. However, maximizing the benefits of foraging while minimizing the risk of predation in uncertain environments poses many challenges, especially in novel environments. We conducted two manipulative experiments, observed activity times, and analyzed diets to examine the foraging behavior and ecology of naturally occurring populations of brown anoles (*Anolis sagrei*) across habitats varying in the degree of urbanization and predation risk. We found that anoles occupying urban and suburban habitats were less willing to exploit foraging opportunities when experimentally presented to them compared to anoles in natural forest habitats. Differences in the daily patterns of activity were only found for anoles occupying urban habitats containing a ground-based predator. Consistent with these activity patterns, anoles from these habitats had longer latencies to feed and spent less time on the ground after feeding when predators were active compared to when predators were inactive. This temporal behavioral shift was not found in urban habitats without the ground predator. Our results suggest that anoles modify their foraging behavior in response to urbanization and associated predation-risk.

37-2 CHEN, C.*; COPLEY, JT; LINSE, K; ROGERS, AD; SIGWART, JD; Japan Agency for Marine-Earth Science and Technology, Japan, University of Southampton, UK, British Antarctic Survey, Cambridge, UK, University of Oxford, UK, Queen's University Belfast, N. Ireland; cchen@jamstec.go.jp
Dragon heart and dragon scales: anatomy of the scaly-foot gastropod' *Chrysomallon squamiferum*

The iconic 'scaly-foot gastropod' from deep-sea hydrothermal vent ecosystems of the Indian Ocean is distinctive for the dermal scales covering its foot. These iron-sulfide coated sclerites, and its nutritional dependence on endosymbiotic bacteria, are both noted as specialist adaptations to the 'extreme' environment of hydrothermal vents. The distinctive scales are reminiscent of the girdle scales in polyplacophoran molluscs (chitons) and the multipart scleritomes of many early fossil molluscs. Despite striking external similarities, the sclerites and chiton scales are secreted by starkly different mechanisms. This convergence highlights the ability of molluscs to rapidly adapt mineralised dermal structures. We also present new evidence for further specialist adaptations revealed through dissection and 3D reconstruction of the internal anatomy. Of particular interest is the hypertrophied circulatory system. A well-developed ctenidium supported by extensive blood sinuses provides oxygen for the host but the circulatory system is enlarged beyond the scope of other similar vent gastropods. It has a remarkably voluminous heart representing approximately 4% of the body volume, with a very muscular ventricle. This proportionally giant heart primarily supplies the highly vascularised oesophageal gland, the organ that houses the endosymbionts. Thus we infer the elaborate cardiovascular system most likely evolved to oxygenate the endosymbionts in a hypoxic environment and/or to supply them with hydrogen sulfide. As a result of specialisation to resolve energetic needs in a chemosynthetic environment, this dramatic 'dragon-like' species has become a carrying vessel for its bacteria.

104-7 CHEVIRON, ZA*; VELOTTA, JP; WOLF, CJ; STORZ, JF; MCCLELLAND, GB; SCOTT, GR; U Montana, U Nebraska, McMaster U; zac.cheviro@msu.umt.edu
Evolutionary and functional genomics of the attenuation of maladaptive plasticity in highland deer mice (*Peromyscus maniculatus*)

Phenotypic plasticity can either facilitate or hinder colonization of novel environments depending on whether the ancestral plastic response moves the expressed phenotype toward the environment-specific phenotypic optimum (adaptive plasticity) or away from it (maladaptive plasticity). When acclimatization responses reduce performance in a novel environment, natural selection should favor their attenuation, but the regulatory mechanisms underlying these blunted responses are poorly understood. Acclimatization responses to high elevation are well suited for exploration of both the adaptive value and mechanistic underpinnings of plastic responses because exposure to hypobaric hypoxia induces a number of physiological changes in lowland taxa. Although many of these changes are beneficial, some are maladaptive, and tend to be selected against in species that are adapted to life at high-elevation. In vertebrates, both adaptive and maladaptive physiological changes are coordinated by the hypoxia-inducible factor (HIF) signaling pathway. Here we report the finding that highland and lowland populations of deer mice exhibit extreme allele frequency variation at *EPAS1*, a gene that encodes the oxygen-sensitive alpha-subunit of the HIF2 transcription factor that regulates the HIF signaling cascade. We characterize phenotypic and transcriptomic changes in response to both chronic and acute hypoxia in individuals carrying alternative *EPAS1* alleles, and relate them to variation in aerobic performance. Our results suggest that variation in *EPAS1* may contribute to blunting of ancestral acclimatization responses that can hinder aerobic performance at high elevation (i.e. pulmonary vasoconstriction and excessive erythropoiesis), providing insight into the evolutionary modification of maladaptive plasticity.

103-6 CHINA, V*; ELMALIACH, T; HOLZMAN, R; Tel-Aviv University, Tel-Aviv. The Interuniversity Institute, Eilat; victor.china@gmail.com

Hydrodynamic regime affects feeding success and encounter rates with prey to determine feeding rates of larval fish during the critical period

Larval fishes experience extreme mortality rates, with 99% of a cohort perishing within days after they start to actively feed. While recent evidence suggests that hydrodynamic factors constrain larval feeding during early ontogeny, feeding in fish (and larvae) is a complex process that also involves numerous interacting behavioral and biomechanical components. How these components change throughout ontogeny and how they contribute to feeding success remain unclear. Using a dataset of over 300 feeding attempts, we quantified the effects of key morphological and behavioral traits on the feeding success of *Sparus aurata* during early ontogeny. Feeding success was determined using high-speed videography, under both natural and increased water viscosity treatments. We identified significant differences between successful and unsuccessful feeding attempts: Path analyses revealed that larval size affected feeding success both directly and indirectly, via its effect on mouth size and opening speed. *Sparus* larvae exhibited a behavioral response to the viscosity treatments, modifying their feeding kinematics by reducing ram speed and initiating feeding strikes from a closer distance to their prey. These modifications, while resulting in a relatively high success rate, compromised their overall feeding rate, suggesting an hitherto unrecognized trade-off between strike success and encounter rate. Our results also highlight the impeded feeding performance in a low Reynolds regime, mediated by larval size and inability to rapidly and broadly expand the mouth cavity at smaller size. We suggest that these performance impediments will mainly affect the ability of larvae to feed successfully on large evasive prey during early ontogeny.

71-5 CHIN, D.D.*; LENTINK, D; Stanford University; ddchin@stanford.edu

How foraging birds support bodyweight from takeoff to landing

Birds frequently fly short distances as they forage among and within trees. Many small birds also exhibit bounding behavior during these low speed flights. While it is generally accepted that bounding at high speeds is used to save energy, it is still unclear why bounding is also observed at slower speeds. Takeoff and landing are particularly critical for foraging flights, but very few studies have quantitatively studied the transition of force generation from the legs to the wings. No studies have done so through the direct measurement of the aerodynamic forces produced in flight. By utilizing a new aerodynamic force platform (AFP), we can now directly quantify all of these forces for freely flying birds. We used this novel setup to study the perch-to-perch flight of a generalist bird, the Pacific parrotlet, over various distances and inclinations characteristic of foraging flight. Our time-resolved force measurements show how weight support generated by their legs and wings vary during these flights. When perches were set further apart, the parrotlets exhibited a brief bounding phase in flight. Aerodynamic weight support from the wings was predominately generated during each downstroke, with little to no weight support generated during upstrokes and bounds. Combining these in vivo force measurements with kinematic analysis provides further insight into how birds use their legs and wings to generate weight support, and when and why they may use bounding flight.

65-7 CHMURA, HE*; KRAUSE, JS; PEREZ, JH; MCGUIGAN, MA; RAMENOFKSY, M; WINGFIELD, JC; Univ. of California, Davis; hechmura@ucdavis.edu

Know when to go: Timing departure for autumn migration in an arctic-breeding songbird (*Zonotrichia leucophrys gambellii*)

Across the year, energetic demands fluctuate as birds reproduce, molt, and migrate. A growing body of evidence suggests that challenges experienced within any of these behavioral stages affect the energetics and/ or phenology of subsequent stages. Such consequences or "carry-over effects" may affect the timing and success of future life within or across years. While there is growing evidence for carry-over effects of spring migration on reproduction, few studies have examined the influence of breeding time on autumnal migratory departure. Due to the harsh weather conditions of spring and fall, arctic-breeding songbirds experience a narrow window of time in which to breed, molt, and depart for migration. We used arctic breeding Gambel's white-crowned sparrow (*Zonotrichia leucophrys gambellii*) as a study system in which to investigate carry-over effects of breeding on the post-reproductive period. Data were collected during 2014 and 2015 at Toolik Field Station on the North Slope of Alaska. Birds were monitored using hand-held and automated radio-telemetry through the post-fledging period. Meteorological data were also collected to test for a relationship between weather and migratory departure. We use these data to evaluate whether longer term carry-over effects from breeding or short term fluctuations in weather conditions are more important in determining timing of fall migration. Results suggest that there is tremendous variation in migratory departure timing across individuals and that re-nesting pairs could delay migration. Additionally, local weather conditions like early snowfall may affect migratory departure. We evaluate these findings in light of current and projected climate change in the Arctic.

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New tools to engineer cellular circuitry in behavioral neuroscience
 Optogenetics permits myriad events in cell signaling, excitability, and gene transcription to be optically perturbed and sensed, thereby providing a set of input/output interfaces to biological circuits with the biochemical precision of pharmacological agents and the spatiotemporal resolution of optoelectronic devices. The rapidly expanding toolbox is ultimately comprised of proteins that induce or report physiological changes in response to light. This talk will focus on the creation of novel optogenetic tools with enhanced biochemical functions and spectral range, which have been gained through genomic discovery of novel photoreceptors from diverse organisms, structure-guided protein engineering, and de novo protein design. Applications of these tools in decoding the computational principles of biological circuits, as well as strategies for creating new protein-based tools that remotely respond to longer forms of electromagnetic radiation useful for non-invasive perturbation and imaging in awake and behaving large mammals, will also be discussed.

87-4 CHUNG, DJ*; BRYANT, HJ; SCHULTE, PM; UBC;
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Thermal acclimation and adaptation effects on mitochondrial performance in the Atlantic killifish

Whole-animal thermal limits are thought to be constrained by processes acting at the level of the mitochondria. In this study we tested the effects of thermal acclimation and local adaptation on mitochondrial performance in the Atlantic killifish, *Fundulus heteroclitus*. We assessed heart and brain mitochondrial performance, as temperature effects on these organs are thought to place constraints on whole-animal performance. We used a Substrate Uncoupler Inhibitor Titration (SUIT) protocol to assess mitochondrial performance following thermal acclimation (5, 15, 33°C) in Northern (Nova Scotia) and Southern (Georgia) killifish. We hypothesized that low-temperature acclimation would be associated with modest compensation of mitochondrial performance, with Northern cold-adapted killifish exhibiting a greater increase than their Southern counterparts. High-temperature acclimation was predicted to cause a decline in performance that was greater in Northern killifish compared to Southern killifish; an effect we have previously demonstrated in liver mitochondria. Following acclimation to both 5 and 33°C, killifish heart and brain mitochondria exhibited a suppression of respiration (compared to 15°C). These suppression effects were largely associated with flux through ETS complex I. In addition, there was no clear differentiation between populations in these mitochondrial processes. This work demonstrates that thermal acclimation responses in the brain and heart differ from that of the liver, although the primary site of modification (ETS complex I) is the same. The absence of subspecies-specific responses indicates that mitochondrial performance does not account for subspecies differences in whole-animal thermal limits. These effects may, however, be a mechanism underlying the broad thermal tolerance of the species as a whole.

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Analyses of crustacean peptidergic signaling systems using high-throughput transcriptome sequencing

Crustaceans have long played important roles in increasing our understanding of neuropeptidergic signaling. For example, the first invertebrate neuropeptide to be isolated and fully characterized was from a crustacean, and the process of neurosecretion was first formally demonstrated using a crustacean neuroendocrine organ. Moreover, the cardiac and stomatogastric nervous systems of decapods have provided many key insights into peptidergic co-transmission and neuromodulation. Given these and other important scientific contributions, it is surprising that, until recently, little work had focused on crustaceans in terms of genomic and transcriptomic analyses, including investigations directed at elucidating their peptidergic signaling systems. In my presentation, I will describe the workflows that my lab has developed to identify neuropeptide precursor- and receptor-encoding transcripts from the transcriptomes of wide array of crustacean species, as well as the strategy that we have used to predict neuropeptidomes from these data. Recent analyses of a neural transcriptome from the American lobster, *Homarus americanus*, will serve as one example of the power of *in silico* transcriptome mining for identifying and characterizing native peptidergic systems in crustaceans. For this species, the structures of nearly 200 distinct neuropeptides and several dozen receptors were predicted using high-throughput nucleotide sequence data. This strategy for peptide prediction has allowed for the identification of many new crustacean peptide families, and the *in silico* discovery of a diverse set of peptide receptors has provided important insights into physiological control in these animals.

21-7 CLAESON, K.M.*; DAVIS, E.B.; SIDLAUSKAS, B.L.; PRESCOTT, Z.M.; Phila Col Osteopathic Med, Univ. of Oregon, Oregon State Univ., Dalhousie Univ.; *kerincl@pcom.edu*

The Sabertooth Salmon, *Oncorhynchus rastronus*, gets a facelift.

Oncorhynchus (*Smilodonichthys*) *rastronus* was first named for its incredible premaxillary dentition. Each premaxilla bears an enormous conical tooth, originally reconstructed as canine-like and ventrally directed. However, this giant prehistoric salmon was mistakenly identified as saber-toothed. New, exceptionally preserved specimens from an unnamed latest Miocene or earliest Pliocene deposit in Central Oregon indicate that the premaxillary bones and their enormous dentition were directed laterally rather than ventrally; a feature never observed in any other salmonid. The result is a configuration akin to horns rather than fangs. Here we describe new observations on these additional fossils and contrast them to other Miocene specimens, as well as to modern Eastern Pacific species of *Oncorhynchus*. Newly discovered morphology includes the presence of accessory dentition on the premaxilla, posterior to the massive premaxillary horn, which is significantly smaller. There is no visible kype on the dentary. On the dentaries, the only teeth are minute, laterally directed and at the mesial ends. These observations, plus the inland freshwater locality and their skeletal maturity imply that these were upstream migratory fishes preparing to spawn. Yet it appears that the metamorphosed spawning morphology observed in modern species is not present. It is probable that some tooth resorption occurred given the paucity of teeth along the dentary, but the lack of outward evidence of a kype may imply a different strategy for indicating mate dominance. The elaborate premaxillary horns may have aided in fights for space or improved the ability to shovel gravel while making redd nests. Alternatively, the lateral teeth may have improved substrate contact allowing the fish to maintain position in stream environments.

111-6 CLARK, K.F.*; GREENWOOD, S.J.; University of Prince Edward Island; fclark@upei.ca

Transcriptomic approaches to host-pathogen-environment interactions for the American lobster *Homarus americanus*

The American lobster (*Homarus americanus*) fishery is the most economically important commercial fishery in Canada. The health and sustainability of the lobster fishery is critical to maintaining tens of thousands of jobs in rural communities throughout Atlantic Canada and Quebec. Current transcriptomic technologies are key to answering the complex applied and basic research questions that are essential for ensuring the longevity of the fishery. We have recently transitioned from oligonucleotide microarray technologies to RNA-Seq approaches to increase the depth and breadth of our transcriptomic exploration of a lobster's response to pathogens or anthropogenic environmental contaminants. Here we will highlight the results of transcriptomic analyses of lobster immune responses during bacterial and microparasitic pathogen challenges. Our findings highlight the importance, and discovery, of hundreds of new lobster immune isoforms in immunological pathways such as pathogen recognition and response, coagulation, cellular encapsulation, phenoloxidase activation and melanization. The elucidation of immune pathways in lobsters, and other crustaceans, provides the basis of informative comparative immunological studies and a greater understanding of crustacean and invertebrate immunology.

132-1 CLIFTON, GT*; BIEWENER, AA; Concord Field Station, Harvard U., Bedford, MA, CFS, Harvard U., Bedford, MA; glenna.clifton@gmail.com

How to swim and hunt like a loon

Loons (*Gaviiformes*) are arguably one of the most successful groups of swimming birds. As specialist foot-propelled swimmers, loons are capable of diving up to 70 meters and remaining underwater for several minutes. They survive by capturing fish, a skill that requires a high level of maneuverability and speed. Despite the swimming prowess of loons, their locomotion has never been critically investigated. Our study used high-speed underwater cameras to film rehabilitating common loons (*Gavia immer*) at the Tufts Wildlife Clinic in order to analyze their swimming and turning strategies. Loons swim by synchronously paddling their feet laterally reaching 3 strokes per second. The swimming style of loons is unlike that of grebes or cormorants, instead incorporating aspects of both. The lateral foot movements of loons resemble grebes. However, loons accelerate through 30-60% of the paddling cycle similar to cormorants, whereas grebes maintain 24% regardless of speed. Swimming loons use head bobbing, previously documented in only 23 avian families. The eye of the loon is held still then accelerated 2-2.5 times faster than the body. This behaviour improves visual acuity by stabilizing the retina then increasing parallax to potentially improve depth perception. Our study is also the first to observe free maneuvers by diving birds. We find that loons alter relative timing and orientation of their feet to change direction. Turning loons consistently delay the propulsive stroke of the inside foot, which sometimes acts as a rudder to induce a sharper turn. Our findings are instrumental for understanding loon performance as well as the independent evolution of foot-propelled swimming in multiple avian taxa. Furthermore, loons could serve as inspiration for swimming robots, boats, or other engineered hydrodynamic structures.

87-3 CLAY, T.A.*; GIFFORD, M.E.; Univ. of Arkansas at Little Rock, Univ. of Central Arkansas; taclay@ualr.edu

Population level differences in thermal sensitivity of energy assimilation.

Previous work has shown that among species of terrestrial salamanders, thermal performance metrics are correlated with average environmental conditions. Species with large ranges usually encompass a wide range of environmental gradients as a result of variations in elevation or latitude. Given a large range of environmental conditions, we could expect to see population level adaptations to local environmental conditions. We explored the thermal sensitivity of energy assimilation within two species of *Plethodon* to answer: are there local adaptations to environmental conditions and are these consistent with theoretical predictions? We examined populations at the extremes for each species, with respect to latitude, populations that were separated by 500km and with respect to elevation, populations that were separated by 900m. Controlled feeding trials were conducted at ecologically relevant temperatures to produce thermal performance curves for each population. Preliminary work suggests that elevation and latitude affects thermal sensitivity of energy assimilation. Specifically, populations from warmer environments, low elevation or low latitude, may have higher assimilation rates than populations from cooler environments, high elevation and high latitudes. These preliminary observations are consistent with a pattern of co-gradient variation.

43-3 CLIFTON, IT*; CHAMBERLAIN, JD; GIFFORD, ME; University of Central Arkansas, University of Arkansas at Little Rock; iclifton1@cub.uca.edu

Adaptive differentiation in morphology after colonization of novel environments

When a species colonizes a new environment there are likely to be phenotypic changes associated with the colonization. These phenotypic changes are driven by novel environmental pressures unique to the newly inhabited areas. We studied the response of diamond-backed watersnake (*Nerodia rhombifer*) to colonization of novel environments with different prey regimes than the "ancestral" environments. Feeding morphology is likely to be influenced by prey size, especially in gape-limited predators. While *N. rhombifer* typically occupy natural areas such as rivers, sloughs, and oxbows, they have also colonized man-made fish farms. These farms tend to specialize in the types of fish they produce with some farms raising large-bodied fish and others raising small-bodied fish. Our study suggests that snakes that colonized large-prey sites have evolved relatively larger heads than those snakes that colonized small-prey sites. To explore whether the cranial variation observed among populations could be a consequence of a genetic response to selection, we provide evidence of significant heritability for all cranial traits.

SI-10 CODDINGTON, Emma J; Willamette University, Salem;
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Love in the time of Cortisol: Hormones mediate context-appropriate behaviors by modulating sensorimotor integration on multiple timescales

One of the long-term goals of my research program is to identify and characterize the multiple rapid effects of steroid hormones on the neurons and neural circuits that have behavioral relevance. We are pursuing the following questions: (1) How do hormones impact neurons on different timescales to affect the selection of context-appropriate behaviors? and (2) How do small ephemeral signaling molecules, endocannabinoids, behave as a switch upon which hormones act? We are using a combination of *in vivo* single-unit and slice whole cell electrophysiology, behavior, and imaging to investigate these questions in the clasp-controlling region of the hindbrain of an amphibian, Rough-skinned newts. Our results have begun to elucidate two novel mechanisms in which the steroid hormone corticosterone (CORT) mediates rapid and non-genomic behavioral changes. The first is by modulating intrinsic and synaptic electrical properties of clasp-controlling neurons. We know that endocannabinoids block CORT's ability to suppress clasping behavior, and we are currently investigating how endocannabinoids are involved at the level of neural signaling. Secondly, CORT blocks receptor-mediated endocytosis of vasotocin; acting non-genomically and rapidly but for a finite length of time (~30-45 min), effectively silencing the typically pro-courtship effect of vasotocin in a behaviorally relevant manner. These findings are consistent with our working hypothesis that CORT employs disparate cellular mechanisms in a cascade that functions within a rapid time frame of ms to min. This cascade being critical for context-appropriate behavioral responses to occur because neurons respond differently to specific temporal input patterns, and must allow for flexible behavioral selection processes.

4I-5 COHEN, KL*; WARKENTIN, KM; Boston University;
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Mechanism of early hatching of hourglass treefrogs in drying and ant attacks

Embryos of many species adaptively alter hatching timing in response to environmental cues. Most frogs hatch by secreting hatching enzyme from unicellular hatching glands (HG) on the epithelium, but mechanistic studies have not addressed the regulation of hatching timing. In many species HG peak in abundance long before hatching and secrete enzyme gradually, but we found that red-eyed treefrogs release enzyme only at the moment of hatching. Hourglass treefrogs, *Dendropsophus ebraccatus*, lay terrestrial eggs that hatch early to escape both dehydration and ant attacks. We study how *D. ebraccatus* accelerate hatching in both contexts, using an integrative framework to examine regulation at developmental, physiological, and behavioral levels. First, we split egg clutches into dry and well-hydrated treatments. Using scanning electron microscopy we found that, although eggs begin hatching after 70 h of development, HG in both treatments peak in abundance at about 32 h, then decline similarly. The pattern of HG abundance over time, plus our observations of gradual membrane degradation, indicate that enzyme secretion is gradual. However, in response to simulated ant attacks, embryos rapidly made a localized rupture in the membrane to escape. Scanning transmission electron microscopy revealed that HG are full of secretory vesicles before hatching, and depleted of vesicles just seconds after induced hatching, indicating acute release. We will also use qPCR to compare hatching enzyme expression and time-lapse photography to compare embryo behavior between hydration treatments. Although *D. ebraccatus* release enzyme gradually prior to spontaneous and dehydration-induced hatching, they can also release enzyme rapidly to escape from acute threats. Other anurans that exhibit gradual hatching enzyme release may also be capable of rapid release to escape acute threats.

125-2 COHEN, J.M.*; MCMAHON, T.; VENESKY, M.; CIVITELLO, D.J.; ROZNIK, B.; ROHR, J.R.; University of South Florida, University of Tampa, Allegheny College;
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Outbreaks of the amphibian chytrid fungus *Batrachochytrium dendrobatidis* are controlled by host adaptations to climate

Batrachochytrium dendrobatidis (*Bd*), the amphibian chytrid fungus, is considered one of the deadliest pathogens on the planet and is associated with hundreds of amphibian declines and extinctions. *Bd* growth and amphibian immunity are both temperature-dependent and thus temperature likely influences *Bd* outbreaks. In the past, most *Bd* models have assumed that amphibians are susceptible at temperatures where *Bd* grows best in culture (~20 °C), but here, we show that susceptibility varies based on the temperature to which host species are adapted. Two species from warm climates were susceptible to *Bd* at cold temperatures (10-18 °C), while a cold-tolerant montane species was most susceptible under warm conditions (26-28 °C). In addition, we tested for the relationship between temperature and *Bd* prevalence in the field by accumulating prevalence records for 4,775 amphibian populations from 250 published articles and extracting climate data specific to the location and date that each population was sampled. On average, peak pathogen growth occurred at a temperature only slightly cooler than in culture (~18 °C). However, amphibian populations from cool climates (averaging <15 °C) experienced peak prevalence at relatively warm temperatures (~23 °C) while those from warm climates (>20 °C) peaked at cooler temperatures (~16 °C), suggesting that *Bd* outbreaks may depend on characteristics of hosts and *Bd* growth in culture might not accurately reflect growth in the field. Researches must parameterize spatial models of *Bd* distribution to account for how *Bd* grows on hosts (as opposed to in culture), and should consider species-level traits when modeling susceptibility of a specific species.

S5-5 COHN, MJ; University of Florida; mjcohn@ufl.edu
Development of external genitalia: from evolutionary origins to congenital malformations

The cellular and molecular genetic mechanisms of external genital development are beginning to be elucidated from studies of the mouse genital tubercle, an embryonic appendage adjacent to the cloaca that is the precursor of the penis and clitoris. At early stages, patterning of the genital tubercle is similar in males and females. Sexual differentiation of the genitalia occurs at later stages, when sex-specific hormonal cues interact with developmental control genes to masculinize or feminize the genital tubercle, although the nature of these interactions remains unclear. Congenital malformations of external genitalia are among the most common birth defects in humans, with hypospadias, a failure of urethral tube closure, affecting ~1:250 live births. Affected children can have mislocalized, multiple or oversized urethral openings, and males with severe hypospadias are born with ambiguous genitalia. Despite this, there is a relatively poor understanding of the cellular and molecular mechanisms that control development of external genitalia. Prenatal exposures to environmental endocrine disrupting chemicals (EDCs) may play a causal role in the high incidence of genitourinary malformations. How the developmental genetic mechanisms that pattern the genital tubercle are affected by exposure to EDCs is largely unknown. We are integrating mouse developmental genetics, genomics, and environmental toxicology in order to identify causes of genitourinary malformations and the targets of EDCs in the genital tubercle. From an evolutionary perspective, genitalia evolve faster than any other organ system, which has led to striking diversity of morphological forms. This natural diversity provides a rich opportunity to dissect the mechanisms of genital evolution and to investigate the evolutionary underpinnings of external genital development and congenital malformations.

S4-3 COLLEY, N.J.*; NILSSON, D-E.; Univ. of Wisconsin, Lund University; njcolley@wisc.edu

Photoreception in Phytoplankton

In many organisms, from protists to humans, simple photoreceptors monitor ambient lighting. They function to assess the time of day for circadian rhythms and seasonal changes, as well as for the detection of harmful UV light and as depth gauges in the water column. Photoreceptors can be organized into eyespots, and in a wide variety of unicellular organisms, including *Chlamydomonas*, *Euglena* and several species of dinoflagellates, eyespots are light-sensitive organelles residing within the cell. Eyespots can be composed of photoreceptor proteins and red-orange carotenoid screening pigments. This association of photopigment with screening pigment allows for detecting light directionality, leading to light-guided behaviors such as positive and negative phototaxis. In *Chlamydomonas*, the eyespot is part of the chloroplast and its light-sensitive photopigment is the microbial channelrhodopsin (ChR1 and ChR2). Dinoflagellates are unicellular protists that are ecologically important constituents of the phytoplankton. They exhibit a great deal of diversity in morphology, nutritional modes and symbioses, and can be photosynthetic or heterotrophic, feeding on smaller phytoplankton. Certain dinoflagellates, such as *Kryptoperidinium foliaceum*, have eyespots that are used for light-mediated tasks such as phototaxis. Other dinoflagellates belonging to the family, *Warnowiaceae*, have a more elaborate eye. Their eye-organelle is a large structure consisting of a focusing lens, highly ordered retinal membranes and a shield of dark pigment. This complex eye-organelle is similar to multicellular camera eyes, such as our own. Unraveling the molecular makeup, structure and function of dinoflagellate eyes, as well as light-guided behaviors in phytoplankton can inform us about the selective forces that drove evolution in the important steps from light detection to vision.

29-2 COLLINS, E.E.*; HALANYCH, K.M.; MAHON, A.R.; Central Michigan Univ., Auburn Univ.; eecollin1@gmail.com

Phylogeography of Ammotheidae (Arthropoda, Pycnogonida) in the Southern Ocean

Pycnogonids, or sea spiders, are obligate marine arthropods distributed across all oceans. Geographic and subsequently biological isolation has occurred in the Southern Ocean since the creation of the Antarctic Circumpolar Current (ACC) approximately 41 million years ago resulting in many taxa that are endemic to the region. Sea spiders in Antarctic waters are exceedingly diverse (20% of all species are present) and many are only found in the Southern Ocean (64% of all Antarctic sea spiders are endemic). The use of molecular tools has provided a greater understanding of sea spider biodiversity, particularly for those groups thought to have circumpolar distributions. This study employs mitochondrial and nuclear markers to investigate diversity and phylogeographic relationships within the Ammotheidae, a common sea spider family in the Southern Ocean. Sampling throughout the Western Antarctic Peninsula and seas (Bellingshausen, Amundsen, and Ross Seas) provides new insight for both the biodiversity and potential cryptic species within the family and also for population connectivity across large distances around the continent.

57-1 COLLINGS, AJ*; PORRO, LB; RICHARDS, CT; Royal Veterinary College, United Kingdom; ajcollings@rvc.ac.uk

3D kinematics and pelvic motion during walking locomotion in the red-legged running frog (*Kassina maculata*)

Kassina maculata retain the characteristic anuran body plan and jumping ability, however employ walking and running as their primary mode of locomotion. Since their asymmetric forelimb and hindlimb lengths and short spines are not considered particularly well-suited for walking/running, we hypothesised that lateral rotation of the pelvis in walking may compensate for this morphology. 3D kinematic data were collected using high speed video from three views. Twelve external skin markers, placed on the right hindlimb and body, were used to create stick figure models to track limb segment motion and body rotation. Footfall patterns indicate duty factors consistently above 0.5, despite travelling over a range of speeds from 1.57-5.76 body lengths s⁻¹ (mean = 2.89 body lengths s⁻¹), suggesting all observed frogs (n=11 trials from 3 frogs) used a walking gait. Hindlimb joint motions were synchronised and sinusoidal with the majority of femur motion occurring as protraction and retraction in the frontal plane. The models estimated an average pelvic angular excursion of approximately ±5° with respect to the body axis, implying that lateral pelvic rotation potentially increases hindlimb step length. A 3D kinematic model is under development to calculate the hypothetical requirements of the limb to compensate in the absence of lateral pelvic rotation.

I-3 COLLINS, CE*; HIGHAM, TE; Univ. of California, Riverside; clint.collins@email.ucr.edu

The biomechanics of individuals: Geckos vary the employment of adhesion and locomotor kinematics in response to changes in substrate incline

Effectively escaping through complex, three-dimensional environments is a principal driver of terrestrial animal biomechanics. However, the underlying suites of mechanisms (*e.g.* interacting morphological components) by which animals achieve maximal performances are varied and contentious. The adhesive apparatus of geckos involves novel morphological structures that permit locomotion on inclined and even inverted surfaces. The intricate method by which geckos employ the adhesive system likely has many cascading trade-offs on locomotion. Using a pad-bearing cursorial gecko from Namibia (*Rhoptropus afer*), we use path analysis to test the hypothesis that deploying or withholding adhesion directly impacts the coordination of locomotion on level and inclined surfaces. Second, we use bootstrapping to quantify how individual variation contributes to our understanding of how species deal with the physical parameters of their habitat. We quantified locomotor kinematics in 45 individuals collected from natural populations in Namibia. Thus, the range of trade-offs and proximate causes of individual variation within a species may be clarified. Results suggest the adhesive system is more nuanced than previously thought and that individuals vary in the extent to which they employ adhesion during level and uphill locomotion. Given that the adhesive apparatus is a finely-tuned system that the animal controls, our results indicate that adjusting adhesion is an important aspect of coordinating and modulating locomotion. Furthermore, quantifying a range of individuals from natural populations is important to understand the role of biomechanics in evolution. Supported by NSF IOS-1147043 to TEH and a Newell Award to CEC.

21-8 CONRAD, J.L.; NYIT COM / AMNH; jack.conrad@gmail.com
Iguanomorpha (Squamata) and the importance of fossils
 Iguanomorpha is a speciose clade including chameleons, agamas, basilisks, anoles, and iguanas, among others. The iguanomorph fossil record includes some extinct clades (e.g., Gobiguania and Priscagamidae) and numerous other fossil species. Inclusion of fossil iguanomorphs has been conspicuously spotty in recent morphological and combined-evidence analyses. The possible iguanian *Bharatagama* (Triassic) is absent from published analyses despite being the only putative pre-Cretaceous (K) iguanian. A recent morphological study suggested that Gobiguania is non-holophyletic, but failed to include the anchor taxon for that clade – one of only five well-preserved taxa used to establish it. I sought to test the phylogenetic relationships of Iguanomorpha by including those fossils mentioned above and others critical for reconstructing ancestral morphologies (e.g., *Afairiguana*, *Lapitiguana*, *Geiseltaliellus*). Using my own iguanomorph data matrix (169 species and 1318 morphological characters) as a starting point, I mimicked taxon and character samplings of earlier studies. These analyses recovered topologies similar to the ones recovered in the studies they mimicked. By contrast, analyses of my full data set recover a holophyletic Gobiguania, Isodontosaurus (K) as the basalmost member of the agama-chameleon clade, and find *Arretosaurus* (Eocene) to be the sister taxon to *Priscagama* (K). Priscagamidae and Gobiguania are basal (non-iguanian) iguanomorph clades. *Bharatagama* is united with *Pleurosaurus* (Rhynchocephalia) based on the presence of a robust dentary coronoid process and procumbent anterior dentition; it is not an iguanian. These relationships persist when published molecular data were used to perform a combined evidence analysis. In addition to offering a novel phylogenetic hypothesis, these findings further emphasize the importance of historical data offered by fossils in any phylogenetic study, even one based on combined morphological and molecular data.

34-4 COOPER, L.N.*; ASHLEY, N.T.; Western Kentucky University; lcooper033@topper.wku.edu
Effect of sleep disruption upon cytokine gene expression of zebra finch *Taeniopygia guttata*
 Sleep is a natural physiological process that is essential for survival, and prevention of sleep leads to cognitive dysfunction as well as a marked inflammatory response in mammals. However, a number of vertebrate taxa, including birds, exhibit resilience to sleep loss over the annual cycle (e.g., breeding, migration). We have developed a non-invasive method of disrupting sleep in caged birds that involves an automated, sweeping horizontal bar that arouses sleeping birds. Adult zebra finches on a 12-h light:12-h dark rotation were exposed to fragmented sleep cycles (bar moves every 2 min) for a 12-h period (either dark or light cycle) or no disruption (control group), and then pro-inflammatory cytokine gene expression (IL-1, IL-6) was assessed in liver, spleen, fat, heart and brain using RTPCR. We predicted that sleep disruption would lead to a pro-inflammatory response. Results from this study will provide insight into how birds cope with sleep loss from an immunological perspective.

6-4 CONRADES, A/D*; BRANDT, L; Truman State University; adconrades@att.net
Lake Nicaragua shoreline fish diversity prior to Nicaraguan canal construction
 Nicaragua is the poorest country in Central America. To encourage economic growth and trade, in 2013 the Nicaraguan government joined with the Hong Kong Nicaragua Development Corporation (HKND) to build an interoceanic canal. The Nicaraguan canal's proposed path connects the Pacific Ocean with the Caribbean Sea, passing through Lake Nicaragua close to *Isla de Ometepe*. While the canal project could mean construction and maintenance jobs for Nicaraguans, the project requires dynamite blasting and dredging through the lake, as well as water pollution from increased traffic and equipment. Many local communities depend on Lake Nicaragua as a primary source of food, drinking water, sanitation, transportation, and tourism. Despite the risks to the lake's ecosystems, the HKND has been moving forward with little or no reported environmental assessment to date. Our study attempts to characterize the diversity of shoreline fishes in Lake Nicaragua along the *Ometepe* coast prior to canal construction, particularly around the city of San Ramon. Fishes were caught from six locations on seven different days using seine nets and hand lines, counted, photographed, and identified down to genus. Catch data suggests a low observed species richness (n=10) and disproportionate species evenness. Estimates of actual species richness also indicated relatively low fish diversity along the *Ometepe* shoreline. We hypothesize that *Ometepe* shoreline fish populations could be vulnerable to disturbance and unlikely to recover after the canal's construction. While our current data implies ecological threats to Nicaraguan shoreline fishes, further fish surveys need to occur as well as extensive assessment of surrounding aquatic and terrestrial ecosystems to fully measure the biological impact of the canal's construction.

11-7 COOPER, WJ*; CARTER, CB; SWEET, EM; GALINDO, D; WAGNER, M; LAKE, E; Washington State University; jim.cooper@wsu.edu
Filling evo-devo's developmental gap: metamorphosis, integration and functional evolution
 Filling evo-devo's developmental gap: metamorphosis, integration and functional evolution Animal Evo-Devo has focused almost exclusively on embryonic stages, but most evolutionary morphological studies examine adult characters. Adults and embryos are very different. Adult morphology is the product of extensive developmental remodeling of embryonic structures. We lack an understanding of how changes in remodeling mechanisms have facilitated the evolutionary diversification of adult form. Most animals undergo a physical metamorphosis (extensive anatomical remodeling) that coincides with a shift in habitat. Furthermore, many species possess complex biomechanical abilities that arise during metamorphosis. The functional integration of complex structures requires the morphological integration of their sub-components. Metamorphosis may therefore: 1) play a significantly larger role in determining adult form and ecology than embryogenesis, and 2) represent an important developmental mechanism for establishing integration. Since integration is a critical feature in shaping diversification, metamorphosis may be of strong importance to determining evolutionary potential. The developmental mechanisms that direct integration are only poorly known. Thyroid hormone (TH) signaling is the predominant determinant of animal metamorphosis and represents an important target for Evo-Devo research. Here we present data which indicate that TH signaling is important for establishing the morphological and functional integration of zebrafish jaws. Comparative analyses of the functional morphology of feeding in closely related species suggest that modulation of TH signaling may have played an important role in the diversification of fish feeding mechanisms.

42-5 COPPARD, S.E.; Hamilton College, Clinton, New York;
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Patterns of expression and evolution of cryptochrome and timeless genes involved in lunar spawning: Temporal prezygotic isolation among sympatric species of the pantropical sea urchin *Diadema*
Diadema setosum and *D. savignyi* are sympatric throughout much of the Tropical West Pacific and Indian Oceans and exhibit no spatial isolation on coral reefs. *Diadema savignyi* typically spawns on the full moon and *D. setosum* around the time of the new moon, the out of phase spawning rhythms functioning as a temporal reproductive barrier to hybridization. In the wild hybrids are rare. However, artificial cross-fertilization experiments have produced viable hybrids at equal rates and sperm concentrations relative to intraspecific crosses. This suggests that temporal reproductive isolation is important for maintaining specific integrity. In this investigation we assessed temporal expression profiles of mRNAs from cryptochromes (*Cry*) (which include members that are blue-light photoreceptors and can detect moonlight), and timeless genes (*tim*), which are involved in regulating the circadian clock. Expression levels of mRNAs were analyzed in the spine-base skin and muscle, tubefeet, and gonads from *D. savignyi* and *D. setosum* collected from their natural habitats, every 6 hrs on the moons first quarter, full moon, third quarter and new moon, over one lunar month. In *D. savignyi*, *dCry1*, *vCry1-lt*, *Cry-D* and *tim2* were significantly up-regulated in all three tissues on the full moon, with greatest significant up-regulation of *vCry1-lt* at 18:00 hrs and *dCry1*, *Cry-D* and *tim2* at midnight. Such up-regulation is likely to result in increased sensitivity to moonlight, with increased lunar radiance acting as a stimulus for spawning. In *D. setosum*, greatest significant up-regulation of *dCry1*, *vCry1-lt* and *tim2* was recorded at 06:00 hrs on the new moon in all three tissues. This is when the most abrupt change in illumination occurs during the night/dawn transition and is likely to influence spawning time in *D. setosum*. Both *dCry1* and *vCry1-lt* were found to have regions under positive selection, and are strong candidate genes for regulatory control of lunar spawning in sympatric *Diadema*.

I-5 CORN, K.A.*; FARINA, S.C.; GIBB, A.C.; SUMMERS, A.P.; Cornell University, Ithaca, NY, Harvard University, Cambridge, MA, Northern Arizona University, University of Washington;
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Scaling of Burial Mechanics in *Parophrys vetulus*, the English Sole

Flatfishes (Pleuronectiformes) rapidly bury themselves under sediments using body undulations and fin movements. During burial, a fish must fluidize a volume of the substrate to displace it into the water column and distribute it over the surface of the body. Thus the burial behavior forces the fish to interact with the fluid environment and a granular medium and is affected by size of the organism and grain size. We used the English Sole, *Parophrys vetulus*, as a model to explore the effects of scaling on burial. We recorded burial events from 15 fish across a size range (5 to 30 cm in total length), keeping sand grain size consistent, using high speed video at 250 fps and determined undulation frequency, time to burial, and percent body coverage. We found larger fishes took longer to bury and moved with a lower undulation frequency, but were able to cover themselves as effectively as smaller fish (91.6%). Undulation frequency decreased with body length to the -0.53 power; time to burial increased to the 0.67 power. We also used 5 individual fish of similar size (5.7 - 8.1 cm) and changed the size of the particle provided as substrate (125 - 710 microns). We found grain size does not affect the undulation frequency or time to burial of small fish, but as particle size increases, the percentage of the body covered decreases. It is possible that fish cannot fluidize particles of larger grain sizes as effectively as they can smaller grain sizes. Taken together, these results reveal that the timing of flatfish burial is a function of fish size and the success of the behavior is affected by the relative grain size of the sediment.

99-1 CORCORAN, A.J.*; CONNER, W.E.; Wake Forest University;
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How moths escape bats: predicting outcomes of predator-prey interactions

What determines whether prey escape pursuit predators? To answer this question, biologists have developed mathematical models that incorporate geometries of attack, pursuit and escape trajectories, and relative kinematic performance of predator and prey. However, these models have rarely been tested with data from actual predation-prey events. To address this problem we recorded multi-camera infrared videography of bat-insect interactions in a large outdoor enclosure. We recorded 235 attacks by four *Myotis volans* bats on a variety of moths and 50 high-quality attacks were reconstructed in 3-D. Despite bats having higher maximum velocity, deceleration, and overall turning ability, prey escaped 115 of 184 attacks (62.5%) in which evasive maneuvering was present. Bats captured nearly all moths (50 of 51; 98%) not evading attack. Existing escape models failed to accurately reflect prey behavior or predict the outcomes of attacks. In contrast, prey radial acceleration and escape angle correctly classified the outcomes of 44 of 50 attacks (88%). Based on these findings and prey behavior we developed a novel geometrical model of predation that incorporates predator reaction time, relative prey turning ability and velocity, and escape angle. We discuss implications of our predation model for the co-evolution of predator and prey pursuit and escape strategies.

27-2 CORNELIUS, EA*; REGIMBALD, L; LOVE, O; FRANCOIS, F; KARASOV, W; Univ. of Wisconsin-Madison, Univ. du Quebec a Rimouski, Univ. of Windsor; ecornelius@wisc.edu

Immune function and body composition of a wild bird faced with food unpredictability

Food supplementation to wild birds occurs across landscapes and over every season. However, natural food abundances may sometimes not be adequate. In winter, especially, natural food availability might be unpredictable whereas the availability of human provided food remains more constant. This variability in resources might then have a negative impact on immune function, as might occur if adequate energy and nutrients for mounting an immune response is not acquired. To test this idea we compared immune function and physiology of captive black-capped chickadees (*Parus atricapillus*) with a constant and unpredictable food supply. Control birds received ad libitum food each day of the experiment; birds assigned to the unpredictable treatment received only 80% of their daily energy requirements on random days and ad libitum food on other days. Throughout the course of the study we examined multiple aspects of the immune system (constitutive and induced), body mass, fat and lean mass. Treatment birds maintained higher mass over the course of the study and had significantly higher fat mass compared to control birds. Treatment birds mounted a weaker immune response to lipopolysaccharide; however, they maintained a high level of complement lysis activity compared with control birds. Results from this study demonstrate that during times of variable and uncertain food availability, like extreme weather events or long winters, certain aspects of the immune system might be compromised even if animals maintain more body fat as a hedge against uncertainty.

4-3 CORNELIUS, JM*; MEDDLE, SL; HAHN, TP; Eastern Michigan Univ., Univ. of Edinburgh, Univ. of California, Davis; jcornel7@emich.edu

Public information can change your brain: mineralocorticoid and glucocorticoid receptor expression in food-reduced red crossbills differs depending on their neighbors food treatment

Public information was recently found to influence the physiological and behavioral response to food reduction in songbirds: red crossbills (*Loxia curvirostra*) that were food reduced for several days did not have significant elevations in circulating baseline corticosterone (CORT) or activity levels unless their neighbors were also food reduced. Physiological and behavioral responses to glucocorticoids are, however, enacted through receptors that may be expressed differentially in target tissues. We investigated the influence of public information on the expression of the high-affinity mineralocorticoid receptor (MR) and low-affinity glucocorticoid receptor (GR) mRNA in captive red crossbills. Given the role of MR in negative feedback mechanisms on basal CORT secretion, we predicted public information from food-restricted individuals would reduce MR expression in brain regions known to regulate hypothalamic-pituitary-adrenal activity - thereby allowing increased or sustained HPA-activity during subsequent stressors. Such a mechanism may explain why food reduced crossbills paired with food reduced neighbors show higher CORT secretion than those paired with well-fed neighbors. Our results supported our predictions in regards to MR: MR expression in hippocampus was lower in birds with food-reduced neighbors. Interestingly, food reduction itself appeared to have no influence on MR or GR expression.

9-3 CORRALES-UGALDE, M.*; SUTHERLAND, K. R.; Oregon Institute of Marine Biology, University of Oregon; marcoc@uoregon.edu

The role of morphology and behavior in prey capture by Hydromedusae

The class Hydrozoa is the most diverse medusozoan class and includes species with a broad range of swimming and feeding mechanisms. When a medusa encounters prey, nematocysts distributed along the tentacles are directly responsible for prey capture. The goal of this study was to analyze whether variations in nematocyst distribution and density were related to the prey capture patterns of hydromedusae. High definition videos of the filter feeder *Mitrocoma cellularia* and the ambush predator *Aglantha digitale* feeding on *Artemia salina* larvae showed that capture locations along the tentacles were species-specific: in *M. cellularia* captures frequently occurred adjacent to the bell margin, but in *A. digitale* captures occurred further along the tentacle length. To determine the relationship between capture location and nematocyst density, we analyzed images of tentacles from both species taken with differential interference contrast microscopy. Overall, the nematocyst distribution in these two species was related to the different mechanisms for capturing and transferring prey from the tentacle toward the mouth. Gaining a better understanding of the mechanisms used by a predator to successfully capture food gives us a baseline for understanding prey selection patterns.

111-4 CORNELL, A*; HOU, JJ; WILLIAMS, TD; Simon Fraser University; acornell@sfu.ca

Song and male social behavior as a supplemental cue for female breeding phenology: an experimental, field study

Although photoperiod is widely recognized as the primary environmental cue controlling seasonal reproduction, slight variation in individual timing of breeding can have major fitness consequences in birds. Supplemental cues that fine tune egg-laying date are poorly characterized but are thought to include temperature, food, and social factors. A recent study suggested that social cues (presence of a male partner) can have direct effects the female reproductive axis (vitellogenesis and follicle maturation) in European starlings (*Sturnus vulgaris*) breeding in semi-natural outdoor aviaries (Perfito et al. 2015). Although many studies have experimentally manipulated song and/or the social environment of breeding birds, few appear to have investigated female responses, specifically timing of egg-laying. We conducted a two-year field study investigating the relationship between female breeding behavior and male presence, song rate, and song quality in free-living European starlings. During the month preceding laying, we surveyed social behavior using visual observation, while simultaneously recording bird song for analysis in Raven. In the second year we experimentally increased the stimulus of male song by playing high quality song at nest boxes. Preliminary results show large variation in song rate among nest boxes (0-32 songs/30 min), with length of the song bout highly correlated with song quality. Male behavior was strongly correlated to female activity at the nest box but not to lay date. Experimental manipulation of song increased activity at the song-treated boxes in terms of male presence and male song rate. We will discuss natural variation in pre-breeding social behavior as well as results from experimental manipulation, and its possible effects on female breeding phenology.

92-3 CORYELL, R.L.*; TURNHAM, K.E. ; AYSON, E.G.J.; ALACALA, A.; SOTO, F.; GONZALES, B.; NISHIGUCHI, M.K.; New Mexico State University, Las Cruces NM, New Mexico State University, Las Cruces NM, Southeastern Asian Fisheries Development Center, Tigbauan, Panay, Silliman University, Dumagetti, Negros, University San Carlos, Cebu City, Cebu, Western Philippine University, Palawan; coryellr@nmsu.edu

Phylogeographic patterns in the Philippine archipelago drive symbiont diversity in the bobtail squid-Vibrio mutualism

Environmentally transmitted symbioses between bacteria and their animal hosts can be influenced by a number of variables that shape both the distribution and occurrence of each partner, particularly in marine habitats. Factors such as water temperature, salinity, and nutrient availability, while relatively stable, can fluctuate with the mixing of adjoining currents. Sepiolid squids (Cephalopoda: Sepiolidae) form mutualistic associations with bioluminescent bacteria from the genus *Vibrio* (Proteobacteria: Vibrionaceae). While a multitude of host-mediated factors are important for shaping squid-*Vibrio* assemblages, their population structure can vary depending on geography and an assortment of abiotic factors. Therefore, we examined the genetic architecture of *Euprymna albatrossae* and their *Vibrio fischeri* symbionts in the Philippine archipelago using a combined phylogeographical approach to define whether abiotic factors drive the population dynamics of this mutualism. Diversity measures of symbiont populations within and between sites were highly variable compared to their specific *Euprymna* host populations, which had less introgression among the samples measured. Additionally, *Vibrio* populations shared multiple haplotypes across wide geographical ranges. These results indicate that additional factors besides host specificity can contribute to the overall distribution of symbiotic vibrios, leading to a more diverse landscape of host-symbiont assemblages in this beneficial association.

53-2 COSTELLO, MJ; University of Auckland;
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Global biodiversity and biogeography of parasites

Most species on Earth harbour several parasite species. If half of all marine species had one host-specific parasite we would expect over 100,000 described species of parasites. However, at present < 10% of described marine species are parasites. Is this because parasites are grossly under-sampled and described compared to their hosts? Will new discoveries of parasite species at least double the number of known marine species? Or are parasites far less host-specific than believed, perhaps also due to under-sampling of hosts? Other reasons that parasites may be more widespread than recognised may be because they use their high fecundity, efficient dispersal to infect new hosts, and alternative hosts to extend their geographic range. This presentation will compare the relative species richness and biogeography of marine parasites and their hosts to find clues to help answer these questions.

56-1 COX, RM*; MCGLOTHLIN, JW; BONIER, F; University of Virginia, Virginia Tech, Queen's University; rmc3u@virginia.edu
Hormones as mediators of phenotypic and genetic integration: an evolutionary genetics approach

At its core, evolutionary endocrinology represents a synthesis between comparative endocrinology and evolutionary genetics. This synthesis can be viewed through the breeder's equation, a cornerstone of quantitative genetics that, in univariate form, states that a population's evolutionary response is the product of the heritability of a trait and selection on that trait ($R = h^2S$). Under this framework, evolutionary endocrinologists have begun to quantify the heritability of, and the strength of selection on, a variety of hormonal phenotypes. With reference to our work in birds and lizards, we review these studies while emphasizing the challenges of applying this framework to hormonal phenotypes that are inherently plastic and mediate adaptive responses to environmental variation. Next, we consider the untapped potential of evolutionary endocrinology as a framework for exploring multivariate versions of the breeder's equation, with emphasis on the role of hormones in structuring genetic covariance. As an extension of the familiar concepts of phenotypic integration and hormonal pleiotropy, we illustrate how the hormonal milieu of an individual acts as a local environment for gene expression, thereby influencing the quantitative-genetic architecture of integrated, multivariate phenotypes. In particular, we show how classic hormonal manipulations and quantitative-genetic breeding designs can be integrated with next-generation transcriptomic surveys to link genotypes to phenotypes via hormonal regulation. We emphasize that hormones are more than mechanistic links in the translation of genotype to phenotype: they are interactive features of the evolutionary process, structuring the genetic variances and covariances that determine a population's evolutionary response to selection.

83-6 COX, CL*; POLLOCK, NB; JOHN-ALDER, HB; ANDREW, AL; CARD, DC; CASTOE, TA; COX, RM; Georgia Southern University, Rutgers University, UT Arlington, Univ of Virginia; clcox@georgiasouthern.edu

Evolutionary lability in the modulation of growth-regulatory gene networks by testosterone

A central goal of evolutionary endocrinology is to understand how the pleiotropic effects of hormones facilitate or constrain the evolution of sexual dimorphism. Endocrine networks are conserved and shared between the sexes, which should impede the evolution of sexual dimorphism. However, hormones with sex-specific expression (e.g., testosterone, or T) could be coupled and decoupled from the expression of shared regulatory networks to produce diversity in patterns of sexual dimorphism. Our research addresses how a sex-biased hormone (T) pleiotropically regulates the expression of shared regulatory networks and sexual size dimorphism (SSD). First, we studied brown anoles, which have extreme male-biased SSD that develops as growth diverges between the sexes during development. We found that phenotypic divergence between the sexes was mediated by T and accompanied by an increase in sex-biased gene expression in the liver, an integrator of growth and energetics. Notably, expression of growth-regulatory insulin signaling/mTOR networks diverged between the sexes during ontogeny and was altered by exogenous T in both sexes. Second, we extended this work to test of how T impacts gene expression in lizards with both male- and female-biased SSD (spiny lizards). We found that T has the opposite impact on gene expression in growth-regulatory networks for species with female-biased SSD (eastern fence lizard), compared to male-biased brown anoles. This research reveals how the relationships between conserved regulatory networks and a single pleiotropic hormone (T) can facilitate the evolution of different patterns of sexual dimorphism.

2-8 COX, S. M.*; GILLIS, G.B.; University of Massachusetts, Mount Holyoke College; coxzanne@gmail.com

Sensory modalities and coordinated landing in cane toads

Coordinated landing requires preparation. Limbs must be positioned to hit the ground first and joint and muscle stiffness need to be modulated with respect to impact conditions to decrease muscle and skeletal damage. Such preparation requires the ability to accurately predict the timing and magnitude of impact forces, a potentially complex feat of sensorimotor integration. Cane toads (*Bufo marinus*) have recently become a model for studying the biomechanics and neuromuscular control of landing, in part because they appear to be able to predictably tune pre-landing forelimb muscle activity patterns to hop length. Here we test the role of three potentially important sensory modalities in facilitating coordinated landing: vision, vestibular feedback, and hindlimb proprioception. Experiments involved using high-speed video recordings and electromyography to compare forelimb kinematics and muscle activity in cane toads before and after manipulations compromising the function of a particular sensory system. Preliminary results indicate that removing vision has the smallest effect on movements and muscle activity associated with coordinated landing, while ablating the vestibular system effectively eliminates a toad's capacity to coordinate landing after a hop.

54-5 CRALL, JD*; GRAVISH, N; MOUNTCASTLE, AM; KOCHER, SD; OPPENHEIMER, R; KAO, AB; PIERCE, N; COMBES, SA; Harvard University, Princeton University, University of California, Davis; james.crall@gmail.com
Automated tracking reveals the importance of individual variation for division of labor in primitively eusocial bumblebees (*Bombus impatiens*)

Insect societies are complex, self-organized systems that demonstrate collective intelligence through the interactions of many individuals. Recent evidence suggests that social insect groups are comprised of individuals that vary widely in their behavior. The origins and consequences of such variation are not entirely clear, however, and the study of this behavioral variation has been challenging because of the technical hurdles associated with tracking large numbers of individuals. Here, we use an automated tracking system to study collective behavior in bumblebees (*Bombus impatiens*), a primitively eusocial relative of honeybees characterized by small colonies without distinct behavioral castes. Individual bumblebees show striking variation in both foraging and in-nest behavior, which is largely unassociated with morphological differences. In particular, even among foraging bees, there are strong differences between individuals in foraging intensity, with a few bees performing the vast majority of foraging work for the colony. We show that such individual variation can potentially be explained by a simple model of task allocation. Finally, we describe experiments in which we either removed or impaired active foragers within the hive to examine the plasticity of individual behaviors. Overall, our results suggest that individual variation plays an important role in regulating collective behavior, even in primitively eusocial species, and may help shed light on the evolutionary origins of division of labor in more complex insect societies.

26-2 CRINO, O.L.*; JENSEN, S.M.; GRIFFITH, S.C.; BUCHANAN, K.L.; Deakin University, University of Montana, Macquarie University; ondi.crino@deakin.edu.au
Reproductive plasticity in wild zebra finches: trade-offs between the HPA and HPG axes in heterogeneous environments

Opportunistic breeding is a strategy used to maximize reproductive success in unpredictable environments. Unlike species that breed seasonally, opportunistic breeders are thought to maintain partial activation of the reproductive axis in order to rapidly initiate breeding when environmental conditions become suitable. The initiation of breeding in opportunistic species is likely to be fine-tuned with respect to an array of environmental variables, but the physiological mechanisms that influence reproductive readiness across heterogeneous environments remain relatively unexplored. Zebra finches (*Taeniopygia guttata*) are found across the majority of the Australian continent from the arid center to the monsoonal belt in the northern tropics. Zebra finches initiate breeding in response to unpredictable precipitation and are an ideal species to explore the physiological underpinnings of opportunistic breeding in a free-living system. We examined trade-offs between reproductive readiness and stress responsiveness in wild zebra finches at five field sites with varying degrees of rainfall across a latitudinal gradient in Australia. Using adrenocorticotropic hormone (ACTH) and gonadotropin-releasing hormone challenges, we assessed maximum output of corticosterone (CORT) and testosterone. Across all sites, zebra finches released similar amounts of CORT in response to ACTH challenges. However, zebra finches in the northern most (predictable) sites responded to restraint stress with lower levels of CORT output compared to zebra finches in the southern (unpredictable) sites suggesting a downregulation of the HPA axis. Examining differences in HPG axis function between sites will allow us to interpret these results in terms of trade-offs between the HPA and HPG axes.

66-1 CRANDELL, KE; University of Montana; kristen.crandell@umontana.edu

Aerodynamics, kinematics, and skeletal function in the slow flight of birds

Slow flight is extremely energetically costly per unit time, yet highly important for takeoff and survival in birds. However, at slow speeds it is presently thought that most birds do not produce beneficial aerodynamic forces during the entire wingbeat: instead, they fold or flex their wings during upstroke, prompting the long-standing prediction that the upstroke produces trivial forces. Here, I examined the kinematics, aerodynamics, and skeletal contribution to the upstroke in birds that use both major upstroke styles that birds exhibit. Diamond doves that keep their wings extended in a "wingtip-reversal" upstroke (at $Re=50,000$) produce a kinematic and aerodynamic signature similar to the clap-and-peel mechanism previously reported only in insects ($Re=8,000$). In contrast, zebra finch use a "flexed-wing" upstroke that is aerodynamically inactive. Integrating an XROMM (X-ray Reconstruction of Moving Morphology) study of pigeons and starlings, I demonstrate that the supination of the tip-reversal upstroke occurs via a slide of the carpometacarpus across the cuneiform of the wrist. Collectively, I reveal that the clap and fling mechanism utilized by many species is a wing motion that is aerodynamically beneficial and largely due to an interaction of the skeletal elements.

24-1 CROFTS, S B*; SUMMERS, A P; New Jersey Institute of Technology, Friday Harbor Labs; crofts@njit.edu
Changes in tooth form and function of hard-prey consumers, the Placodontia

Placodonts, a group of extinct marine reptiles from the mid to late Triassic, are inferred to have consumed hard prey by crushing their shells, and their teeth are typically described as low, round, or flat. Tooth size and position are variable both across the diversity of placodonts and in an individual. Here we explore how the anatomy of the occlusal surface varies, with focus on the ability of the tooth to break hard prey and resist damage from the gustatory efforts. Flat teeth will break shelled prey with less force than cupped teeth, and with as much or less force than domed teeth. Pointed crowns make tooth failure more likely compared to flat or cupped surfaces. Based on these trade-offs, we predicted an 'optimal' shape for crushing teeth: a tooth with a flat or shallowly convex occlusal surface which can both crush shelled prey items while resisting tooth failure. Teeth that vary from the predicted morphology may suggest a different diet or indicate that some other aspect natural history is at play. Shape was quantified by measuring the occlusal radius of curvature from all placodont genera. Differences in radius of curvature between species agrees with the predicted pattern, with conical or rounded teeth, occurring in groups closer to the base of the tree, where hard prey was not as important in the diet. Flatter teeth were found in most of the true hard prey specialists. However, in the placochelyids, a lineage of the late Triassic, the main crushing teeth do not follow this trend, but instead have a more complex morphology suggests an unappreciated dietary specialization or an alternate approach to crushing.

S4-1 CRONIN, T.W.; UMBC; cronin@umbc.edu

Extraocular, nonvisual, and simple photoreceptors: Introduction

It has been recognized for decades that animals sense light using photoreceptors besides those that are devoted strictly to vision. However, the nature of these receptors, their molecular components, their physiological responses, and their biological functions were long obscure. Only recently have researchers begun to learn how critical these nonvisual or very simple visual responses are to organismal function; and new approaches, including the explosion of research incorporating high-throughput molecular genetic techniques, have led to a revolution in our understanding of the evolution, anatomical distribution, and function of nonvisual photoreception in a variety of evolutionarily distinct animals. Historically, these types of receptors have been described primarily among invertebrates, although they were recognized to be present in fishes, reptiles, and birds. Their presence in mammals was completely unsuspected until the end of the 20th century. In this symposium, we bring together specialists from throughout the field to review the current state of knowledge regarding extraocular, nonvisual, and simple photoreceptors in a large diversity of organisms ranging from protists to higher vertebrates and invertebrates.

42-4 CROWDER, C*; BABONIS, L; MEYER, E; MARTINDALE, M; WEIS, V; CROWDER, camerr; Oregon State University, Whitney Laboratory for Marine Biosciences; crowderc@onid.oregonstate.edu

Characterization of gene expression profiles associated with light and temperature induced spawning in the sea anemone *Nematostella vectensis*

The induction of spawning in the sea anemone, *Nematostella vectensis*, is predictably associated with an increase in temperature and light. Although, these variables have been identified as triggers, little is known about the transduction events and molecular mechanisms that coordinate gametogenesis and spawning. Global gene expression profiling using RNA-Seq analysis allows for an unbiased assessment of transcriptome level gene expression throughout time. Here we examine the expression and abundance of *N. vectensis* transcripts throughout light and temperature induced spawning at 8 time points prior to, during, and after spawning. *N. vectensis* is a model species, within the phylum Cnidaria, and an examination of the transcriptomic regulation of spawning will identify key cnidarian reproductive pathways as well as compliment previous works detailing gene expression changes associated with development.

20-3 CULLEN, J.A.*; PLUMLEE, J.D.; TINHAN, T.; WELLS, R.J.D.; MARSHALL, C.D.; Texas A&M University, College Station, Texas A&M University, Galveston, Texas A&M University, Galveston; Texas A&M University, College Station; jcullen@tamu.edu

Impact of Allometry and Feeding Biomechanics on Ontogenetic Dietary Shifts in Three Coastal Sharks

Allometric growth and feeding biomechanics are important factors for studying changes in bite force production and how this influences prey selection over ontogeny. Sharks are an interesting model system to test these parameters since they often undergo one or more ontogenetic dietary shifts towards functionally challenging prey. These dietary shifts are likely influenced by increasing bite force production and gape. In some shark species, bite force 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 restricted to a limited number of species and size classes. Bull (*Carcharhinus leucas*), blacktip (*Carcharhinus limbatus*), and bonnethead (*Sphyrna tiburo*) sharks are common along the Texas coast, and coastal habitats in Texas function as nurseries for these species. Mechanical advantage, muscle mass, and anatomical cross-sectional area were compared to determine which contributed most to the scaling of bite force. Stomach contents of size classes for all three species were compared to determine if and when dietary shifts occur with respect to changes in bite force. Comparisons among all three species will begin to characterize their relative feeding performance from morphological, biomechanical, and ecological perspectives.

106-3 CUNNINGHAM, G.B.*; LECLAIRE, S.; TOSCANI, C.; BONADONNA, F.; St. John Fisher College, Centre d'Ecologie Fonctionnelle et Evolutive, CNRS; gcunningham@sjfc.edu

Responses of King penguin (*Aptenodytes patagonicus*) adults and chicks to two food-related odours

Many species of penguins are sensitive to dimethyl sulphide (DMS), a scented compound that a variety of marine animals use to find productive areas of the ocean where prey is likely to be found. Here we show that King penguins (*Aptenodytes patagonicus*) are also sensitive to DMS. Near a King penguin colony at Ratmanoff beach in the Kerguelen archipelago we deployed DMS on a lake and monitored the number of birds swimming in a well-defined area. We also presented DMS to sleeping adults on the beach. Penguins swam more in the presence of DMS on the lake, but did not respond to cod liver oil deployments. These results mirror at-sea studies of other penguins. On the beach, sleeping birds twitched their heads and woke up more for the DMS than for the control presentations. In the future we hope to confirm that King penguins use DMS as a surface cue that informs them of productivity under the water by deploying odours at sea. However, this study is an important first step in understanding how these birds locate prey over significant distances.

115-5 DABE, E.C.*; KOHN, A.B.; MOROZ, L.L.; DABE, Emily; Univ. of Florida; emily.dabe@gmail.com

Single cell epigenetics in polyploid and diploid cells: the search for cell identity

From humans and amphibians to invertebrates, there are many instances of polyploidy of cells with more than 2 copies of a genome per cell. The opisthobranch mollusc, *Aplysia californica* has endopolyploidy, where central neurons are highly polyploid, but all peripheral tissues are diploid. In fact, *Aplysia* neurons, some of the largest in the animal kingdom, can have over 100,000 copies of the genome in a single cell. These repeatedly identifiable neurons allowed us to perform single-cell epigenomic profiling and compare the role of DNA methylation in regulating gene expression in polyploid versus diploid cells. We isolated single polyploid neurons (R2, LPL1, MCC) and peripheral diploid tissues (salivary gland and heart) from mature *Aplysia* that were matched for size and age. We then quantified both genomic DNA copy number in the polyploidy cells and also bisulfite treated gDNA to determine whether each copy of the genome had the same methylation pattern for the same genes. We aimed to test whether multiple genome copies in polyploid neurons are methylated in the same way as diploid cells. Quantal-style analysis of all individual methylation sites implied that polyploidy genome copies are methylated in the same way. Next, to characterize genomic basis of neuronal identity, we have complemented methylome profiling by RNA-seq profiling from the very same identified neurons focusing on serotonergic and cholinergic neurons. As a result, we identified several potential regulators of serotonergic phenotype and validated expression of these transcription factor candidates using *in situ* hybridization. This analysis provides the first unbiased view of the genomic regulatory machinery in identified neurons in neural circuits controlling stereotyped and learned behaviors. Supported by NSF, NIH and NASA.

1-6 DAI, J.*; FARAJI, H.; SCHIEBEL, P.E.; GONG, C.; TRAVERS, M.; HATTON, R.L.; GOLDMAN, D.I.; CHOSET, H.; Carnegie Mellon University, Oregon State University, Georgia Institute of Technology, Georgia Institute of Technology; jind@cmu.edu

Geometric Swimmer on Granular Material

Chionactis occipitalis (the Mojave Shovel-nose snake) lives in a desert habitat where it uses body undulations to move effectively across the sandy terrain. Animal experiments have shown that *Chionactis* (N=10) travelling on granular substrates exhibits a particular set of waveforms which can be approximated by a sinusoidal variation in curvature - a serpenoid curve. Furthermore, all snakes tested used only a narrow subset of all available waveform parameters--measured as the relative curvature of the waveform, $\kappa\lambda_s = 5.0 \pm 0.3$, and number of waves on the body $\xi = 1.8 \pm 0.1$. We hypothesize that a particular choice of parameters to describe the serpenoid curve produces a waveform that offers distinct locomotive benefit. To test this hypothesis, we used a physical model (a snake robot) to empirically explore the space of serpenoid motions at different curvature amplitudes. As expected from geometric locomotion theory, the amplitude of the gait cycle had a significant influence on the performance of locomotion. Two key results from these experiments are (1) displacement per cycle increases with amplitude at small amplitudes, but reaches a peak value of 0.55 body-lengths at relative curvature $\kappa\lambda_s = 6.0$, and (2) the peak mechanical cost of transport of these motions (speed at a given power, or power to move at a given speed) is at a slightly lower amplitude than the maximum-displacement gait, which reflects the extra effort required to capture all of the available displacement, vs repeating more cycles of a slightly less efficacious gait in the same time period.

112-1 DAGHOOGHI, M; BORAZJANI, I*; University at Buffalo, State University of New York; iman@buffalo.edu

How fish schooling improves swimming performance?

Fish schooling is typically observed in many fish species, which is thought to provide hydrodynamic advantages. Previous theoretical models have predicted improvements in swimming performance of fish schools due to two physical mechanisms: vortex hypothesis, which states that the relative velocity between fish and the flow is reduced through the induced velocity of the organized vortex structure of the incoming wake; and the channeling effect, which states that the relative velocity is reduced by the enhancement of the flow between swimmers in the direction of swimming. Although experimental observations confirm hydrodynamic advantages, there is still debate regarding the two mechanisms. We have carried out the first three-dimensional simulations at realistic Reynolds numbers to investigate these physical mechanisms. Through large-eddy simulations of self-propelled synchronized swimmers in various rectangular patterns, we found evidence in support of the channeling effect, which enhances the flow velocity between swimmers in the direction of swimming as the lateral distance between swimmers decreases. Our simulations show that the coherent structures, in contrast to the wake of a single swimmer, break down into small, disorganized vortical structures, which have a low chance for constructive vortex interaction for rectangular pattern. Therefore, the vortex hypothesis, which is hypothesized to be the main mechanism for diamond patterns, was not found in rectangular patterns, and needs to be further studied for diamond patterns in the future. By exploiting the channeling mechanism, a fish in a rectangular school swam faster as the lateral distance decreased, while consuming similar amount of energy. The fish in the rectangular school with the smallest lateral distance (0.3 fish lengths) swam 20% faster than a solitary swimmer while consuming similar amount of energy.

40-3 DAKIN, R*; FELLOWS, TK; ALTSHULER, DL; University of British Columbia; roslyn.dakin@gmail.com

Hummingbirds visually control forward flight using image features instead of image pattern velocity

Optic flow can provide information about the distance between an observer and passing obstacles. It has been proposed that flying honeybees, flies, and birds use a feature of optic flow called pattern velocity to navigate narrow passageways. Although this hypothesis is well supported for bees and flies, the evidence for birds is indirect and based on their avoidance of vertical features that provide high pattern velocity. We directly tested the influence of pattern velocity on hummingbird flight trajectories by manipulating the motion of patterns on the side walls of a narrow flight tunnel traversed by Anna's hummingbirds. We found that for both vertical stripe and dot patterns, the tested birds' flight trajectories were not influenced by pattern velocity manipulations as predicted if they were avoiding high pattern velocities. Further experiments demonstrate that hummingbirds instead avoid features that are larger in the vertical axis, which can explain their avoidance of vertical stripes without invoking pattern velocity. For example, birds strongly deviated towards small-sized horizontal stripes when presented with large horizontal stripes on the opposite side. In contrast, when the left and right side had vertical features of the same height (but different width), birds stayed approximately centerline. We propose that visual expansion may play a key role in allowing birds to avoid obstacles in complex environments.

40-4 DALTON, B E*; CARLETON, K L; University of Maryland, College Park; bdalton@umd.edu

Coexpression of opsins in each cone class spectrally tunes regions of the retina to distinct parts of the visual field

Different parts of the visual field are viewed by distinct regions of the retina which can differ in sensitivity. Variation in spectral sensitivity within the retina is documented in a growing number of taxa. In such species, the appearance of objects and signals will depend on the sensitivity of the retinal region that detects them. Spectral sensitivity relies on the visual pigments, composed of an opsin protein bound to a chromophore. Altering either molecule can modify the pigment's absorbance spectrum. We use dual-labeling fluorescent *in situ* hybridization to determine the distribution of opsins across the retinas of cichlid fishes in their single cones and each member of their double cones (pairs of partially fused cone cells). African cichlids are noteworthy because they form new species rapidly, due in part to coevolution of spectral sensitivity and male nuptial coloration. We found that in *Metriaclima zebra*, each cone class mixes a different pair of opsins in a retinal region that views a distinct background. This opsin coexpression increases absorbance of the corresponding backgrounds, and modeling indicates this could facilitate detection of dark objects. Thus, opsin coexpression may be a novel mechanism of spectral tuning. However, our calculations indicate coexpression of some opsins can hinder color discrimination, creating a trade-off between visual functions. We also demonstrate that the location and relative proportion of opsins within the *M. zebra* retina can be altered by the rearing light environment. The background spectra at different angles in a cichlid's environment might influence the specific pattern of spectral sensitivity that develops across its retina, biasing signal evolution and contributing to the rapid radiation of this diverse group of fishes.

68-1 DALY, M*; MACRANDER, J.M.; BROE, M; The Ohio State University; daly.66@osu.edu

The tree's the thing: phylogeny as a way of understanding the diversity of venom in sea anemones

Technological obstacles have largely been eliminated in the study of venom in non-model systems, allowing broad-scale characterization of the diversity and function of venom in diverse organisms. In these newly explored systems, phylogenetic perspective can prove especially illuminating, linking and extending previous studies and providing context and point of comparison in interpreting new data. Here we highlight the ways in which phylogenetic perspective has proven crucial to understanding the diversity and diversification of constituents of the venom arsenal of sea anemones (Cnidaria: Anthozoa: Actiniaria).

S2-8 DALY, M; Ohio State Univ; daly.66@osu.edu

Are extremeophiles phylo-extremists? An investigation into the rates and nature of evolution in deep sea, polar, and hydrothermal vent sea anemones

Adaptation to life in extreme environments is expected to have evolutionary consequences for organisms. Minimally, organisms inhabiting extreme environments must have features that facilitate their survival in these challenging environments. The physiological, geographical, and ecological conditions of the environment may also act as isolating mechanisms, reinforcing differences between extremophiles and their kin. These circumstances may lead to adaptive radiations and strong genetic and phenotypic differentiation between extremophile and "regular" lineages. Here we explore use phylogenetic comparisons to explore the genetic and phenotypic signature of life in extreme environments in sea anemones (Cnidaria: Anthozoa: Actiniaria). We find evidence for some clade-specific radiations in extreme environments and identify features that appear to coincide with life in extreme environments, but see little evidence for widespread genomic or evolutionary rate differences between lineages in polar, vent, and hydrothermal habitats, compared to those in tropical, temperate, or shelf habitats.

122-5 DANOS, N.*; TYTELL, E.D.; Tufts University; nicole.danos@tufts.edu

Characterizing the nonlinear elasticity and damping properties of the lamprey body using dynamic bending tests.

As a fish swims, both the flow around it and the sensory information received by the nervous system are influenced by the mechanical properties of its body. Body stiffness depends on the material properties of the body and its cross-sectional shape. Fish bodies are also probably viscoelastic, which means that the effective stiffness would change as bending frequency changes. Finally, muscle activation patterns, including co-activation of the left-right axial musculature, are also likely to be key determinants of body stiffness and damping properties. We study a widely used model for swimming neuromechanics, the lamprey *Ichthyomyzon unicuspis*, to investigate the mechanical properties of an *in situ* whole body preparation. In this preparation, a servomotor bends the lamprey body laterally, and the forces and torques are measured by an in-line force transducer. Axial muscle at the point of bending is stimulated electrically. We ask how bending frequency, body location, and muscle activation patterns affect body stiffness and damping. Preliminary results show anterior body regions are stiffer than tail regions and the effect is most pronounced at high bending frequencies. We also find that muscle activation does not change body stiffness much compared to passive bending when the muscles are activated in phase with bending, i.e. during muscle shortening. However, coactivation of left and right side muscle substantially increases body stiffness. We will further discuss these trends as well as the effect of body location, bending frequency, and muscle activation on the body's damping properties.

S6-6 DANTZER, Ben; University of Michigan; dantzer@umich.edu
Ecology muddles the relationship between hormones and life history traits

Hormones have pervasive associations with behavioral and life history traits. Despite an aim to generalize these relationships, there is often little consistency across studies or taxa. This is likely because relationships between hormones and life history traits are context-dependent and contingent upon the ecological and/or social environment. Long-term studies of wild animals living in variable environments present a unique opportunity to investigate the association between hormones and life history traits across ecological gradients. Here, I will describe the association between stress hormones (glucocorticoids) and measures of reproductive success in a long-term study of North American red squirrels (*Tamiasciurus hudsonicus*) in the Yukon, Canada. I will present how natural variation in food abundance, population density, and predators as well as experimental manipulation of food and density are associated with changes in glucocorticoids and reproductive success in female and male red squirrels. Overall, I will emphasize the importance of long-term field studies and how understanding the ecology of the study species can lead to a better understanding of the relationship between hormones and life history traits.

S3-3 DAVID, Andrew A*; MATTHEE, Conrad A; LOVEDAY, Benjamin R; SIMON, Carol A ; Clarkson University, Potsdam, NY, Stellenbosch University, Stellenbosch, South Africa, Plymouth Marine Laboratory, Plymouth, United Kingdom ; adavid@clarkson.edu

Projected dispersal and range expansion of a potentially invasive polychaete in South Africa

A major goal of invasion biology is predicting the spread and range expansion of introduced species such as that of the polychaete, *Boccardia proboscidea*, along the South African (SA) coast. Since *B. proboscidea* was in its incipient stages of a potential invasion, the closely related, *Polydora hoplura* was used as a "proxy species". To assess dispersal potential, a high-resolution circulation model of the SA coast was constructed and coupled to a particle-tracking model. The results showed limited connectivity between eastern and western boundaries, with Cape Point proving to be a prominent barrier. These results were in contrast to high genetic connectivity observed in a population genetic study conducted on *P. hoplura*. The discrepancy was likely due to the inability of genetic studies to detect anthropogenic dispersal. Furthermore, temperature had a significant effect on larval survivorship and developmental rate of both species under thermal regimes representative of the SA coast. Survivorship curves for the two species were similar where high mortality was observed at the extreme low (< 17°C) and high temperatures (> 28°C). *P. hoplura's* response to the different temperature treatments was congruent with its current distribution and due to similar survivorship curves we predicted that *B. proboscidea* can potentially become established along the same stretch of coast though anthropogenic dispersal will be the determining factor for widespread dispersal.

S11-5 DAS, S*; DURICA, D.S.; MYKLES, D.L.; Colorado State University; sdas@colostate.edu
Transcriptomics of signaling gene networks controlling the activity of the crustacean molting gland

Next generation sequencing platforms and improved computational resources can be used to identify novel genes and pathways in a non-model organism. Although there are multiple resources available for *de novo* assembly, annotation, and measurement of differential expression of RNAseq data, this bioinformatics field is still evolving to generate a standard method of analyzing data. Our goal was to evaluate the current tools and databases available for a comprehensive and comparative annotation of the molting gland, or Y-organ, transcriptome of the blackback land crab, *Gecarcinus lateralis*. Following assembly of Illumina sequence data using Trinity and sequence clustering via CD-HIT-EST, a transcriptome with 251,357 contigs was generated. Multiple resources and databases were used to assign functional and pathway annotation to the contig sequences. Both nucleotide and protein sequences, obtained via Transdecoder, were BLASTed against the NCBI NR, Swissprot, and Uniprot-Uniref90 databases, which resulted in annotation of about 20% of the sequences. Functional annotation of the sequences was performed using Blast2GO and the pathway annotation was generated via Kyoto Encyclopedia of Genes and Genomes. In addition to assigning BLAST information to nucleotide and protein sequences, the Trinotate suite was used to identify protein domains, transmembrane domains, and signal peptide sequences. Furthermore, we used the Interproscan resource to match the protein sequences against 16 protein signature databases. The analysis yielded genes encoding components of the mTOR, TGF β , MAP kinase, Wnt, Hedgehog, Jak-STAT, and Notch pathways. Employment of these various methods is necessary for a comprehensive annotation of sequences generated from non-model organisms. Supported by NSF (IOS-1257732).

S6-7 DAVIDOWITZ, G; Univ. of Arizona; goggy@email.arizona.edu

Synergism and antagonism at the physiological level regulates the evolution of life histories at the phenotypic level

Too much mechanistic detail impedes our ability to make general predictions of the response to simultaneous selection on multiple life history traits, whereas too few details may result in predictions that lack mechanistic support. Here we provide a framework that strikes a balance between the two showing how antagonism and synergism at the physiological level enables and constrains simultaneous selection at the phenotypic level of two life history traits, body size and development time. Previous work with the tobacco hornworm *Manduca sexta* has shown that these two life history traits are regulated by the interaction of the same three underlying physiological factors: growth rate, the timing of the cessation of juvenile hormone secretion and the timing of the secretion of the ecdysteroid hormones. After ten generations of selection on all four combinations of body size and development time (Big/Short, Big/Long, Small/Short, Small/Long) the three physiological and two life history traits differed significantly from the initial population. The three physiological factors explained 93% of the response of development time to simultaneous selection and 99% of the response of body size. When the two life history traits were under synergistic selection, the response to simultaneous selection was due largely to juvenile hormone and the ecdysteroids and constrained by growth rate. When the life history traits were under antagonistic selection, the response to selection was due primarily to the change in growth rate and constrained by the two hormonal traits. Evidence suggests that this framework has broad applicability to a diverse range of taxa including green algae, plants, amphibians and mammals and to other insects.

121-5 DAVIES, C. S*; SMYTH, K. N; GREENE, L. K; DREA, C. M; Duke University, Durham, NC.; charli.davies@yahoo.co.uk
Hormonal 'masculinization' in female meerkats (*Suricata suricatta*)

Traditionally in mammals, males are the more aggressive sex, owing in part to the action of androgens; however, in some species, the roles are reversed. In the most iconic example of aggressively mediated female dominance - the spotted hyena (*Crocuta crocuta*) - females are morphologically and behaviorally masculinized. Although testosterone (T) in female hyenas remains lower than in males, during gestation, ovarian androstenedione (A_4) is increasingly converted to T, which has been implicated as a mediating mechanism for this sex-role reversal. The generalizability of this model to other 'masculinized' species remains unclear. In the meerkat (*Suricata suricatta*), a cooperative breeder with extreme female reproductive skew, the proximate mechanisms of female dominance are unknown. Here, we first tested for sex and status effects on adult serum concentrations of A_4 , T and estradiol (E_2). As in hyenas, nonpregnant female meerkats (n= 30) had greater A_4 concentrations than did males (n=50). More unusually, nonpregnant female T concentrations were equivalent to those of males. E_2 values showed the more traditional sex difference. Moreover, within females (but not within males), dominant meerkats had greater concentrations of sex steroids than did subordinates. We next examined the effects of pregnancy on female endocrine profiles and found that gestation magnified these sex and status effects, notably raising total androgen concentrations of females well above those of males. We suggest that female meerkats are hormonally masculinized: Androgens may thus mediate female, but not male, dominance, partially explaining the extreme reproductive skew in females of this species. Supported by NSF IOS-1021633.

72-4 DE BRUIJN, R*; HAU, M; Max Planck Institute for Ornithology, Seewiesen, Germany, Max Planck Institute for Ornithology, Seewiesen, Germany; University of Konstanz, Germany; rdebruijn@orn.mpg.de

Glucocorticoid reaction norms to temperature and reproductive success

Understanding the fitness relevance of hormonal phenotypes in free-living individuals has recently become a focus within behavioral ecology and evolutionary physiology. Hormones like glucocorticoids (GC) are key mediators of individual adjustments to environmental conditions, but their considerable plasticity has hampered progress in identifying hormonal phenotypes of individuals. Here, we use a reaction norm approach to characterize GC phenotypes and their relevance for fitness (reproductive success) in free-living great tits (*Parus major*). In early evening on cold winter nights, 24 great tits were captured from their roosts (nest boxes) and sampled for baseline corticosterone concentrations. Birds were then immediately returned to their roosts and nest box temperature was increased for 14 of the birds, while the rest served as control. Each trial lasted 3 hours, after which birds were recaptured and another blood sample was taken to assess the effect of the temperature manipulation on baseline GC. Birds were then kept in a cloth bag for 30 minutes to obtain a stress-induced GC sample and subsequently injected with dexamethasone. A final sample was taken 90 minutes later to assess negative feedback efficacy. Birds were then returned to the boxes. During the following breeding season, baseline and stress-induced GCs were obtained in 16 of the same birds, and their yearly number of fledglings was assessed. We will discuss relationships between baseline GC responses to environmental changes (temperature) and overall HPA-axis functioning as possible evidence for a GC phenotype. Additionally, we will discuss the implications of the responses to temperature in winter in relation to parental investment and reproductive success in spring for fitness.

100-1 DAWSON, IL*; TAYLOR, GK; WALKER, SM; University of Oxford; ines.dawson@sjc.ox.ac.uk

Torsion and Twist in *Drosophila melanogaster* Flight

In order to generate lift and to fine-tune manoeuvres, insects exploit a variety of kinematic parameters during flapping flight, such as adjustments to stroke plane angle, twist, wing beat frequency, and the timing in pronation and supination. To date, there is little flight data available containing information on all of these parameters. We employed high-speed videogrammetry and custom high-fidelity 3D tracking software to extract the kinematic parameters from 363 flight recordings of *Drosophila melanogaster*, which provides a large kinematic and aerodynamic dataset for modelling insect flight.

We examined asymmetric and symmetric kinematic parameters to determine whether they belonged to specific flight modes. In order to understand how the manoeuvres were performed and controlled from a structural and mechanical perspective, we fitted the data to various kinematic models. We predicted changes in angle of attack with a torsion spring model, changes in wingtip motion using simple harmonic models, and we explored the aerodynamic performance of the manoeuvres by calculating their forces with a quasi-steady blade element model.

95-3 DEAN, MN*; SEIDEL, R; KNOETEL, D; LYONS, K; BAUM, D; WEAVER, JC; FRATZL, P; MPI, ZIB, CSULB, ZIB, Wyss Inst.; mason.dean@mpikg.mpg.de

To build a shark - 3D tiling laws of tessellated cartilage

The endoskeleton of sharks and rays (elasmobranchs) is comprised of a cartilaginous core, covered by thousands of mineralized tiles, called tesserae. Characterizing the relationship between tesseral morphometrics, skeletal growth and mechanics is challenging because tesserae are small (a few hundred micrometers wide), anchored to the surrounding tissue in complex three-dimensional ways, and occur in huge numbers. We integrate material property, histology, electron microscopy and synchrotron and laboratory μ CT scans of skeletal elements from an ontogenetic series of round stingray *Urolophus halleri*, to gain insights into the generation and maintenance of a natural tessellated system. Using a custom-made semiautomatic segmentation algorithm, we present the first quantitative and 3d description of tesserae across whole skeletal elements. The tessellation is not interlocking or regular, with tesserae showing a great range of shapes, sizes and number of neighbors. This is partly region-dependent: for example, thick, columnar tesserae are arranged in series along convex edges with small radius of curvature (RoC), whereas more brick- or disc-shaped tesserae are found in planar/flatter areas. Comparison of the tessellation across ontogeny, shows that in younger animals, the forming tesseral network is less densely packed, appearing as a covering of separate, poorly mineralized islands that grow together with age to form a complete surface. Some gaps in the tessellation are localized to specific regions in all samples, indicating they are real features, perhaps either regions of delayed mineralization or of tendon insertion. We will use the structure of elasmobranch skeletons as a road map for understanding shark and ray skeletal mechanics, but also to extract fundamental engineering principles for tiled composite materials.

51-1 DEARING, MD*; SKOPEC, MM; SCHRAMM, KM; KITANOVIC, S; WILDERMAN, PR; HALPERT, JR; University of Utah, Weber State University, UConn; denise.dearing@utah.edu
Mechanisms underlying dietary specialization in woodrats: possible role of CYP2B enzymes

Mammalian herbivores that consume plants high in natural toxins confront the possibility of being poisoned with each meal. The ability of some species to specialize on plants high in toxins is hypothesized to be the result of highly effective detoxification enzymes that rapidly metabolize toxins. We have been testing this hypothesis by characterizing and comparing the detoxification enzymes of a herbivorous woodrat that specializes on juniper with those of the generalist feeder. Consumption of juniper increased the content of P450 enzymes nearly 2x in both species. Ingestion of juniper was reduced in the specialist when P450 enzymes were inhibited by the administration of the general P450 inactivator 1-aminobenzotriazole. Of three major xenobiotic metabolizing P450 subfamilies in mammals (CYP1A, CYP2B, CYP3A) only CYP2B increased (2x) in response to juniper consumption based on Western blotting. An in depth analysis of the CYP2B isoforms revealed multiple members in each species and significant species differences in the amino acid sequences, with key differences at substrate recognition sites. An analysis of CYP2B function based on hexobarbital clearance demonstrated faster clearance of this compound in the specialist than the generalist. We are currently conducting other assays to compare the turnover and metabolism of juniper-derived substrates by woodrat liver enzymes. The results suggest that P450 enzymes, particularly CYP2B, may be important in ingestion of juniper and the metabolism of juniper toxins. Whether these enzymes can explain the mechanism underlying dietary specialization requires further investigation. NSF IOS 1256383

95-8 DENNY, M.W.*; KING, F.A.; Stanford University; mwdenny@stanford.edu

Mechanical Characterization of a Key Adaptation: The Extraordinary Joint Material of Coralline Algae

Seaweeds survive on wave-swept shores primarily by being flexible, which poses a problem for coralline algae because their calcified cell walls are rigid. Approximately 100 million years ago, crustose coralline algae evolved a key adaptation - joints - that renders them flexible and has allowed the resulting articulated corallines to dominate space on some of Earth's most wave-beaten coasts. The material from which these joints are constructed has unusual mechanical properties: it is eight times as extensible and four times as strong as typical algal tissue, and is immune to the fatigue that normally accompanies repeated impositions of force. In this talk, we report on new measurements of joint material properties: creep, the strain-rate dependence of stiffness, and the behavior of the material when subjected to cyclic loading. These measurements, when combined with previous information, allow us to formulate a simple model that explains how the chemical composition and macromolecular structure of cell-wall material accounts for the material's unusual properties. We propose that cell wall material is a fiber-reinforced composite in which cellulose provides the fibers and a galactan gel forms the matrix. The fibers are not crosslinked, which allows the material to creep indefinitely, but the viscosity of the matrix ensures that the material is both elastic and strong when subjected to wave-induced fluid-dynamics forces. Our model makes predictions (e.g., the wrapping angle of cellulose fibers) that can be tested by future measurements.

32-4 DEMAINTENON, M.J.*; STRONG, E.E.; University of Hawaii at Hilo, Smithsonian Institution, National Museum of Natural History; demainte@hawaii.edu

Molecular phylogeny of the neogastropod family Columbellidae

The neogastropod family Columbellidae is a highly successful group of small epibenthic marine snails, with 725 living species in 69 nominal genera distributed in temperate to tropical waters worldwide. Extensive polymorphism has caused the establishment of a plethora of names currently treated as synonyms. Although columbellids can be found from the intertidal to depths of 2,000 meters, maximum diversity is in shallow tropical habitats; 40 to 50 species can co-occur at single West Pacific sites, with syntopic occurrences of up to 10 to 12 species. Species vary widely in habitat, diet, larval development and adult anatomy, and provide many potential avenues for studying macroevolutionary trends. Membership in the family is traditionally confirmed using the unique morphology of the radula and, as in all shelled gastropods, species are typically defined and identified by conchological characters. The monophyly of the group and its constituent genera have never been rigorously tested. To reconstruct columbellid phylogeny, we assembled a data set including five mitochondrial and nuclear gene markers, for multiple representatives each of over 80 species in 25 genera and representative outgroups from the buccinoid and muricoid neogastropods. Correspondence of the resulting phylogeny with the traditional classification based on anatomical and morphological data will be assessed. Preliminary results based on partial data for three markers suggests that Columbellidae as it is understood based on the unique radular morphology is monophyletic, but traditional subfamilies based on radular morphology, anatomical data and conchological characters are not. In addition, several nominal genera based primarily on conchological characters such as the presence or absence of axial sculpture are polyphyletic.

18-3 DENTON, R.D.*; GREENWALD, K.R.; GIBBS, H.L.; Ohio State University, Eastern Michigan University; robert.d.denton@gmail.com

Differences in endurance and realized dispersal between sexual and unisexual salamanders

Differences in dispersal can allow coexistence when competition is high, such as between sexual species and sexual parasites. Among vertebrates, sexual parasites are often all-female lineages that require sperm from sexual species to reproduce. Unisexual Mole Salamanders (*Ambystoma* sp.) are the oldest known parasitic lineage in vertebrates, which are evolutionary and ecologically successful. However, whether differences in dispersal contribute to their long-term coexistence with sexual species is unknown. The geographic range of unisexuals includes a wide area of fragmented, agricultural land. In terms of dispersal, unisexuals could be wide-spread because they are superior dispersers in these landscapes, exploiting ephemeral breeding habitats and naïve males. We test this hypothesis by using indirect genetic methods and direct physiological measurements to compare dispersal ability between sympatric sexual and unisexual salamanders. Specifically, we used genetic assignment tests based on DNA microsatellite data to estimate dispersal distances between populations within an agricultural area of Ohio. We then measured walking endurance of wild-caught animals on a treadmill under standardized conditions. Contrary to predictions, sexual salamanders disperse on average twice as far and have 1.5 times the walking endurance compared to unisexuals. We conclude that differences in dispersal cannot account for coexistence between sexual and unisexual salamanders, as theoretical models designed for sexual/asexual coexistence indicate an extinction scenario for unisexual *Ambystoma*. We predict that the frequent introgression of nuclear DNA from sexual salamanders into the unisexual lineage requires new theory to match the uniqueness of this unusual reproductive mode.

106-2 DERBY, C.*; CHOE, M.; ELSAYED, F.; MILLER, S.; WILLIAMS, S.; GONZALEZ, C.; BHARADWAJ, A.; CHAMBERLAIN, G.; Georgia State University, Integrated Aquaculture International; cderby@gsu.edu
Translational Chemoreception: From Studying Chemosensory Processing to Developing Feeds in Aquaculture of Marine Crustaceans

Aquaculture feeds, especially those for marine shrimp, utilize a major proportion of the global production of fish meal. Plant proteins are readily available, economical, and sustainable potential alternatives to fish meal. However, feeds containing high levels of plant proteins without marine protein have reduced attractability and palatability. The goal of our study was to identify chemical mixtures that increase the attractability and palatability of feed, substituting for fish meal. Our approach uses information about mechanisms of chemosensory processing and discrimination in marine crustaceans. We formulated a series of feed attractant mixtures (FAM) of varied composition, complexity, and cost, and we tested their efficacy in two laboratory assays, using krill meal as a comparator, on Pacific white shrimp, *Litopenaeus vannamei*. An attractability assay measured if shrimp moved toward, probed, and grabbed the release site of FAM. A palatability assay tested the ability of FAM, when incorporated into feed pellets, to increase ingestion. We found that FAM was highly attractive to shrimp, and that aqueous extracts of pellets containing FAM could be as attractive as pellets containing krill meal. FAM increased the amount of feed ingested above control levels and was sometimes as effective as krill meal; the increase varied with the amount and/or type of animal protein in the pellets. Our results demonstrate that chemical mixtures can be highly attractive to shrimp, and when incorporated into high-soy pellets, can increase feed palatability. Future directions include developing formulations with optimal efficacy:cost ratios and validating these results in grow-out experiments. Supported by Soy Aquaculture Alliance/United Soybean Board.

S2-6 DEVANEY, S.C.; Los Angeles Pierce College; devanesc@piercecollege.edu
Using ecological niche modeling to understand distribution of a deep-sea eel

The ocean's midwaters (the mesopelagic and bathypelagic zones) make up the largest living space on the planet, but are undersampled and relatively poorly understood. The true distribution of many midwater species, let alone the abiotic factors most important in driving that distribution, may not be known. Because collecting specimens and data from the deep ocean is expensive and logistically difficult, it would be useful to be able to predict where species of interest are likely to occur so that sampling effort can be concentrated in appropriate areas. The distribution of a representative midwater fish, the gulper eel *Eurypharynx pelecanoides* (Teleostei: Saccopharyngiformes), was modeled with MAXENT software to examine the viability of species distribution modeling for midwater fishes. This species was chosen because it is widespread and relatively abundant, easily recognized and unlikely to have been misidentified in database records, and is a true midwater fish, not known to undertake significant vertical diurnal migration.

108-1 DERBYSHIRE, P.J.*; O'SHEA, J.E.; The University of Western Australia; Peter.Derbyshire@research.uwa.edu.au
Cardiac Innervation of the dragon *Ctenophorus ornatus*
 Control of cardiac output is dependent on the hormonal and nervous control mechanisms throughout the cardiovascular system and most notably within the heart. From teleost fish to mammals there is a noticeable variation in the complexity of cardiac control with mammals considered to have the most complex cardiac control mechanisms. Cardiac innervation studies in snakes indicate that, although the atrial chambers have a similar innervation pattern to that of mammals, the ventricle does not contain the cholinergic nerves found in mammals such as bats. These studies however may not have had the capacity to stimulate the nerves within the ventricle enough to elicit a response. Twenty four hearts from the reptile *Ctenophorus ornatus* were dissected into atrial and ventricular chambers and suspended from a force displacement transducer and placed in an organ bath containing reptile saline solution. Nerves were characterised by electrically stimulating the nerves, mimicking the response using exogenously applied adrenaline and acetylcholine before using known receptor blockers to block the response during further stimulation. By stimulating the nerves in the ventricular chambers at supra-maximal frequencies an increased neural cholinergic and adrenergic response is shown. The results of this nerve characterisation indicate the capacity for a squamate to have both adrenergic and cholinergic nerves innervating all chambers of the heart showing a complexity of control unseen previously in reptiles. Preliminary studies into other squamate reptiles have indicated a capacity for this level of cardiac control.

95-4 DEVRIES, M*; WEBB, S; TU, J; DEHEYN, D; TAYLOR, J; Scripps Institution of Oceanography, UC San Diego; mdevries@ucsd.edu
From oxidative stress to exoskeleton material properties, intertidal mantis shrimp demonstrate tolerance to future ocean conditions
 Fluctuations in ocean CO₂ concentration and temperature can be especially dramatic in the intertidal zone. Thus, one may expect intertidal organisms to be less susceptible to ocean acidification (OA) and ocean warming (OW) compared to deeper organisms. While many intertidal organisms tolerate OA and OW in experiments, they usually experience changes in exoskeleton mineralization or increased oxidative stress. The intertidal mantis shrimp is a fierce predator that utilizes calcified, specialized appendages to deliver forceful punches to its prey. We examined oxidative stress in response to OA and OW as well as the exoskeleton structure, mineral content, and material properties of the merus segment of the predatory appendage and the carapace in the species, *Neogonodactylus bredini*. Mantis shrimp were maintained in three conditions for six months: 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). In contrast to previous studies on intertidal organisms, neither protein level indicators of oxidative stress nor exoskeleton calcium content showed significant responses to OA and OW. The merus, however, had significantly higher %Mg in reduced pH conditions, but there were no differences in stiffness and hardness of either the carapace or merus. These results indicate that, unlike other intertidal organisms, mantis shrimp tolerate an expanded range of pH and temperature without experiencing oxidative stress or large changes to the exoskeleton, thereby leaving the integrity of the predatory appendage intact. Given the power of the appendage, our findings imply that mantis shrimp may greatly impact intertidal food webs under future ocean conditions.

112-2 DI SANTO, V*; KENALEY, CP; LAUDER, GV; Harvard University; vdsanto@fas.harvard.edu

Batoid locomotion: integrative study of mechanics and energetics in the little skate

Batoid fishes are unique among elasmobranchs in having dorso-ventrally flattened bodies with largely expanded pectoral fins that form a disc. Benthic batoids lift from the substrate and swim in the water column by undulation of their pectoral fins where the thrust is generated by propulsive waves of bending along the pectoral fin, from anterior to posterior. This unique locomotory mode has long been of scientific interest, with many attempts in recreating the kinematics for underwater bio-inspired robots, based on the assumption that undulatory movement is in fact efficient. To understand the kinematics and energetics of batoid locomotion we present three integrated experiments on pectoral fin locomotion in the little skate *Leucoraja erinacea*: a three-dimensional kinematic study accompanied by a descriptive analysis of fluid dynamics using digital particle image velocimetry at two speeds (1 and 2 BL/s), and a quantification of the energetic costs of locomotion at three speeds (0.75, 1, 1.25 BL/s) using a swim tunnel respirometer. We analyzed nine points on the left pectoral fin of three skates to compare kinematics variables, including amplitude, frequency, wave speed, and body angle, at two speeds. The shape of the pectoral fin is considerably different during upstroke and downstroke. During the downstroke, there is a sharp transition point in the middle of the fin margin as the wave propagates posteriorly. The bioenergetic study on five skates demonstrates a decline in oxygen consumption rates across the speeds tested, and the lowest swimming metabolic rates measured in any elasmobranch. However, the cost of transport calculated from oxygen consumption data reveals that little skates are rather inefficient swimmers when compared to other elasmobranchs and teleosts.

102-5 DIAL, T.R.*; BRAINERD, E.L.; Brown University; terry_dial@brown.edu

Guppy offspring are born at different stages of morphological and functional maturity among populations

The Trinidadian guppy, a livebearing fish, has proved a fruitful model for studying rapid evolution in the field. Reduced predation in headwaters rapidly leads to stiff competition and the evolution of larger offspring size among low predation (LP) populations, relative to their high and high-high predation (HP, HHP) conspecifics. At birth, guppy neonates must locomote and forage independently, thus we ask: are guppies of varying size all born at the same level of morphological and functional maturity? We collected neonates (n=25 per pop), measured feeding and escape start performance and then stained specimens to quantify musculoskeletal maturation. While the external body proportions of offspring (ranging from 5.5-7.2mm standard length) scale with isometry (no change in relative shape), we find size and development of internal morphologies vary significantly among guppy offspring. Each neonatal size class has ossified approximately 30% more of their head skeleton than the next smallest class. In the tail region, the hypural plate is unossified in HHP neonates, where it is ossified and separated into two distinct arms in the LP neonates. Additionally, HHP neonates have more curved, U-shaped myomeres, where their larger conspecifics possess more adult-like, V-shaped myomeres. Head muscle area is relatively large in larger offspring, scaling with standard length as $L^{2.5}$. We find that these differences improve the functional abilities of larger offspring, such that escape start performance and gape size at occlusion is relatively high (positive allometry) in larger neonates. The observed covariation of size and maturity appear to amplify the negative performance effects of being born small, which likely reduces survivorship and increases the severity of the critical period for the smallest guppies.

71-6 DIAL, KP*; MARTIN, TE; TOBALSKE, BW; Univ. of Montana, Missoula; kdial@mso.unt.edu

Effects of predation on the acquisition of flight ability during ontogeny in altricial birds.

Locomotor development among species is remarkably diverse, and we sought to improve understanding of the selective pressures driving this diversification. Herein we demonstrate relationships between the onset of flight capacity at the end of the post-natal stage of development and the daily predation rate during this phase of ontogeny. Focusing on passerines, we studied 11 species in a temperate forest in Arizona, USA (average predation rate 0.028/day), and 15 species in a tropical forest in Malaysia (average predation rate 0.050/day). We measured flight capacity using video recordings (120 Hz) from drop tests, which we digitized and analyzed for rate of whole-body acceleration. In both study areas, species experiencing higher predation rates developed more rapidly and spent less time in the nestling phase. In the temperate forest, flight capacity at fledging was negatively related to predation rate. For example, gray-headed juncos, an open-cup nesting species, fledge 11 days post hatching (d.p.h) but can only support 24% of their body weight using their wings, while mountain chickadees (cavity nesters) fledge at 20 d.p.h. and are fully capable of flight. In tropical forest, higher predation rates were associated with more rapid development of flight capacity, but most of the species (73%) could fly or support at least 81% of their body weight (w) at fledging, and all could support > 50% w. In sum, flight capacity was negatively related to predation rate in temperate forest and positively related in tropical forest. Comparing non-cavity nesting species, flight ability to improve avoidance of predation after fledglings leave the nest seems to be of greater priority in tropical forests. Overall, our results provide novel insight into the role of predation in promoting diversity of locomotor performance during ontogeny.

122-2 DIAMOND, K.M.*; SCHOENFUSS, H.L.; WALKER, J.A.; BLOB, R.W.; Clemson Univ., St. Cloud State Univ., Univ. of Southern Maine; kmdiamond@clemson.edu

Is fish escape performance influenced by flow? Tests in the Hawaiian stream goby, *Sicyopterus stimpsoni*

Many fish live in habitats with flowing water and are subject to predation in such environments. However, there are few data to indicate how water flow affects fish escape performance. To test for effects of water flow on fish escapes, we measured the fast-start performance of juveniles of the amphidromous Hawaiian goby, *Sicyopterus stimpsoni*. In nature, these fish must escape ambush predation while migrating to upstream adult habitats, through high-velocity flow. We used a variable-speed flow tank to establish three different flow conditions encountered in natural streams (zero, low, and high flow). With fish oriented upstream, under each flow condition we stimulated fish from each of three different attack directions relative to flow: aligned with flow (i.e., cranial), perpendicular (i.e., from the side), or aligned opposite to flow (i.e., caudal). Analysis of effect sizes indicated that there are strong effects of flow conditions and attack direction on the frequency of response failure across treatments. Juvenile *S. stimpsoni* had uniformly high response rates for attacks from a caudal direction (opposite flow); however, response rates for attacks from a cranial direction (matching flow) decreased dramatically as flow speed increased. Bow waves from predators attacking with flow might be masked by the flow environment, impairing attack detection by the lateral line systems of prey. Thus, the likelihood of successful escape performance in fishes can depend critically on environmental context, including water flow. Future studies will evaluate whether predators in this system take advantage of stimulus dampening by attacking prey in the same direction as ambient flow.

17-6 DICK, M.F.*; GUGLIELMO, C.G.; University of Western Ontario, London, ON; *mdick23@uwo.ca*

An integrative assessment of the effects of polyunsaturated fatty acids on songbird flight performance

A high intake of polyunsaturated fatty acids (PUFA) is hypothesized to influence the migratory performance of birds. Current evidence suggests beneficial roles for both n-3 and n-6 PUFA, however it is unclear if the effect is due to PUFA in general or the type of PUFA. We directly tested the effect of diets high in long chain n-3 and n-6 PUFA on flight performance and related indicators of migratory performance in yellow-rumped warblers (*Setophaga coronata*). The birds were fed diets high in either monounsaturated fatty acids (MUFA), long chain n-3 PUFA, or n-6 PUFA for 6 weeks. During this time, the proportion of 22:6 n-3 and 20:4 n-6 increased in adipose tissue and flight muscles in the n-3 and n-6 PUFA diets, respectively. We assessed endurance flight performance with wind tunnel flights of up to 6h. We found that diet had no significant effect on voluntary flight duration or metabolic flight efficiency. Additionally, no significant differences in basal or peak metabolic rates were found. However, key metabolic enzymes in the flight muscles revealed increased activity of aerobic and oxidative enzymes and decreased anaerobic enzyme activity in the n-6 PUFA group, and the reverse was true in those fed high n-3 PUFA diets. The exact impact of these alterations to migratory performance is unclear. Overall, this study supports the ability of dietary PUFA to modulate muscle physiology, but we were not able to detect any differences to animal performance. The relationship between the metabolic enzymes and endurance flight performance, along with antioxidant capacity and oxidative damage, will also be reported on and discussed in relation to dietary PUFA and testing markers of migratory performance.

16-7 DIMOND, A.*; RUTH, B.; LUTTON, B.V.; Endicott college; *blutton@endicott.edu*

Assessment of Leukocyte Mobilization in *Leucoraja erinacea*

In the extensive history of bone marrow studies, understanding the mechanisms of hematopoietic stem cell activation and mobilization of immune cells into the bloodstream has been of critical interest to physicians and scientists. Important implications exist for this field of research for cellular transplantation protocols for hematological diseases, as well as for diseases related to vascular disorders. However, scientists have generally favored investigations of the endosteal (i.e., bone) niche in comparison to its vascular counterpart. Over the past decade, there has been a gradual shift in perspective, with the scientific community beginning to acknowledge the autonomous importance of both endosteal and vascular microenvironments. Elasmobranchs (sharks, skates and rays) are cartilaginous fishes and therefore lack the endosteal niche present in mammalian bone marrow. These animals possess hematopoietic tissues (the Leydig and epigonal organs) uniquely composed of only a vascular niche, where hematopoietic stem and progenitor cells are maintained and produced, respectively. Inhibiting the connection between the chemokine ligand, CXCL12, and its receptor, CXCR4, has been shown to be critical for stem cell activation and mobilization of immune cells. In this study, tissues were collected from little skates (*Leucoraja erinacea*) treated with either elasmobranch ringers solution or AMD3100, a CXCR4 antagonist used to mobilize cells in human transplant donors. The efficacy of AMD3100 was assessed via serological, histological and immunohistochemical staining methods and significant mobilization of leukocytes was discovered. These data clarify the source of mobilized leukocytes in elasmobranchs and provide proof of principle that these animal models are useful for studies of hematopoiesis and angiogenesis.

17-2 DILLON, M.E.; GIRI, S*; University of Wyoming, Laramie; *sus_p24@hotmail.com*

Interactive effects of temperature and parasites on energy reserves of native bees

Native bees are critical pollinators in diverse ecosystems. Recently detected declines in bee populations may therefore have serious ecological and economic implications. Parasites may be a primary driver of declines in many native bees, but the physiological mechanisms underlying the effects of parasites on bee populations are still poorly understood. Parasites may challenge host physiology in several ways. They may weaken the host by consuming the host's energy reserves and by inducing a host immune response both to the parasites themselves and to any pathogens they vector. These combined effects can reduce performance and survival of individuals and may ultimately limit population viability. The outcome of this interaction between native bees and their parasites may be mediated in part by environmental temperatures, with implications for geographic and temporal variation in persistence of native bee populations. We investigated the largely unexplored effects of environmental temperature on bee-parasite interactions in Annapurna Conservation Area (ACA), Nepal. In samples of two ecologically and culturally important honey bees (*Apis laboriosa* and *Apis cerana*) collected from an altitudinal (and therefore temperature) gradient within the ACA, we measured load and prevalence of four major bee pathogens and parasites (*Varroa jacobsoni*, *Acarapis woodii*, *Nosema spp.*, and *Crithidia spp.*), and studied the effects of parasite load on lipid, sugar and glycogen content of individual bees. These results will help elucidate the effects of environmental temperatures on population-level impacts of parasites on native bees, providing critical insight into how native bee populations may respond to rising global temperatures.

60-7 DITSCHKE, P.*; FORD, W.; SUMMERS, A.P.; University of Washington; *pditsche@UW.edu*

The role of cup elasticity in suction attachment in Northern Clingfish

While artificial suction cups can stick to smooth substrates, Northern clingfish have the remarkable ability to stick to surfaces with a large range of roughness. We know that the hierarchical structures on the margin of the suction disc (papillae (~150µm) that are covered with rods (~5µm), which themselves are divided into small filaments at their tips (~0.2µm)) enable adaptation to the irregularities of the substrate surface. We also assumed that the low stiffness of the suction disc plays a crucial role to adapt to the surface. In the current study we used a biomimetic approach to investigate the affects of the elasticity of the suction cup on its ability to attach to rough surfaces. We produced suction cups of the same shape with different elasticity (Young's modulus from 0.155-2.4 MPa) and measured attachment time to various substrate roughness (0-269 µm grain size). We found that stiffer suction cups attach for shorter times to rougher substrates than softer, more elastic suction cups. Suction cups made from materials with elasticity closest to the clingfishes (*Gobiesox maendricus*) showed the best attachment suggesting an optimum elasticity for a given substrate.

91-5 DIXON, GB*; BAY, LK; MATZ, MV; Univ. of Texas, Austin; alfire.sidik@gmail.com

DNA methylation is a signature of transcriptional and evolutionary stability in stony corals

The likeness of gene regulation to a light switch—either turned on or off—is considered instructive but overly simplistic. There is however an epigenetic element that operates in this simple binary fashion. In invertebrates, DNA methylation divides genes into just two categories—a strongly and weakly methylated set. What, if any, is the adaptive significance of this division? In this study, we combine methylome sequencing (MBD-seq), RNA-seq, and an evolutionary analysis of 20 anothozoan transcriptomes to characterize the transcriptional and evolutionary nature of these two categories. As seen in insect models, expression of strongly methylated genes tends toward spatial and temporal stability, akin to ‘housekeeping genes’ described in microbes. In contrast, expression of weakly methylated genes tends to be flexible across time, space, and environment. Strongly methylated genes also evolve slowly, displaying categorically lower rates of nonsynonymous (dN) and synonymous substitutions (dS). Strong methylation also correlates with codon bias, suggesting that lower dS may result from selection for optimal codons in these widely and stably expressed genes. Together these results bolster our understanding of gene body methylation as a signature of transcriptional and evolutionary stability.

27-1 DOLAN, B.P*; FISHER, K.M.; COLVIN, M.E.; PETERSON, J.T.; KENT, M.L.; SCHRECK, C.B.; Oregon State University, U.S. Geological Survey; brian.dolan@oregonstate.edu

Innate and adaptive immune responses in migrating spring-run adult Chinook Salmon, *Oncorhynchus tshawytscha*

Adult Pacific salmon species cease feeding at the start of their migration from salt water to fresh water and must use energy reserves to swim against currents, compete for mates, evade predation, and generate immune responses to contend with freshwater pathogens. We quantified the immune response in migrating adult Chinook salmon, *Oncorhynchus tshawytscha*, at different times and locations during the run using several different assays. We measured the levels of immunoglobulin heavy chain mu and heavy chain tau mRNA transcript in the anterior kidney and found that levels of both secreted and membrane bound forms of the heavy chain either did not diminish or only partially diminished during migration and spawning. We also measured the innate anti-bacterial ability of plasma isolated from fish to prevent the growth of a lab strain of *E. coli*. Contrary to the humoral immune response, the innate anti-bacterial components of plasma diminished at later time points in the run and after spawning. Fish were also examined for the presence and severity of eight different pathogens in different organs. While pathogen burden tended to increase during the migration, no specific pathogen signature was associated with diminished immune responses. Additionally, diminished immune responses were not due to increased IL-10 production, as transcripts for this cytokine were similar at all time points that were examined. These results suggest that loss of immune functions in adult migrating salmon are part of the life history of Chinook Salmon and are likely induced by diminished energy reserves or hormonal changes which accompany spawning.

85-5 DODSON, T*; SWEENEY, AM; University of Pennsylvania; tcodson@gmail.com

Origins of Polydispersity In Cephalopod Photonic Systems - Are Squids Masters of RNA Editing?

Over the evolutionary span of ~450 million years, cephalopods have radiated into various ecological niches; this radiation is correlated with the structural divergence of tissues with optical function. These evolved optical devices include beam collimators, fiber-optic light guides, broadband reflectors, and dynamic directional mirrors. The reflectin-family proteins from which most of these diverse structures are assembled may be a cephalopod synapomorphy. Reflectins are an unusual, highly diverse family of apparently disordered proteins defined by a ~30 aa conserved motif that shows high conservation across decapod species, but also high polydispersity in individual species. Using RNASeq, mass spectrometry, and nucleotide substitution models, we characterized editing of reflectin transcripts in three tissues with eye-camouflaging function. Our transcriptome analysis of three distantly-related squid taxa reveals unprecedentedly high levels of RNA editing specifically of reflectin proteins, even given recent observations that cephalopods generally have very high levels of editing. Our mass spec evidence demonstrates that this editing at the RNA level in fact leads to massive physical polydispersity of reflectin proteins. Additionally, the RNA editing that occurs in reflectin proteins exhibits different patterns from the RNA editing in the cephalopod nervous system. The talk will also discuss hypotheses about the possible physicochemical roles of polydispersity in the evolved self-assembly of these proteins in the optical devices they inhabit.

122-3 DONATELLI, CM*; SUMMERS, AP; TYTELL, ED; Tufts University, University of Washington; cassandra.donatelli@tufts.edu

Twist and Flex: Locomotor Variation in Elongate Fishes

Fish swim by passing a wave of motion from their heads, through the body, to the tail which produces thrust. In addition to the yaw motion of the tail, some twisting also occurs about the long axis of the body. This twisting motion, or wobble, is especially prominent in elongate fishes. Wobble can be seen passing down the fish's body with the wave of motion in a dorsal view of the fish swimming. To measure wobble, we collected video data from six species of elongate fishes, *Anoplarchus insignis*, *Xiphister mucosus*, *Lumpenus sagitta*, *Pholis laeta*, *Apodichthys flavidus*, and *Ronquilus jordani*, using automated video analysis software developed in Matlab. We measured swimming speed, wave speed, tail beat frequency, lateral amplitude, and wobble amplitude. From the video data, we can see that the *A. flavidus* and *P. laeta* wobble the most, while *R. jordani* wobbles the least. We also used a material testing system (MTS) to measure torsional stiffness at several points along the length of the fish's body. As we expected, stiffness increased as number of vertebrae decreases for 5 of the 6 species. *A. insignis* appears to be the least stiff species, though its vertebral count is the second highest. We will present results on how the torsional stiffness of the body and the number of vertebrae correlates with the amount of wobble.

50-7 DORGAN, K.M.*; D'AMELIO, C; LINDSAY, S.M.; Dauphin Island Sea Lab, School of Marine Sciences, University of Maine; kdorgan@disl.org

Strategies of burrowing in soft muddy sediments by diverse polychaetes

Muddy sediments are elastic solids through which morphologically diverse animals extend burrows by fracture. Muddy sediments inhabited by burrowing infauna vary considerably in mechanical properties, however, and at high enough porosities, muds can be fluidized. In this study, we examined burrowing behaviors and mechanisms of burrow extension for three morphologically diverse polychaetes inhabiting soft muddy sediments. Worms burrowed in gelatin, a transparent analog for muddy sediments, and in natural sediments in a novel viewing box enabling visualization of behaviors and sediment responses. *Scalibregma inflatum* and *Sternaspis scutata* can extend burrows by fracture but both also extended burrows by plastic deformation or rearrangement of sediment aggregates and by combinations of fracture and plastic deformation. Mechanical responses of sediments corresponded with different burrowing behaviors of *Scalibregma*, which uses direct peristalsis to extend burrows by fracture or a combination of plastic deformation and fracture and uses a retrograde expansive peristaltic wave to extend burrows by plastic deformation. Burrowing speeds differed between behaviors and sediment mechanical responses, with slower burrowing associated with plastic deformation. *Sternaspis* exhibited less variability in behavior and burrowing speed but did extend burrows by different mechanisms consistent with observations of *Scalibregma*. *Ophelina acuminata* did not extend burrows by fracture, rather plastically deformed sediments similarly to the related *Armandia brevis*. Our results extend the range of natural sediments in which burrowing by fracture occurs but the dependence of burrow extension mechanism on species, burrowing behavior, and burrowing speed highlights the need for better understanding of mechanical responses of sediments to burrowers.

105-8 DOW, E/G*; RODRIGUEZ-LANETTY, M; Florida International University; edow002@fiu.edu

A new ionotropic glutamate receptor lineage and its putative role in cnidarian immunity

Ionotropic glutamate receptors (iGluRs) are ligand-gated ion channels, characterized for their role in synaptic communication in vertebrate nervous systems, and also implicated in the chemosensory and olfaction of insects. Here we examined the hypothesis that an iGluR lineage has evolved in cnidarians with a role in the innate immune pathways. By 2D-gel electrophoresis profiling in tandem with Mass Spectrometry, it was determined that the symbiotic model cnidarian, *Exaiptasia pallida*, increases the protein levels of an iGluR (EpiGluR) homolog during the response to exposure of the infectious bacterial agent *Vibrio coralliilyticus*. Bioinformatic analyses support the identity of this gene as an iGluR. Phylogenetic analyses, using the full coding gene, indicate the EpiGluR ligand-binding domain is not specific to classical synaptic-involved NMDA, kainate, or AMPA ligands and phylogenetically branches out of the insect antennal ionotropic receptors (IR) clade. This supports the hypothesis that the cnidarian EpiGluR belongs to a separate evolutionary lineage within the phylogeny of iGluRs, and has retained molecular characteristics to respond to chemical stimuli. In plants, iGluR homologs have been implicated in sensing molecular patterns, such as pathogen- and damage-associated molecular patterns (PAMPs, DAMPs) that act together in order for a host to differentiate between pathologically damaging microbes and beneficial or harmless microbes. Based on this, we postulate that iGluRs may mediate the PAMP-triggered immunity via calcium channels by pattern-recognition particles. These findings provide the beginnings of a foundation for further functional analysis of these receptors to better comprehend the role of EpiGluR and its ligand-specificity within cnidarian immunity.

99-6 DOUGHERTY, L/F*; NIEBERGALL, A/K; CALDWELL, R/L; University of California, Berkeley; lindseydougherty@berkeley.edu
Predators and prey: examining flashing as a signal in *Ctenoides ales*, "disco" clams

The "disco" clam *Ctenoides ales* is known for its vivid flashing display which results from light-scattering silica nanospheres. Hypotheses regarding the fitness value of the flashing include the luring of phototactic prey items or predator deterrence through aposematism. The effect of the light display on planktonic prey items was examined during three experiments. First, *in situ* water samples were taken while SCUBA diving from inside individual clams during high-light (flashing visible) and low-light (flashing not visible) conditions. Second, plankton samples were collected offshore and then exposed in the laboratory to artificial clams made from *C. ales* valves with LED strips of light that were off, on, or flashing. Finally, additional plankton samples were exposed to video playback with two lines; one constant, and one flashing, which mimicked the spectra and the flash rate (Hz) of the clam. All samples were compared against each other and controls, and examined for plankton volume and diversity. Results indicated there was no trend toward higher prey numbers in any of the treatments or sample groups. To test aposematism, predators were identified using video analysis, underwater observation, and dead valve collection. Valve damage type was linked to potential predators, and laboratory interactions were filmed when possible. Predator analyses are ongoing, including the study of potentially volatile sulfuric compounds present in the tissue of the clam.

130-5 DOWD, WW*; JIMENEZ, AG; JAYAWARDENE, S; ALVES, S; DALLMER, J; Loyola Marymount University, Colgate University; wadowd@lmu.edu

Micro-scale environmental variation amplifies physiological variation among individual mussels

The contributions of temporal and spatial environmental variation to physiological variation remain poorly resolved. Rocky intertidal zone populations are subjected to thermal variation over the tidal cycle, superimposed with micro-scale variation in individuals' body temperatures. Using the sea mussel (*Mytilus californianus*), we assessed the consequences of this micro-scale environmental variation for physiological variation among individuals, first by examining the latter in field-acclimatized animals, second by abolishing micro-scale environmental variation via common garden acclimation, and third by restoring this variation using a reciprocal outplant approach. Common garden acclimation reduced the magnitude of variation in tissue-level antioxidant capacities among mussels from a wave-protected (warm) site, but it had no effect on antioxidant variation among mussels from a wave-exposed (cool) site. The field-acclimatized level of antioxidant variation was restored only when protected-site mussels were outplanted to a high, thermally stressful site. Variation in organismal oxygen consumption rates reflected antioxidant patterns, decreasing dramatically among protected-site mussels after common gardening. These results suggest a highly plastic relationship between individuals' genotypes and their physiological phenotypes that depends on recent environmental experience. Corresponding context-dependent changes in the physiological mean-variance relationships within populations complicate prediction of responses to shifts in environmental variability that are anticipated with global change.

92-2 DOWLE, E J*; BRACEWELL, R; PFRENDER, M; MOCK, K; BENTZ, B; RAGLAND, G; Kansas State University, University of Montana, University of Notre Dame, Utah State University, Utah State University, USDA Rocky Mountain Research Station; eddydowle@ksu.edu

Reproductive isolation and environmental adaptation shape the phylogeography of Mountain Pine Beetle (*Dendroctonus ponderosae*)

The Mountain Pine Beetle (MPB) is an eruptive pest of various pine species native to western North America, reaching from northern Mexico to Canada along the Rocky Mountain and Sierra Nevada ranges. Current MPB ranges are expanding as a result of climate change and infestations cause extensive damage to susceptible forests. Applying genome-wide RAD sequencing to over 700 individuals from 37 populations, we are examining phylogeographic structure, gene flow, and adaptation across the range. Strong population structuring occurs between geographic regions with extensive admixing occurring in the sky island populations residing in the Great Basin. However results also suggest that there are distinct genetic boundaries between some geographically proximate regions. Experimental crossing experiments have previously found postzygotic isolation between geographically distant populations. Moreover crosses between the geographically close populations of Oregon and Idaho also showed a reduction in hybrid male fitness despite their proximity. Population structuring of the autosomes and sex chromosomes show that these populations are permeable to gene flow at autosomal sites but Y chromosome sites show clear disjunction between regions. Population structure suggests that separate genetic lineages occur across similar latitudes in the Rockies and Sierra Nevada. Leveraging a complementary QTL study of development time, a crucial trait in seasonal synchronization, we also discuss tests for parallel adaptation across lineages.

8-3 DUBSKY, K.M.*; KARSTEN, K.B.; California Lutheran University; kdubsky@callutheran.edu

The social effects of tail loss on *Sceloporus occidentalis*

As with many lizards, male Western Fence Lizards (*Sceloporus occidentalis*) are territorial. The more dominant males keep larger territories with better basking spots, hiding places, and food resources. A better territory means that the male will likely have more females nearby and therefore more mating opportunities. Also like other lizards, *S. occidentalis* can voluntarily lose their tails to avoid predation. However, because they store fat in their tails, losing them may lower the lizards' chance of survival and their social status. We conducted this study to determine if tail loss in males affects ability to maintain territory or access to females. We collected data from males and females in 2014 from May to August and in 2015 from March to August. Each time we spotted a lizard, we marked it for identification and collected a GPS point at the exact location where it was found. We mapped individual territories using these points through GIS software. In total, we found points for 29 males and 22 females. In June of 2015, we brought seven males into the lab. First, we measured their bite force, sprint speed, and morphology, and took high speed videos of each lizard sprinting at 1000 fps. We then removed tails from three of the males and measured and video recorded their sprint speed again. After a month of tail regrowth, we recorded the lizards again to assess if tail loss affected sprinting biomechanics. After recording video, we returned all lizards back to their original locations.

6-5 DREW, JA*; LÓPEZ, EH; GILL, L; MCKEON, M; MILLER, N; STEINBERG, M; SHEN, C; Columbia University, Stanford University, Duke University; jd2977@columbia.edu

Collateral Damage to Marine and Terrestrial Ecosystems from Yankee Whaling in the 19th Century

During the 19th century American whalers made over a thousand voyages in pursuit of great whales for oil and whalebone. These Yankee whalers undoubtedly had a major impact on the population of the great whales, but these leviathans were not the only taxa that were targeted. Here we describe the taxonomic diversity of the 'collateral damage' of the American whaling industry during the 19th century. Using data from 40 whaling logs spanning 48 voyages occurring between 1840 and 1899, we show that Yankee whalers captured over 5085 animals from 34 different taxonomic categories, including a wide range of marine and terrestrial species. The greatest non-great whale species targeted by numbers of individuals were walrus (*Odobenus rosmarus*), ducks (Anatidae) and cod (*Gadus* sp.). By biomass, the most targeted species were walrus, grampus (a poorly defined group of Odontoceti) and cod. These results are the first compilation of the diversity of species captured by the American whaling industry and indicate that the ecosystem impacts of whaling extended beyond great whale populations, and reverberated on both marine and coastal environments.

93-7 DUDLEY, R.*; MUNK, Y.; YANOVIK, S.P.; Univ. of California, Berkeley, University of Louisville; wings@berkeley.edu
Arachnid Aloft: Directed Aerial Descent in a Neotropical Canopy Spider

The behavior of directed aerial descent has been described for numerous taxa of wingless hexapods as they fall from the tropical rainforest canopy, but is not known in other terrestrial arthropods. Here we describe similar controlled aerial behaviors for large arboreal spiders in the genus *Selenops* (Selenopidae). We dropped 59 such spiders from either canopy platforms or tree crowns in Panama and Peru; the majority (93%) directed their aerial trajectories towards and then landed upon nearby tree trunks. Following initial dorsoventral righting when necessary, falling spiders oriented themselves and then translated head-first toward targets; directional changes were correlated with bilaterally asymmetric motions of the anterolaterally extended forelegs. Aerial performance (i.e., the glide index) decreased with increasing body mass and wing loading, but not with projected surface area of the spider. Along with the occurrence of directed aerial descent in ants, jumping bristletails, and other wingless hexapods, this discovery of targeted gliding in selenopid spiders further indicates strong selective pressures against uncontrolled falls into the understory for arboreal taxa.

129-3 DUELL, M.E.*; SMITH, B.H.; Arizona State University; meduell@asu.edu

Allometry of visual pattern learning: body size does not predict performance

Most animals on earth are small but we know little of their behavioral abilities. There is no general consensus on whether small animals have similar, better or worse behavioral functionality compared to larger animals. No study to date has determined the scaling of behavioral capacities using controlled assays for well-defined behaviors or using phylogenetic analysis for broad applicability. Among insects, there is simply not enough data available to determine how well small organisms perform relative to larger animals. We determined the scaling relationships of visual morphology, learning performance and body size using stingless bees, a tropical tribe of social bees. This group has three orders of magnitude in body size variation among many species and will readily perform in behavioral tests. We collected stingless bee foragers from ten species varying in body mass from 2-115mg and calculated the resolving power of their eyes using radius of curvature estimation. Bees were individually introduced to a Y-maze with black and white vertical line patterns that were designed to span the range of spatial acuity of each bee species. We determined what the patterns look like in 'bee vision' using an achromatic visual model. We tested bees' ability to differentiate patterns and compared this to their anatomical resolving power and body size. Then we determined the learning rate for each species in the maze. Using phylogenetic generalized least squares analysis, we found that there was no correlation between body size and pattern learning performance among the stingless bee species studied. Small species performed equally compared to larger species in differentiation and learning tasks despite lower resolving power. This suggests neurophysiological or behavioral compensation for small body size.

108-6 DUQUETTE, AM*; MCCLINTOCK, JB; AMSLER, CD; HALANYCH, KM; University of Alabama at Birmingham, Birmingham, AL, Auburn University, Auburn, AL; amd82886@uab.edu

Inter- and intra-specific comparisons of the Mg-calcite contents of skeletal components of a suite of Antarctic echinoderms

Marine invertebrates in the Southern Ocean are considered to be at particularly high risk to ocean acidification (OA). Echinoderms are especially vulnerable because they use "high magnesium calcite" (>4% MgCO₃) to construct their skeletal elements. Calcite comprised of high levels of magnesium is more soluble than either calcite or aragonite alone. The increased solubility of MgCO₃ is compounded by the fact that the Southern Ocean has naturally low carbonate ion concentrations. As the saturation levels of calcite and aragonite in the Southern Ocean reach sub-saturation levels under ocean acidification, echinoderms will need to cope with both skeletal dissolution and the potential for increased energetic cost in producing and maintaining skeletal material. Representatives of the Echinoidea, Ophiuroidea, and Asteroidea (collected from a variety of biogeographic regions of Antarctica) were dissected and their skeletal elements powdered and analyzed for magnesium-calcite content using x-ray diffraction (XRD). Comparisons across the three classes of echinoderms, intra-specific comparisons among skeletal components, and comparisons across geographic regions will be reported. These data will provide the first analysis of MgCO₃ levels in skeletal elements of echinoderms that occur south of ~70 degrees latitude. The new information will facilitate future predictions about the vulnerability of Antarctic echinoderms to continued ocean acidification.

130-1 DUNCAN, EA*; MILLER, LP; DENNY, MW; ALLEN, BJ; California State University, Long Beach, San Jose State University, California, Hopkins Marine Station of Stanford University, Pacific Grove, CA; liz.duncan90@gmail.com

Predicting effects of environmental variability on thermal risk to black abalone: Combining ecomechanics with behavior

Black abalone (*Haliotis cracherodii*) were once a common intertidal inhabitant on rocky shores in California, but have experienced dramatic population declines and local extinctions due to overharvesting and the emergence of withering syndrome (WS). Susceptibility of black abalone to infection by WS is related to higher body temperature variability during aerial exposure at low tide, suggesting that temperature stress is a key risk factor determining their long-term viability. Our research is designed to quantify how body temperatures and associated risk of disease to black abalone might be altered in response to anthropogenic climate change. We created a heat-budget model for black abalone and coupled it with long-term meteorological records at Hopkins Marine Station (HMS) to generate information about environmental and topographic controls of body temperature at this site. Combined with published data on WS infection rates, we quantified how potential risk to abalone changes as a function of daily body temperature variation. We simultaneously collected real-time data across microhabitats at HMS on the distributions of body temperatures (T_b) of live abalone with a calibrated infrared camera and operative environmental temperatures (T_e) with species-specific thermal mimics. These data will be combined to derive quantitative measures of the thermal quality of the habitat at HMS and the precision, accuracy, and effectiveness of thermoregulation by black abalone in the field.

4-4 DURANT, S.E.*; LOVE, A.C.; BELIN, B.; TAMAYO-SANCHEZ, D.; SANTOS-PACHECO, M; DICKENS, M.J.; CALISI, R.M.; Oklahoma State Univ, Barnard College, Columbia University, Barnard College, Columbia University, UC Berkeley, Barnard College, Columbia University/UC Davis; sarah.durant@okstate.edu

Captivity alters neuroendocrinology of house sparrows.

Captivity causes stress in most wild-caught vertebrates. While many species eventually acclimate to captive conditions, some species never adjust to their new environment. Wild-caught house sparrows are commonly-used in captive studies, yet physiological data from our lab suggest they do not acclimate to captivity within 9 weeks of capture. We examined whether neuroendocrine changes in the hypothalamus of house sparrows coincided with plasma corticosterone (an avian glucocorticoid) and immune responses. We measured mRNA expression of glucocorticoid receptor (GR; binds to corticosterone), corticotropin releasing hormone (CRH; neurohormone involved in the stress response), and gonadotropin inhibitory hormone (GnIH; inhibits reproduction) immediately upon capture (controls) or after 24, 45, or 66 days in captivity. We also quantified cells immunoreactive for GnIH (GnIH-ir) using immunohistochemistry. We found that GR expression and GnIH-ir cell counts initially increased in response to captivity but did not differ from control birds after 66 days in captivity. CRH and GnIH expression exhibited similar responses to captivity, but this was not statistically significant. We did not detect significant correlations between changes in neuroendocrine measurements and corticosterone or immune responses. However, control birds with high CRH expression also had greater capacity to secrete corticosterone. Captivity affected physiological measures of birds throughout the entire period of captivity; however, these effects are likely not driven by changes in expression of the neuroendocrine endpoints we measured.

511-4 DURICA, D.S.*; DAS, S.; Univ. of Oklahoma; ddurica@ou.edu

Ecdysteroid control of limb regeneration and growth in the fiddler crab *Uca pugilator* using transcriptomics

A next generation sequencing approach was employed to study global gene expression patterns in three distinct stages of limb regeneration, and in blastemas with disrupted and intact ecdysteroid signaling. SOAPdenovo-Trans assembly generated 208,404 contigs, averaging 583 nt. This database is available at http://www.genome.ou.edu/crab_illumina.html and is both sequence and keyword searchable. This database was used to further explore the putative role of ecdysteroid signaling during the regeneration process. As proof of principle, the depth of sequence analysis has led to discovery of alternate EcR and E75 A/B domain isoforms, not identified through previous genomic or cDNA library screenings. EcR RNAi knockdown leads to a block in blastemal cell proliferation. Relative expression levels of cell division candidate genes between receptor knockdown and control libraries indicate a down-regulation of proliferation marker genes like *PCNA*, *MCM2* and the cell cycle regulatory gene *CycB* in the knockdown library. This is accompanied by up-regulation of the nuclear receptor *HR3*, which inhibits *CycB* expression in insect systems. Excessive cuticle deposition seen in RNAi-treated animals correlated with an up-regulation of cuticular protein transcripts in knockdown libraries. Interestingly, cuticular proteins normally expressed at later molt cycle stages are aberrantly expressed in the early blastema. A lowering of circulating ecdysteroid titers observed as a consequence of receptor knockdown also correlates with an increase in *MIH* mRNA steady state transcripts in blastemal tissue of experimental animals. We postulate that an increase in *MIH* expression might in turn feedback systemically to lower circulating ecdysteroid titers below a critical level needed to maintain cell proliferation.

69-3 DZIEDZIC, K.E.*; MEYER, E.; Department of Integrative Biology, Oregon State University, Corvallis, OR, USA; katherine.dziedzic@science.oregonstate.edu

Profiling gene expression in an intertidal sea anemone (*Anthopleura elegantissima*) across habitats and symbiotic states

Changing ocean conditions are already impacting fitness and distribution of coastal marine organisms. Our ability to predict the biological consequences of ongoing changes is hampered in many cases by the scarcity of fundamental data on biological responses to environmental conditions. In this study, we focused on an intertidal anemone *Anthopleura elegantissima* that encounters extreme variation in environmental conditions across the intertidal zone and across its geographic range. This anemone typically occurs in symbiotic relationships with unicellular algae, with the dinoflagellate (*Symbiodinium*) dominating in most of its range and a green algal symbiont (*Elliptochloris*) occurring in low light and high latitudes. To investigate biological responses to this variation in environmental conditions and symbiotic status, we developed a reference transcriptome assembly and profiled gene expression using RNASeq, testing for changes in gene expression across latitudes, at different tidal heights, and in different symbiotic states. Our study profiles responses to existing variation in conditions to better understand how this organism may respond over time. To develop a more complete picture of biological responses in this system, this analysis was conducted as part of a broader collaboration (SSIMBIO) aiming to develop a systems biology framework for understanding responses to climate change. Collaborators studying diverse topics, including microbial communities and population structure, were also able to analyze the samples used in this study. We describe ongoing efforts to integrate these diverse datasets to develop a molecules-to-ecosystems view of biological responses to changing ocean conditions.

118-1 DZAL, YA*; YORK, JM; FAURE, PA; MILSOM, WK; University of British Columbia, Vancouver, Canada, McMaster University, Hamilton, Ontario, Canada; dzal@zoology.ubc.ca

Are hibernating bats just big babies? Metabolic, thermoregulatory, and ventilatory responses of bats to low environmental oxygen

There are striking parallels in physiological traits between all newborn mammals and adults of species capable of hibernation. Tolerance to low environmental oxygen (i.e. hypoxia) is one of these. As hypoxia tolerance is not present in adults of most non-hibernating species, we hypothesized that differences in hypoxia tolerance in adult hibernators and non-hibernators reflect developmental changes in the way oxygen demand and supply are matched. To test this hypothesis, we exposed newborn and adult hibernators (the big brown bat; *Eptesicus fuscus*), adult daily heterotherms (the Argentine brown bat; *Eptesicus furinalis*), and adult non-hibernators (the little yellow-shouldered bat; *Sturnira lilium*) to progressive reductions in inspired levels of oxygen (21, 12, 9, and 7% O₂) and measured their metabolic, thermoregulatory, and ventilatory responses. Severe hypoxia (7% O₂) led to a profound depression in oxygen demand in newborn (57 ± 6%) and adult (43 ± 12%) hibernators, and adult daily heterotherms (40 ± 14%), independent of decreases in body temperature (<2 °C). Unlike hibernators and daily heterotherms, adult non-hibernators did not reduce oxygen demand or body temperature in hypoxia; instead they increased oxygen supply through a significant increase in ventilation (105 ± 21%). While non-hibernating bats match oxygen supply to demand in hypoxia by a brisk ventilatory response, newborn and adult hibernators, and adult daily heterotherms do so by suppressing metabolism. Our results suggest that bats employ divergent strategies to tolerate hypoxia, and that hibernating bats may in fact just be big babies.

88-6 ECHEVERRI, SE*; ZUREK, DB; MOREHOUSE, NI; University of Pittsburgh; sae53@pitt.edu

Collaborative control of signal-sensor alignment during dynamic courtship in a jumping spider

Signals are often directional, meaning that they are best perceived from certain angles. Similarly, the sensory systems of receivers may often exhibit directionality, leading to spatial biases in their sensitivity to signals around them. This implies that alignment between signals and sensors may often be critical for effective communication. However, we know little in any system about how signal-sensor alignment is established and controlled throughout a signaling interaction. The dynamic courtship dances of the jumping spider *Habronattus pyrrithrix* are an excellent system for investigating signal-sensor alignment. During courtship, males produce a color- and pattern-rich, forward-facing display. Females view this display with multiple pairs of eyes, which are sensitive to different types of visual stimuli. Only the forward-facing principal eyes can perceive color and acute detail. Males and/or females may thus be under pressure to align the male display with the field-of-view of female principal eyes. We measured relative positions of both actors throughout courtship to evaluate how consistently male displays are aligned with the principal eye field of view, and the relative role of each sex in maintaining this alignment. With live females, male displays were consistently aligned with female principal eyes. However, when female position was fixed, this alignment was reduced. In addition, when females were turned to face away, males rarely repositioned themselves to re-align their display. These results suggest that although both sexes contribute to effective alignment during courtship signaling, males rely heavily on female body reorientations to maintain signal-sensor alignment.

32-1 EDGERTON, S.V.*; BENNETT, S.N.; GUBLER, D.J.; California Academy of Sciences, Duke-NUS Medical School, Singapore; seanedgerton@gmail.com
Historical Study of Dengue Virus Type 3 (DENV-3) Evolution & Epidemic Activity in Indonesia 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 here follow up sequence data on DENV-3 strains isolated during epidemics that occurred in Indonesia between 1976 and 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 of these were explosive epidemics with associated severe disease. A smaller outbreak with more sporadic transmission, milder illness and much lower viremia levels occurred in Sleman, Central Java in 1978. 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 transportation routes to Central and East Java, and to 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 virus evolution and genetic variation as a contributor to epidemic intensity and severe dengue disease.

96-7 ELIASON, CM*; SHAWKEY, MD; CLARKE, JA; Univ. of Texas, Austin TX, Univ. of Akron, Akron OH; chad_eliason@utexas.edu

Evidence for early shifts in the melanin-based color system of birds
 Melanin pigments contained in organelles (melanosomes) impart earthy colors to feathers. Such melanin-based colors are distributed across birds and thought to be the ancestral color-producing mechanism. However, we have had limited data on melanin-based color and melanosome diversity in Palaeognathae, which includes the flighted tinamous and large-bodied, flightless ratites and is the sister taxon to all other extant birds. Here, we use scanning electron microscopy and spectrophotometry to assess melanosome morphology and quantify reflected color for 19 species within this clade. We find that brown colors in ratites are uniquely associated with elongated melanosomes nearly identical in shape to those associated with black colors. Melanosome and color diversity in large-bodied ratites is limited relative to other birds and smaller-bodied basal maniraptoran dinosaur outgroups of Aves, whereas tinamous show a wider range of melanosome forms similar to neognaths. The repeated occurrence of novel melanosome forms in the non-monophyletic ratites suggests that melanin-based color tracks changes in body size, physiology or other life history traits associated with flight loss, but not feather morphology. We further anticipate these findings will be useful for future color reconstructions in extinct species, as variation in melanosome shape may potentially be linked to a more nuanced palette of melanin-based colors.

43-1 EDWARDS, D/D*; MOORE, P/A; Bowling Green State University; davide@bgsu.edu

geometric morphometric analysis of *Perlidae* stoneflies across stream hydraulic conditions

Stream flow is the primary abiotic factor influencing stream ecosystem function. Physical forces associated with the flow can affect the morphology of in-stream organisms. Body shape couples organism morphology to turbulent stream flow which can affect individual behavior. Natural systems have increasingly been under siege through flow alterations in the form of dams, land use, and storm events through global climate change. An understanding of the direct and indirect effects associated with the natural flow regime is crucial to identifying and predicting behavioral and morphological responses of organisms (and by extension ecosystem processes) to flow alterations. *Perlidae* stoneflies were collected and hydraulic conditions were surveyed from 20 pristine streams across Northern Michigan. Sites were chosen for an array of environmental and physical conditions and the prevalence of a USGS gauging station. A geometric morphometric shape analysis was conducted on *Perlidae* individuals using the suite of tps software. Principle component analyses indicate *Perlidae* stoneflies may have evolutionary body shape adaptation to the natural flow regime of their stream. Stoneflies provide an interdependent link between flowing water and the ecological integrity of a stream by enhancing ecosystem processes (i.e.-nutrient cycling). The morphology of benthic macroinvertebrates are heavily influenced by the turbulent flows of their environment. Turbulent flows at the scale of an organisms are heavily influenced by rain events and the influx of water dictated by past and current land use characteristics. As human influence to natural systems increases, particularly in the context of global climate change, the use of organism shape information could be used to infer hydrologic, hydraulic, and ecological condition of streams.

96-2 EMERLING, C.A.*; HUYNH, H.T.; NGUYEN, M.A.; MEREDITH, R.W.; SPRINGER, M.S.; Univ. of California, Berkeley/Univ. of California Riverside, Univ. of California Riverside, Montclair State University/Univ. of California Riverside; caemerling@berkeley.edu

Spectral shifts of mammalian ultraviolet-sensitive pigments (SWS1) are associated with eye length and photic niche evolution

Mammalian vision begins with retinal photopigments composed of a chromophore and an opsin protein. Most mammals possess a short wavelength-sensitive opsin 1 (SWS1) pigment that is primarily sensitive to either ultraviolet or violet light, leading to variation in color perception across species. Despite knowledge of both ultraviolet- and violet-sensitive SWS1 classes in mammals for 25 years, the adaptive significance of this variation has not been subjected to hypothesis testing. We gathered data on SWS1 for 402 mammal species, providing novel SWS1 sequences for 97 species. Utilizing an ancestral sequence reconstruction method, we estimate that the ancestral mammal possessed an ultraviolet SWS1 pigment and violet-sensitive pigments evolved at least 12 times in mammalian history. We also observed that ultraviolet pigments, previously considered to be a rarity, appear to be very common in mammals. We then used phylogenetic comparative methods to test the hypotheses that the evolution of violet-sensitive SWS1 is associated with increased light exposure, extended longevity, and longer eye length. We discovered that diurnal mammals and species with longer eyes are more likely to have violet-sensitive than UV-sensitive pigments. We hypothesize that as mammals evolved larger body sizes, they evolved longer eyes, which limited transmittance of ultraviolet light to the retina due to an increase in Rayleigh scattering, and as mammals began to invade diurnal temporal niches, they evolved lenses with low UV-transmittance to reduce chromatic aberration and/or photo-oxidative damage.

23-2 EMLET, RB; Univ. Oregon; remlet@uoregon.edu
What's up - in the water column? Linking spawned embryos with adult chitons in two separate oceans

By using molecular sequences of COI genes (barcoding) from chiton eggs or embryos collected as plankton and from adults collected in the field, we have identified time of spawning by chitons in southern Australia and temporal patterns of spawning in chitons in coastal Oregon. In Australia we obtained molecular sequences for 24 species of adults and 21 species of eggs/embryos, and we have matched eggs and adults for 10 species. These samples are the first broad molecular survey of the southern Australian chiton fauna and permit construction of hypotheses on phylogenetic relationships of species and radiations of taxa within this fauna. The linking of eggs and their hulls with species also expands our knowledge of how hull morphology is indicative of taxonomic grouping of chiton species. In Oregon, a winter season, daily time-series of coastal plankton, contained many embryos of chitons and several other invertebrate taxa during large wave events. We are investigating whether gamete release during large wave events results in localized retention of short-lived larvae.

90-3 ERNST, D.A.*; CHILDRESS, M.J.; BERTELSEN, R.D.; LOHMANN, K.J.; University of North Carolina at Chapel Hill, Clemson University, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission; dernst@live.unc.edu
Does a magnetic pulse affect spiny lobster behavior in the field?

Although evidence for magnetic orientation in animals is plentiful, little is known about how animals detect magnetic fields. One hypothesis is that crystals of the mineral magnetite provide the physical basis for magnetoreception. When magnetite crystals attempt to align with Earth's magnetic field, they might activate stretch receptors or hair cells, thus transducing magnetic information to the nervous system. Brief, strong magnetic pulses capable of remagnetizing magnetite are known to alter the orientation of several animals capable of magnetoreception. Magnetic material has been detected in the Caribbean spiny lobster (*Panulirus argus*), the only invertebrate known to possess both a magnetic compass and magnetic map. Furthermore, in laboratory experiments, the orientation of lobsters exposed to a magnetic pulse was significantly altered compared to control lobsters. To determine whether a magnetic pulse also affects lobster behavior in the field, lobsters were captured on a patch reef and either: (1) exposed to a magnetic pulse oriented antiparallel to the geomagnetic field; or (2) handled but not exposed to a pulse. Each lobster was then equipped with an acoustic transmitter and released back on the patch reef, which was surrounded by an array of acoustic receivers. Results suggest that lobsters exposed to a magnetic pulse were more likely to rapidly emigrate from the home reef, whereas control lobsters typically remained on the reef. These findings provide additional evidence that lobsters are sensitive to magnetic stimuli and are consistent with the hypothesis that the mechanism underlying magnetoreception involves magnetite.

45-5 ENG, CM*; ROBERTS, TJ; Brown University; carolyn_eng@brown.edu
Does aponeurosis influence the relationship between muscle gearing and force?

Muscle shape changes in pennate muscles affect the force and speed of contraction because they influence the gear ratio through which muscle fibers transmit force and speed to the whole muscle. It has been hypothesized that aponeuroses, the sheet-like tendinous structures that rest on the surface of muscle in close association with fibers, influence muscle gear ratio via their effect on muscle shape change. Specifically, aponeuroses may restrict width-wise bulging during low-force contractions, forcing muscle fibers to rotate to steeper angles of pennation during shortening. We used an *in situ* preparation of the turkey lateral gastrocnemius (LG) muscle to test the hypothesis that disrupting an aponeurosis' ability to transmit transverse forces impedes its ability to resist width changes, leading to an increase in muscle width and decreased gearing during isotonic muscle contractions. Measurement of muscle length and muscle fiber length for a series of contractions at different force levels allowed us to examine how gearing varied with force before and after incising the aponeurosis. Consistent with previous work, we found that gearing decreased with increasing contractile force in the intact muscle. This relationship between gearing and force was maintained even after longitudinal incisions reduced the aponeurosis' ability to transmit transverse forces. Furthermore, incising the aponeurosis did not cause a decrease in gearing during low force contractions. These results suggest that other muscle components such as the intramuscular connective tissue play an important role in modulating dynamic gearing.

107-4 ESCALANTE, I*; BADGER, MA; ELIAS, DO; Univ. of California, Berkeley; iescalante@berkeley.edu
Compensatory behaviors in locomotion performance induced by autotomy in Daddy Long-legs

Animals face predictable challenges throughout their lifetimes. For instance, predation attempts are ubiquitous, and may drive the evolution of adaptations to avoid predators. Some animals have evolved adaptations where they voluntarily release appendages (autotomy) during predation attempts. While autotomy usually increases survival, animals can face long term consequences. Given this, strategies to compensate for damage may have evolved. While this is the case, investigating compensation strategies have not received much attention. We studied compensation strategies in daddy long-legs (order Opiliones) because autotomy is frequent in this group and regeneration does not occur. Specifically, we examined *Prionostemma* sp1 (Sclerosomatidae) in the Costa Rican rainforest to test the hypothesis that compensation occurs through time due to changes in either biomechanical (kinematic) properties and/or the suites of behaviors employed while escaping. By controlling the time since autotomy and the number of legs in animals, we were able to record changes in locomotor performance on a horizontal track through time, using high speed video. Preliminary analyzes show an immediate decrease in locomotion performance after autotomy, followed by gradual changes in kinematics (trajectory, axes of rotation, and stride length) and behaviors employed. Eventually, individuals in certain treatments seemed to approach pre-autotomy levels on locomotion performance. Overall, this project addressed mechanisms of adaptive plasticity and mechanical robustness used by animals to cope with damage. Additionally, these findings have implications for biomechanics and robotics.

127-3 EVANS, H.K.; DEWHIRST, O.P.*; ROSKILLY, K.; HUBEL, T.; HARVEY, R.J.; WILSON, A.M.; ROYAL VETERINARY COLLEGE, LONDON; *hevans@rvc.ac.uk*
Increasing low sample rate GPS path resolution using dead-reckoning: Validation in freely moving animals fitted with wildlife tracking collars

Many scientific studies and research projects require knowledge of the position of an animal on the Earth's surface. When an animal is moving, frequent measurements of its position are required if one is to accurately record range and resource utilisation, contacts between animals and the nature of locomotor activity. Tracking collars fitted to wild animals are typically designed to operate for months or years to avoid the need for frequent battery replacement. This tight power budget restricts the number of GPS position measurements that can be made, giving only a limited picture of an animal's movement, speed and locomotor repertoire. Here we show that this issue can be resolved by using low rate GPS measurements combined with a dead-reckoning approach, utilising measurements from MEMS accelerometers and magnetometers, which operate at much lower power than GPS modules. Dead-reckoning was employed to create a fine scale reconstruction of the animal's path by calculating speed estimates from the accelerometers and heading estimates from the magnetometers. As errors in the dead-reckoned path propagate with time and speed, a drift correction solution, which uses intermittent GPS fixes, was used to keep the reconstruction within acceptable bounds of accuracy. A custom-built wildlife collar was deployed on 10 freely exercising domestic dogs, collecting a total of 45 hours of data. We show that the dead-reckoning method can be used to continuously track legged locomotion between 5 minute GPS fixes with an RMS error of less than 3.8% of path length between GPS fixes. The power cost of this is less than 2.6% of that required to run a GPS module continually.

74-6 FAGGIONATO, D.*; ARNDORFER, R. J.; SERB, J. M.; Iowa State University, Ames, IA; *daviddef@iastate.edu*
Spectra analysis of Gq-opsins from four scallop species

Recent transcriptome analysis of scallops eyes and mantle from our lab has shown that scallops have a suite of four melanopsin-like Gq-coupled opsins. These opsins are expressed both in the eye and in the photosensitive mantle of scallops and virtually nothing is known about their spectral properties. Of the four Gq opsins, we have shown that OPSGq2 has the highest level of expression in mantle and eye. We have isolated five OPSGq2 from five different species (*Argopecten irradians*, Air-OPSGq2, *Placopecten magellanicus*; Pma-OPSGq2, *Mizuhopecten yessoensis*; Mye-OPSGq2, *Chlamys farreri*; Cfa-OPSGq2 and *Pecten maximus*; Pmax-OPSGq2). The five OPSGq2s differ in the amino acid sequence and present some differences in the chromophore pocket, the region of the opsin that surrounds the chromophore and determines which wavelength of light is maximally absorbed. Of the four opsins that we could express in our system, all were showed to be bleached by light and possess a bistable ability to convert the chromophore from the 11-cis to the all-trans conformation and vice versa. By mutagenesis experiments of Air-OPSGq2 and Pmax-OPSGq2, we identified residue changes in the chromophore pocket affecting the wavelength of maximum absorbance. Our results provide the first in vitro characterization of Gq-opsins in bivalves and provide evidence for the feasibility of mutagenesis experiment of Gq-opsins in scallop. Given the dramatic natural variation of scallop life style between species and the complex suite of opsins that they express, our in vitro research advances our understanding of the evolution of light perception and vision. Finally, the feasibility of mutagenesis of scallop opsins may provide possible material for the design of new optogenetic tools.

55-6 FABRE, A.-C.*; PECKRE, L.; BREWER, D.; EHMKE, E.; WESLER, K.; POUYDEBAT, E.; WALL, C.E.; Department of Evolutionary Anthropology, Duke University, Durham, USA, UMR 7179 C.N.R.S/M.N.H.N, Paris, France, Duke Lemur Center, Durham, USA, Duke Lemur Center, Durham, USA; *fabreac@gmail.com*

Influence of grasping ability on forelimb long bone shape in Prosimians

The grasping hand is one of the key morphological hallmarks of human evolution. Our understanding of the human grasping hand is largely built on our interpretation of the specialized primate grasping hand (e.g. the presence of nails instead of claws and skeletal evidence for the presence of manipulative capabilities in early primates utilizing the fine branch milieu). Yet, a holistic approach including the whole forelimb and its behavioral context in grasping and manipulation is currently missing. In this study, we link grasping and manipulation ability to the shape of the lemur forelimb in a broad phylogenetic context. We analyzed behavioral data for 18 strepsirrhine species at the Duke Lemur Center. We performed surface geometric morphometrics analyses on the forelimb long bone shape (quantified from museum skeletal collections). Next, we linked the behavioral data to anatomical data to evaluate the strength of the relationship between grasping behavior and forelimb bone shape in primates. The data obtained greatly extend our understanding of the evolution of forelimb morphology in primates in relation to grasping and manipulation behavior. Our results show that forelimb shape and prehensile behavior are influenced by phylogeny. It also shows that there is a strong co-evolution between forelimb shape and prehensile behavior, especially for the humerus and radius. Interestingly, strong differences in behavior and forelimb shape are observed between some closely-related species.

94-2 FARALLO, VF*; WIER, BN; MILES, DB; Ohio University, John Carroll University; *vfarallo@gmail.com*

Will behavioral compensation buffer species loss in a warming climate?

One major goal in evolutionary ecology is estimating the potential of organisms to respond to altered thermal niches as a consequence of climate warming. One potential response is for individuals to track shifting habitats. However, many species have limited dispersal capacities, which suggests that plasticity or adaptive shifts in their thermal traits are the only potential responses. Furthermore, species may use behavioral compensation to moderate the influence of environmental variation on physiological processes (Bogert effect). Salamanders in the family Plethodontidae are an ideal group for testing whether behavioral compensation results in the ability of species to exploit benign thermal environments. Plethodontids are lungless and breathe through their skin, resulting in high sensitivity to temperature and moisture. Most species have limited home ranges and low dispersal capacities, which suggests that behavioral compensation may enhance the persistence of species in altered thermal niches. We tested the Bogert effect by determining whether three species of plethodontid salamanders exhibit divergent habitat preferences at different portions of their range to maintain similar thermal and hydric conditions. We determined whether behavioral compensation allows species to maintain similar physiological performance, measured as cutaneous water loss (CWL), across habitats that vary in thermal/hydric quality. We also modeled how the temporal and spatial distribution of microhabitats exploited by plethodontid salamanders may change as a consequence of rising temperatures and altered precipitation regimes.

60-2 FARINA, SC*; KNOPE, ML; CORN, K; SUMMERS, AP; BEMIS, WE; Harvard University, University of San Francisco, Cornell University, Friday Harbor Laboratories, Cornell University; stacy.farina@gmail.com

Modularity and coupling in the evolution of the feeding and respiratory systems of cottoid fishes

When two functions use many of the same structures, they are considered to be "coupled," and this coupling is known to constrain morphological evolution. This constraint can be lessened by the introduction of modularity, defined as the presence of structural units, or modules, that work together to perform a function but are not phenotypically co-evolving. In ray-finned fishes, suction feeding and gill ventilation use many of the same skeletal components. Suction feeding involves rapid expansion of the buccal chamber through the coordination of many structures that have a high degree of evolutionary integration (correlation of changes in size across phylogeny). Gill ventilation involves cyclical expansion of the buccal and gill chambers, using many structures involved with suction feeding. We quantified evolutionary integration among structures of the buccal and gill chambers across sculpins and relatives (Cottoidei), a diverse clade of suction feeders. We reconstructed the phylogeny using molecular data from 106 cottoids and analyzed linear measurements of cranial bones from a subset of 23 taxa. Using phylogenetic generalized least squares models, we found that suction-feeding associated characters (size of lower jaw, upper jaw, and operculum) are highly correlated. However, there is weak correlation among branchiostegal size and these structures. Particularly surprising is the lack of correlation between the operculum and branchiostegals, the two actuators of the gill chamber. The branchiostegal apparatus may be a module within the gill ventilatory system that releases some constraint imposed by the close coupling of feeding and ventilation.

57-7 FATH, M.A.*; HSIEH, S.T.; Temple University; tuf77090@temple.edu

Center of mass dynamics in the bipedally running brown basilisk (*Basiliscus vittatus*)

It is well-known that among terrestrial animals with parasagittal limb postures, center of mass (CoM) potential and kinetic energies fluctuate out-of-phase when walking, but fluctuate in-phase during running. Lizards move with a sprawled limb posture, and many are capable of running quadrupedally and bipedally. An earlier study on quadrupedal lizards revealed that despite their sprawled limb postures, their center of mass dynamics also follow an inverted pendulum model when walking, and a spring-mass model when running. However, bipedal locomotion in lizards is both kinematically and kinetically distinct from quadrupedal locomotion. In the present study, we quantify the CoM dynamics of a bipedally-running lizard. Our previous studies show that bipedally running basilisks produce fore-aft and vertical forces similar in magnitude to that produced by other parasagittal runners, but much larger medio-laterally directed forces. We hypothesized that they would exhibit the spring-mass CoM dynamics similar to most other running animals, in spite of their sprawled-limb posture. However, as a result of the large medio-lateral force production, we also hypothesized that they would have higher fluctuations of medio-lateral kinetic energy. We collected kinematic and force data from five adult brown basilisks running across a track way (20 trials total) with an embedded six d.o.f. force plate, while filming two views with a high speed camera (500 fps). CoM dynamics were calculated from the measured vertical, medio-lateral, and fore-aft force. We found that while running, basilisks' CoM kinetic and potential energies fluctuate in-phase, indicative of a spring-mass model style of running. Despite differences in stance and morphology, lizard bipedal running shows functional similarities to other parasagittal runners.

62-3 FARONI-PEREZ, L; CAPA, M; HELM, C; HUTCHINGS, P*;
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Insights into development, function and phylogenetic significance of the sabellariid medial organ

Sabellariids (Annelida) are widely distributed, occurring in all oceans and depths. They reproduce by free spawning gametes and have planktonic larvae, but are strictly tubicolous during benthic juvenile and adult stages. The tube, made of secreted cement and sand grains, can form conspecific aggregations of few individuals to several kilometer reefs. Adults of some species bear an anterior appendage, the median organ (MO), with seemingly sensory function and involved in settlement (recognizing conspecific tubes) and/or reproductive processes (stimulating spawning). We have followed a multifaceted approach to unravel the role of this organ, describe its external and internal morphology throughout ontogenetic development, and assess its taxonomic value. In order to achieve this we: 1) reviewed the literature for absence/presence and morphology of this organ and the species ecological traits in all sabellariids; 2) investigated if the dorsal hump described in some larvae is the primordial form of the MO by studying the pattern of changes throughout the ontogenetic development in *Sabellaria alveolata* using immunohistochemical stainings and confocal laser scanning microscopy; 3) re-examined specimens identified as *Idanthyrsus australiensis* that revealed diversity in the MO external morphology in order to test its taxonomic value. Thus, our results provide new insights into the sabellariid anterior morphology at different developmental stages, the potential sensory role of the MO and its supposed phylogenetic signal.

40-6 FAULKES, Z.*; GARCIA, L.; TERRY, M.; The University of Texas Rio Grande Valley; zen.faulkes@utrgv.edu

Eyes under the beach: the visual system of sand crabs (*Lepidopa benedicti*)

Eyes are often reduced or lost in species that inhabit dark environments, indicating that such habitats relax, or even reverse, selection pressure for eyes. Sand crabs (*Lepidopa benedicti*) change habitats during their lives, resulting in different selection pressures on the visual system during their life cycle. Sand crabs have a pelagic larval stage with typical eyes for a larval crustacean, but metamorphose into a benthic, digging adult that spends most of its life submerged under sand with small eyespots. We tested whether these adult eyespots are functional. To test for phototaxis, adult sand crabs were placed in an aquarium that was half covered and half in light. Sand crabs showed no significant preference for the light or dark side ($\chi^2 = 0.533$; $p = 0.465$). Anatomically, the adult eyespots have no obvious facets typical of arthropod ommatidia, but are innervated by a nerve that connects to the brain. Extracellular electrophysiological recording show that the optic nerve has the ability to generate action potentials, but it is not clear yet if there are any physiological responses to light. Analyses of RNA transcriptomes are underway to determine if opsins are expressed in the anterior region of the adult sand crab. The evidence suggests that the visual system in adult sand crabs is a non-functional remnant of the larval visual system.

78-6 FAVATA, CA*; COLOMBO, RE; MAIA, A; Eastern Illinois University, Eastern Illinois University; cafavata@eiu.edu
Ecomorphology and Swimming Energetics of Longear Sunfish *Lepomis megalotis* in Turbulent Flow

Anthropogenic habitat alteration disturbs fishes at the community and organismal levels, but effects are seldom related to the physiological processes. Metabolism is the most basic rate which may govern organismal life history and behavior, and can help explain ecological interactions of fish. We examined the energetics and distribution of Longear Sunfish, *Lepomis megalotis*, within Kickapoo Creek, Illinois. This is a region of decreased geomorphic stability and the site of multiple stream restoration projects. We sampled Longear Sunfish using pulsed DC barge electrofishing to examine patterns in abundance and distribution along a gradient of habitat conditions. Fish were then brought to the lab where we measured metabolic oxygen consumption using intermittent-flow respirometry during steady swimming. Fish were observed in laminar and turbulent flows to examine effects on performance. Simulated turbulence consisted of three horizontal streets of vortices, each similar in size produced by equally spaced vertical cylinders with diameters similar to fish depth. We found greater metabolic costs of swimming in turbulent flows than in a quasi-laminar regime. Significant regression models on habitat parameters linked distribution of Longear Sunfish to proportions of pool area, silt, sand and boulder substrate, and instream cover variables. Ecomorphological models for Longear Sunfish suggest that increased metabolic demands associated with navigating turbulent flows may help explain habitat use and behavior. Longear Sunfish show fidelity to areas of low flow and turbulence which also contain multiple types of instream cover such as overhanging riparian vegetation and woody debris.

22-5 FEO, TJ*; SIMON, E; PRUM, RO; Smithsonian Institution, NMNH, Yale University; FEO@si.edu
When barbs get their curves: Modeling the development of barb curvature in feathers

Feathers exhibit an extraordinary diversity of shapes and sizes, which are used by birds to accomplish a diverse set of functions. Pennaceous feathers have a complex branched morphology that develops from a tube of epidermis, and variation in branch geometry and morphology determines the shape and structure of feathers. Feather development is complex and mechanically redundant, and it is not readily obvious how different feather shapes develop. In many feathers, barbs are not straight but instead curve in toward, or away, from the feather tip. Barb curvature can have important effects on the shape of mature feathers but the development of barb curvature is unknown. Prum and Williamson (2001) hypothesized that barb curvature develops during barb ridge growth in the tubular feather germ, whereas Feo and Prum (2014) hypothesized that barb curvature develops during barb ramus expansion as the feather unfurls from the sheath. To better understand the development of barb curvature and its effects on feather morphology we first present a theoretical model of barb curvature and then conduct empirical observations of barb curvature in mature and developing feathers. We find that barb curvature can have complex effects on many aspects of feather morphology including vane width, barb length, interbarb distance, and barb ridge width. In real feathers, barbs curve both during barb ridge growth and during barb expansion, with most of the observed curvature developing during barb expansion. Our results demonstrate that barb expansion as the feather unfurls from the sheath is a complex and dynamic process that varies within a feather vane and plays an important role in determining mature feather shape. Barb curvature results in heterogeneity of barb geometry within a feather vane, which could have important implications for the mechanical function of feathers and within feather pigmentation patterns.

78-4 FEILICH, KL; Harvard University; kfeilich@fas.harvard.edu
Towards an understanding of the relation between body morphology, kinematics, and swimming performance in neotropical cichlids

Fishes exhibit a range of body shapes, with each different shape having its own hydrodynamic effect on swimming performance. However, morphology alone does not drive performance; rather, performance emerges from the integration of morphology with kinematics. Thus, in order to determine how fishes with different body shapes perform and what causes performance differences, it is important to examine kinematics and morphology along with metrics of swimming performance. I recorded fin and body kinematics of three differently shaped species of neotropical cichlids: *Cichla ocellaris*, a fish with stereotypical cruising morphology; *Symphysodon aequifasciatus*, a laterally-compressed species with stereotypical maneuvering morphology; and *Crenicichla saxatilis*, a torpedo-shaped fish with stereotypical acceleration-specialist morphology. Kinematics were recorded at a range of speeds starting from 0.5 L/s and increasing by 0.2 L/s every 15 minutes until burst and coast swimming was observed. As measures of performance, gait transition (where observed) and maximum sustainable speeds were recorded. The different species used different kinematic strategies for increasing speed. *Cichla* used a typical subcarangiform transition from labriform to undulatory swimming, decreasing pectoral fin beat frequency and increasing caudal fin beat frequency with speed. *Symphysodon* and *Crenicichla* increased both caudal and pectoral fin beat frequency to increase speed, without ever exhibiting a clear gait transition. These results reinforce the idea that there is no one-to-one mapping between morphology and kinematics. Even very differently shaped fishes can use similar kinematics, as is the case for *Symphysodon* and *Crenicichla*.

97-1 FERRY, LA*; PAIG-TRAN, EW; Arizona State, Cal State Fullerton; Lara.Ferry@asu.edu
Premaxillary protrusion in the ribbonfishes: extreme suction production in the mesopelagic realm?

Jaw (premaxillary) protrusion is thought to be a key innovation correlated with the subsequent radiation and diversification of fishes. Extreme amounts of protrusion are associated with suction prey capture, often on highly elusive prey. Notable examples of this are the sling-jaw wrasse *Epibulus insidiator* and the cichlid *Petenia splendida*; wrasses and cichlids both being extremely speciose clades of fishes. Interestingly, king-of-the-salmon or ribbonfish, *Trachipterus altivelis*, also are capable of extreme jaw protrusion. The ribbonfishes as a group (Trachipteridae, Lampriformes) are not terribly diverse, with only around 10 extant species, yet all members appear to show the capacity for impressive jaw protrusion. Ribbonfish are laterally compressed, deep-pelagic, and vertically migrating. They consume primarily zooplankton and perhaps small fish and squid and move to the surface at night with the deep scatter layer. They have highly protrusile jaws, but lack teeth. Here we present new findings regarding the anatomy of ribbonfish and close relatives, as well as the implications for jaw protrusion and prey capture.

54-2 FIELD, K.E.*; MARUSKA, K.P.; LSU; kfield3@tigers.lsu.edu
Context-dependent chemical signaling, aggression, and neural activation patterns in reproductively-receptive female cichlids
 Social animals must assess the environment to make behavioral decisions. Across vertebrates, processing of social cues to elicit suitable behavioral responses is thought to be mediated by conserved brain nuclei of the social decision-making network (SDMN). In several fish species, chemosensory signaling is crucial for social communication, and female-released compounds can elicit physiological and behavioral responses in male receivers. Here we tested the hypothesis that gravid (reproductively-receptive) females of the highly social African cichlid, *Astatotilapia burtoni*, actively alter their urination rate and behavior in a context-dependent manner, and then examined neural activation patterns in nuclei of the SDMN in different social contexts. Using an innocuous dye to visualize urine pulses, we exposed dye-injected gravid females to four conditions: dominant male, gravid female, brooding (non-receptive) female, and no fish control, and then quantified urination and social behaviors. We found that gravid females do alter urination rates in a context-dependent manner, and that aggressive behaviors differ in the presence of females of different reproductive states. These results suggest that *A. burtoni* females have a similar chemosensory signaling mechanism to that of males, conveying reproductive status or body condition to males and to other females. Using the immediate early gene *cfos* as a proxy for neural activity, we also found that gravid females showed context-dependent activation patterns within specific nuclei of the SDMN that reflect reproductive and aggressive situations. These results reveal the neural substrates that process intra- and inter-sexual social behaviors in a single fish species and provide insights on how the female brain mediates adaptive decisions in varying contexts.

87-7 FINKLER, M.S.; Indiana Univ. Kokomo; mfinkler@iuk.edu
Thermal effects on the growth of late-term *Chelydra serpentina* embryos.

Turtle embryos may experience considerable fluctuation in temperature during development, but laboratory studies frequently incubate eggs under single constant temperatures for the entirety of development. When incubated under single constant temperatures, increased temperatures leads to earlier hatching and smaller body sizes. In this study, I incubated snapping turtle eggs at a constant 29°C for a period of 40 days, then divided the eggs among three different constant temperatures (27, 29, and 31°C) for the completion of incubation. There was no difference among the different groups in embryo size or amounts of yolk at Day 40. However, by Day 50 embryos were larger, and the yolk smaller in eggs incubated at 27°C than in the 29°C or the 31°C group. Contrary to previous observations, eggs that were incubated at 27°C hatched sooner than those at the two higher temperatures. Moreover, hatchling size differed significantly among the three groups, with 27°C yielding the largest hatchlings and 29°C yielding the smallest hatchlings. My findings suggest that variation in temperature at different intervals during embryonic development may induce changes in growth rate that would not be predicted if a simple unidirectional association between growth and temperature is assumed.

16-5 FIELD, KA*; JOHNSON, JS; LILLEY, TM; REEDER, SM; ROGERS, EJ; BEHR, MJ; REEDER, DM; Bucknell University, University of Wisconsin; kfield@bucknell.edu
Whole Transcriptome Analysis of Host and Pathogen Gene Expression in White-Nose Syndrome

White-nose syndrome (WNS) in North American bats is caused by an invasive cutaneous infection by the psychrophilic fungus *Pseudogymnoascus destructans* (Pd). We compared transcriptome-wide changes in gene expression using RNA-Seq on wing skin tissue from hibernating little brown myotis (*Myotis lucifugus*) with WNS to bats without Pd exposure. We found that WNS caused significant changes in gene expression in hibernating bats including pathways involved in inflammation, wound healing, and metabolism. Local acute inflammatory responses were initiated by fungal invasion. Gene expression was increased for inflammatory cytokines, including interleukins (IL) IL-1, IL-6, IL-17C, IL-20, IL-23A, IL-24, and G-CSF and chemokines, such as Ccl2 and Ccl20. This pattern of gene expression changes demonstrates that WNS is accompanied by an innate anti-fungal host response similar to that caused by cutaneous *Candida albicans* infections. However, despite the apparent production of appropriate chemokines, immune cells such as neutrophils and T cells do not appear to be recruited. We observed upregulation of acute inflammatory genes, including prostaglandin G/H synthase 2 (cyclooxygenase-2), that generate eicosanoids and other nociception mediators. We also identified several classes of potential virulence factors that are expressed in Pd during WNS, including secreted proteases that may mediate tissue invasion. These results demonstrate that hibernation does not prevent a local inflammatory response to Pd infection but that recruitment of leukocytes to the site of infection does not occur. These observations support a dual role for inflammation during WNS; inflammatory responses provide protection but excessive inflammation may contribute to mortality.

132-7 FISH, F.E.*; GOUGH, W.T.; TENNETT, K.A.; ADAMS, D.S.; ST LEGER, J; West Chester Univ., PA. Sea World, CA; ffish@wcupa.edu

Flexibility of the flukes of free-swimming cetaceans

The flukes are the primary locomotor structure in cetaceans; they produce hydrodynamic thrust as the tail oscillates dorso-ventrally. As opposed to conventional propellers, the flukes of dolphins were shown to maintain a high propulsive efficiency over an extended range of speeds. It was hypothesized that the flexibility of the flukes was responsible for the high efficiency. The flukes are largely composed of a dense collection of collagen fibers, permitting both spanwise and chordwise bending. We investigated the effect of bending within the caudal region of odontocete cetaceans over a range of swimming speeds of 0.4 to 6.9 m/s. Lateral views from video recordings (60 frames/s) were analyzed for *Tursiops truncatus* and *Orcinus orca* as they swam around a large pool freely or under trainer control. Spanwise bending was restricted to the fluke tips. To measure the degree of chordwise bending of the flukes throughout the stroke cycle, a Flex Index was computed as ratio of the chord length to the camber line length of the longitudinal vertebral axis in the flukes, where a value of unity indicated no flexing. Fluke chord was maximally bent as the fluke reversed vertical direction during the oscillatory cycle with a chord reduction of 2-16%. No difference in Flex Index was found between transitions of upstroke and downstroke, but the Flex Index was greater at the transition points than at mid-stroke. Despite the 12.6-fold size difference between the two species, fluke bending was similar. At speeds greater than 2 m/s, the Flex Index increased directly with increased swimming speed for both species. The flexibility exhibited in the flukes changed with increasing propulsive load and could aid in enhanced propulsive efficiency.

38-4 FITZHUGH, K; Natural History Museum of Los Angeles County; kfitzhug@nhm.org

Ernst Mayr, causal understanding, and systematics: an example using sabelliform polychaetes

Ernst Mayr (1961, *Science* 131: 1501-1506) suggested that understanding features of organisms involves the study of proximate and ultimate causes. Proximate causes occur during the life of the organism and ultimate causes occur prior to the life of the organism, as part of evolutionary history. Descriptive biology was viewed as fundamental for pursuing proximate and ultimate causes. Systematics encompasses these three components. Organisms, *not* taxa, are described, and proximate hypotheses (ontogenetic and functional) are inferred to explain some characters, whereas other characters are explained via ultimate causes in the form of intraspecific, specific, and phylogenetic hypotheses. Ultimate understanding is limited since hypothesis testing is rarely accomplished; descriptive- and proximate-level investigations offer better opportunities. Examples of interactions between descriptive, proximate, and ultimate understanding are presented from research on several features among Fabriciidae and Sabellidae polychaetes. Members of both taxa have two 'peristomial' rings, and distinct mid-ventral patches of cilia occur on the anterior peristomial ring among Fabriciidae and posterior ring among Sabellidae. Phylogenetic hypotheses suggest cilia patches are synapomorphies for the respective families. Since these hypotheses cannot be tested, it will be more productive to investigate whether or not cilia patches are homologous, which might be determined through ontogenetic and histological studies of proximate causes: are cilia derived from the larval prototroch or metatroch? Are anterior and posterior rings peristomial in origin? Pursuing proximate causes offers increased understanding in systematics not available via ultimate causes.

40-2 FLEISHMAN, L.J.; Union College; fleishml@union.edu
Modeling and measuring perceptual color distances in anoline lizards

Anolis lizards communicate with colorful throat fans known as dewlaps. Dewlaps come in a wide variety of colors and our research has focused on trying to explain the evolution of this diversity. We assume that dewlap colors have evolved that are (1) easy for lizards to distinguish from those of sympatric species and (2) are easily distinguished from other natural color patches in the habitat. In order to assess how different colors and different habitat light conditions impact signal color visibility we need to know how distant different colors are in anoline perceptual color space. We know a great deal about the physiology and anatomy of the anoline visual system and can use this knowledge to test different models of distance in perceptual color space. We have also developed two different behavioral assays of color discrimination based on (1) attention responses and (2) food choice, that allow us to test the efficacy of different sensory-system based models. We have found that photoreceptor-noise models, and simpler models based on distance in tetrachromatic color space, both give accurate predictions of response to differences in color stimuli. Using both models and behavior we are currently investigating the impact of low light levels on color discrimination tasks. Our initial results suggest that under shaded forest conditions, distances in perceptual space are reduced, and many species from these habitats have evolved mechanisms to increase the total intensity of light emitting from their dewlaps. One impressive mechanism is the incorporation of transmitted light to create a translucent dewlap that appears to glow. This increase in total light intensity increases the reliability of perception of the dewlap color in low light habitats.

12-7 FLAMMANG, BE*; TURNER, EL; GARBORG, CS; ANDERSON, EJ; New Jersey Institute of technology, Grove City College, Woods Hole Oceanographic Institute/Grove City College; FLAMMANG@NJIT.EDU

Hydrodynamics of remora attachment

Remoras are fishes that attach to marine organisms that swim at a wide range of different speeds. In order to attach to an actively moving host organism, remoras must approach, attach, and adhere under hydrodynamic conditions that exceed those of their normal, individual swimming speed. To date, no research has been done on the hydrodynamics of remora attachment under different speed conditions. We visualized the flow around euthanized remora (*Echeneis naucrates*) and cobia (*Rachycentron canadum*, nearest relative to remoras) moved toward and away from a wall in freestream velocities ranging from 0.01 to 1.16 m/s. Using pressures calculated from a straightforward application of the Bernoulli equation in regions of the flow likely dominated by inertial forces, we show that as the remora approaches a host body a suction effect is created between the disc and host as flow is accelerated relative to free stream. This suction effect was observed both in approach and immediately following detachment of the remora. We also found that the flat disc surface of the remora approximately doubled the suction effect resulting from wall interaction as compared to cobia, which lacks a disc but is otherwise morphologically similar in body shape. We hypothesize that the general flat disc shape of the remora adhesive mechanism may contribute to initial attachment, particularly under high-velocity conditions.

105-6 FLIES, A.S.*; WOODS, G.M.; LYONS, A.B.; HAYBALL, J.D.; University of South Australia and University of Tasmania, University of Tasmania, University of South Australia; andyflies@gmail.com

Understanding the role of the PD-1 co-signalling pathway in the Tasmanian devil facial tumour disease

Blocking binding between PD-1 and its co-receptors B7-H1 (PD-L1) and B7-DC (PD-L2) has yielded durable responses against several types of late stage melanoma, lung, and renal cancers in humans. Recent evidence suggests that blocking PD-1:B7-H1 signalling promotes anti-tumour responses by releasing pre-existing CD8 T cells from inhibitory signalling between PD-1 and B7-H1, and that blocking the PD-1 pathway is most effective in cancers with a high number of mutations. The Tasmanian devil facial tumor (DFTD) is a clonal, transmissible tumor that was first discovered in the wild in 1996 and the DFTD is the primary cause of a greater than 85% decline in the wild Tasmanian devil population. In the nearly 20 years of ongoing transmission the tumor has accumulated greater than 17,000 somatic mutations, and a tetraploid strain of the tumor has been discovered in the wild. We hypothesize that the tumor uses inhibitory co-signalling molecules to evade the immune system, and that an anti-tumor immune response can be induced by blocking inhibitory signalling through PD-1. We have developed a panel of devil specific -PD-1 and -B7-H1 monoclonal antibodies (mAbs) that are capable of blocking PD-1 from binding to B7-H1 and B7-DC. We have found that PD-1 and B7-H1 are expressed in devil lymph nodes, with PD-1 being expressed primarily in germinal centers. We are currently investigating expression of B7-H1 in tumor cells and the tumor microenvironment. We have previously show that the DFT cells do not express MHC, but MHC can be induced via IFN . However, B7-H1 is also upregulated by the tumor in response to IFN treatment, suggesting that blocking B7-H1 in the tumor microenvironment might be critical to the development of the DFTD vaccine.

8-1 FOGLIANO, R.*; ABOLINS-ABOLS, M.; KETTERSON, E.D.; Gettysburg College, Indiana University, Bloomington; fogfro01@gettysburg.edu

Predator-induced plasticity of territorial aggression in male Dark-eyed Juncos (*Junco hyemalis*)

Striking tradeoffs between survival and reproduction is essential to maximizing fitness. Because individuals in many taxa rely on territories for resources and mating opportunities, territorial defense is often a vital component of reproduction. However, territorial displays can be costly as they may decrease survival by increasing visibility to predators. Territorial aggression is therefore expected to be plastic, but the degree to which individuals alter their behavior may vary. This study investigated if life history factors explain variation in plasticity and asked whether plasticity is correlated with fitness by conducting simulated territorial intrusions (STIs) on male Dark-eyed Juncos (*Junco hyemalis*). Each individual (n=26) experienced two STI treatments in randomized order: a high-risk treatment using an Eastern Screech-Owl mount and a low-risk using a novel object. The difference in response was measured as plasticity. Overall, the presence of the owl significantly decreased aggression, especially mean distance and latency to closest approach. As anticipated, plasticity varied immensely among individuals, and a multivariate linear model revealed several non-significant trends. Older males tended to be more plastic, potentially because this trait enhanced their survival at a younger age. Males in better condition tended to be less plastic, possibly because stronger flight muscles allow them to better escape from potential predators. Plasticity did not correlate with breeding success or recapture the following year. These data suggest that territorial plasticity is not under selective pressure, but may confer differential advantages to individuals based on life history traits such as age and condition.

97-5 FORSGREN, KL.*; JAMAL, H; California State University, Fullerton; kforsgren@fullerton.edu

Reproductive Morphology of Oarfish *Regalecus russelii*

Little is known about the reproductive biology of oarfish (*Regalecus russelii*). In the last three years, as many oarfish have been discovered on southern California beaches; two females (Oct. 2013: 4.4m TL, June 2015: 4.3m TL) and one male (Aug. 2015: 4.3m TL, 82.4kg body weight). The ovaries from the June 2015 fish weighed 10.99kg and were 2.14m in length. The ovaries were bifurcated at the anterior-most end, attached by a thick connective tissue 111.0cm from the anterior end, and completely fused 161.0cm from the anterior end. Gonadal fragments from the oarfish were fixed, histologically processed and embedded in paraffin wax. Histological tissue sections from the Oct. 2013 female contained 52.5% primary, 44.9% secondary, and 2.6% tertiary ovarian follicles. Tissue sections from the June 2015 female contained 33.5% primary, 62.3% secondary, and 4.2% tertiary ovarian follicles. No mature or ovulated oocytes were present in ovarian tissue from either female. The compositional differences in ovarian follicles may indicate that the Oct. 2013 oarfish may have previously spawned, whereas the June 2015 oarfish had ovarian follicles that were progressively developing. The testes from the Aug. 2015 fish weighed 40g. The left testis was 64.7cm in length and the right testis was 55.9cm. The testes were attached by connective tissue but not fused. Histological examination indicated that the male may have recently spawned; no spermatozoa were present within the testes and only a few spermatids were visible. The testes were primarily populated with primary spermatocytes. The incredible size disparity between the gonads of similarly sized fish is very interesting. The gross morphological and histological descriptions of these three oarfish may significantly contribute to our understanding of the reproductive biology of oarfish.

55-8 FORIR, M*.; CONRAD, JL; Missouri Institute of Natural Science, NYIT COM / AMNH; cavehog@hotmail.com

A giant fossil chasmosaurine (*Ceratopsidae*, *Dinosauria*) postcranium from Wyoming

The Late Cretaceous (LK) Lance Formation (Maastrichtian) is a well-sampled division from which a variety of vertebrates are known, especially avian and non-avian dinosaur species. A recent expedition by the Missouri Institute of Natural Science (MINS) recovered an incomplete postcranial skeleton (MINS V1036) of an especially large chasmosaurine ceratopsian from Weston County Locality in the Lance Formation of Wyoming. The specimen is represented by cervical, dorsal and caudal vertebrae, a scapulocoracoid, and elements of the pelvic girdle and hind limb. Lack of a skull precludes species allocation. The remains show morphology consistent with *Triceratops*, but no postcranial characters distinguish *Eotriceratops*, *Torosaurus*, and *Triceratops* spp. Moreover, the specimen's extremely large size offers the possibility that it represents a new taxon. Recent studies have reported femur lengths of 1020 mm, 1033.5 mm, and 1104 mm respectively for the LK chasmosaurines *Pentaceratops aquilonius* (OMNH 10165), *Triceratops horridus* (AMNH FR 5033), and *Triceratops prorsus* (USNM PAL 4842). Recent mass estimates suggest that the most robust of these animals, *Triceratops horridus*, reached 14 tonnes. The preserved part of the femur (lacking its proximal end) in MINS V1036 is approximately 1070 mm long and may be conservatively restored to a length of 1140 mm, which conforms to the expected length based on the complete 1143 mm scapula. The femur is similar in robustness to that of AMNH FR 5033. Based on these proportions, we estimate the mass of MINS V1036 to have been more than 18 tonnes. This would make MINS V1036 the largest known ornithischian, exceeding *Shantungosaurus* (with a published estimate of 17 tonnes). Although the Lance Formation is a well-studied paleoenvironment, this discovery demonstrates that further exploration offers the opportunity to expand our understanding of the system.

78-3 FOSTER, KL.*; HIGHAM, TE; Univ. of California, Riverside; kfost001@ucr.edu

Comparative arboreal locomotion of *Anolis* lizards

The *Anolis* system has become a model example of how animals can become adapted to the locomotor challenges imposed by microhabitat structure. *Anolis* lizards of the Greater Antilles are categorized into ecomorphs based on external morphological, ecological, and behavioral properties. Although locomotor performance has been analyzed in a number of species, the details of how these species move are lacking. In particular, it is generally unclear how these animals modify their limb movements in order to move successfully when facing changes in incline and perch diameter, common challenges of an arboreal environment. Here, we compare the three-dimensional fore- and hind limb kinematics of six species of anole collected from Puerto Rico: *A. krugi* and *A. pulchellus* (grass-bush ecomorphs), *A. evermanni* and *A. stratulus* (trunk-crown ecomorphs), and *A. cristatellus* and *A. gundlachi* (trunk-ground ecomorphs). We obtained high-speed video of these animals running on two perch diameters, a broad, flat surface and a narrow surface (diameter ~ 1.2 x femur length), inclined at 0°, 30°, and 90°. Although the grass-bush species climbed the vertical, narrow treatment, they had considerable difficulty climbing up the vertical, broad surface. In contrast, several *A. stratulus* individuals climbed the vertical, broad surface, but were unable to climb the vertical, narrow perch, preferring to jump off the perch and climb the wall instead. Further, most *A. gundlachi* individuals preferred to hop along the broad surface at the shallow inclines but consistently ran on the broad surface at the vertical incline. The detailed limb kinematics, when combined with upcoming muscle physiology experiments, will provide insight into when and how these species modulate their locomotor behavior to move successfully in a complex, arboreal environment.

124-4 FOWLER, A.N.*; ZUZOW, M.; TOMANEK, L.; California Polytechnic State University, San Luis Obispo; aubrie_fowler@yahoo.com

The Proteomic Response of Tidally and Subtidally-entrained California Mussels, *Mytilus californianus*, to Anoxia Stress

Intertidal mussels of the genus *Mytilus* experience extreme shifts in abiotic conditions, specifically oxygen partial pressure, due to tidal fluctuations. We therefore hypothesized that acclimation to a tidal rhythm, as opposed to a subtidal rhythm, preconditions the proteome of the California mussel (*Mytilus californianus*) to respond differently to anoxia, as low oxygen may occur during prolonged low tides. To investigate how entrainment affects the proteomic response to anoxia, mussels were acclimated to tidal and subtidal conditions with a 12-hour photoperiod to mimic natural circadian rhythms. Following a 4-week acclimation, mussels either continued to receive the acclimation conditions (control) or were exposed to 100% nitrogen gas (anoxia). Gill tissue was extracted at 0, 6, and 72 hr. We used gel-based proteomic analysis and identification with mass spectrometry to examine changes in global protein abundance. Tidally-entrained mussels showed lower abundances of superoxide dismutase during anoxia in comparison to mussels acclimated to subtidal conditions, indicating greater levels of oxidative stress in the latter. These differences were accompanied by changes in the abundances of several chaperones of the endoplasmic reticulum (GRP78, PDI), which are involved in the formation of disulfide bonds. Subtidally-entrained mussels also showed higher abundances of NADPH-producing proteins which may help scavenge reactive oxygen species during anoxia. Finally, the abundance of the oxygen-sensing protein aconitase was significantly higher in tidally-entrained mussels. Our results implicate that mussels acclimated to different tidal conditions differ greatly in the cellular processes that are activated in response to acute anoxia stress.

31-5 FRANK, C.L.*; INGALA, M.; RAVENELLE, R.; HOWARD, K.; Fordham University; frank@fordham.edu

The role of cutaneous fatty acids in the resistance of bats to WNS

White-nose Syndrome (WNS) causes severe over-winter mortality for little brown bats (*Myotis lucifugus*). It is due to cutaneous infection with the fungus *Pseudogymnoascus destructans* (*Pd*) during hibernation. Big brown bats (*Eptesicus fuscus*) are resistant to infection with *Pd*. Hibernating *M. lucifugus* normally maintain a skin temperature (Tskin) of 5-7°C during torpor, whereas the Tskin of torpid *E. fuscus* is usually 12-13°C. We conducted analyses of wing epidermis from hibernating *E. fuscus* and *M. lucifugus* to determine their fatty acid compositions, and laboratory *Pd* culture experiments at 4.0 - 13.4°C to determine the effects of these fatty acids on the growth of this fungus. Our analyses revealed that the epidermis of both species contains the same 7 fatty acid types (14:0, 15:0, 16:0, 16:1, 18:0, 18:1, & 18:2), but the epidermis of *M. lucifugus* contains: a) more stearic (18:0) acid, b) less myristic (14:0) acid, c) less palmitoleic (16:1) acid, and, d) less oleic (18:1) acid, than that of *E. fuscus*. The growth of *Pd* was inhibited by: a) myristic and stearic acids at 10.5-13.4°C, only, b) oleic acid at 5.0 - 10.6°C, c) palmitoleic (16:1) acid, and, d) linoleic (18:2) acid at 5.0 - 10.6°C. One set of factors that enables *E. fuscus* to resist *Pd* infections (and thus WNS) is therefore the relatively higher myristic, palmitoleic, and oleic acid contents of the epidermis.

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New roles for fly mechanosensors

The mechanisms by which sensory systems process information can change to meet specific behavioral and ecological demands. Often, behavioral state changes can alter the functioning of a sensory system, or modify interactions between multiple sensory systems. In flies, the modified hindwings known as halteres provide fast, precise mechanosensory information, and are essential for flight. Oscillations of the halteres during flight provide timing signals for wing-steering behavior, and enable the detection of Coriolis forces during body rotation. Although many families of flies use their halteres only for flight, haltere oscillations also occur during walking in one of the largest and successful groups of flies, the Calypttratae (a clade including house flies, flesh flies, and blow flies). Using high-speed videography of both flesh flies (Sarcophagidae) and blow flies (Calliphoridae), we show that large haltere oscillations occur consistently during leg movement behaviors. Recordings of muscle activity showed that these oscillations are not driven by the large indirect muscles of the thorax, as they are during flight. Ablating the fields of campaniform sensilla at the base of the haltere eliminates the haltere oscillations, demonstrating that haltere-driven feedback is necessary for the haltere muscles to maintain the oscillations during walking. Taken together, our results suggest that the circuits driving haltere oscillation may function differently during walking and flying, resulting in differences in both motor output and sensory information processing.

11-1 FREDA, P.J.*; MORGAN, T.J.; RAGLAND, G.J.; Kansas State University; pfreda@ksu.edu

Evolution of Complex Life Cycles: Is Performance Constrained across Metamorphosis?

Organisms are not static over their lifetimes. Characteristic change as the genome unfolds across ontogeny. This change can be extreme, especially over the course of complex life cycles that include abrupt changes in physiology, behavior, and morphology. Larvae and adults of insect species that undergo complete metamorphosis are often subject to distinct environmental conditions, presumably applying selection pressures for highly variable environmental responses, or environmental sensitivity, across development. This begs the question: Is performance under a given set of environmental conditions constrained across metamorphosis or is there the potential for adaptive decoupling in distinct life stages? To answer this question, genetic correlations in lower thermal limits across metamorphosis was estimated for approximately 200 isogenic *Drosophila melanogaster* DGRP lines. Survival curves spanning LD50 and LD90 were estimated for a subset of lines, while survival at -5°C for one hour was measured on all lines, proving a reliable proxy for various summaries of survival curves. Next, genetic correlations were determined in larvae vs. adults from each line. Preliminary results show low genetic correlations, suggesting distinct genetic architecture for thermal stress across development. We also discuss the results of genome-wide association analysis (GWAS) to begin to distinguish mechanisms by which thermal tolerance may be ontogenetically decoupled.

58-2 FREDERICKSEN, M.A.*; ZHANG, Y; HAZEN, M.L.; CHEN, D.Z.; HUGHES, D.P.; Penn State University, Univ. of Notre Dame; maf1057@psu.edu

Visualizing the behavior of zombie ant parasites: fungal cells coordinate inside manipulated hosts

It is well-established that some parasitic microorganisms manipulate the behavior of their host, but the mechanisms by which they accomplish this remain a mystery, especially given the parasites' small size in relation to their hosts. One possible means for overcoming this size discrepancy is for individuals to coordinate their behavior. Fungi from the species complex *Ophiocordyceps unilateralis* infect ants of the tribe *Camponotini*, inducing aberrant host behaviors that precisely place host cadavers in areas suited for parasite dispersal. Fungi are thought to enter the host as individual cells, which proliferate in the hemocoel for two to three weeks. This implies that the timing of host manipulation depends on the parasite reaching an optimal stage of development and distribution within the host. In this study, we examine the distribution of the fungus and its interaction with ant tissues at the time of manipulation. *O. unilateralis* fungi were visualized inside manipulated *Camponotus castaneus* ants using Serial Block-Face Scanning Electron Microscopy (SBF-SEM) and Confocal Laser Scanning Microscopy (CLSM). SBF-SEM images and 3D reconstructions of head and leg muscle tissue reveal that this parasite exhibits coordinated behavior by forming fungal networks through cell-cell fusions. CLSM images of the brain suggest that the fungus surrounds the brain but does not enter it while the host is still alive.

48-5 FRIESEN, CR*; DE GRAAF, S; MCDIARMID, C; OLSSON, M; University of Sydney; christopher.friesen@sydney.edu.au
Tradeoff between pre- and postcopulatory traits: The effect of exercise and oxidative stress on sperm traits in the color polymorphic painted dragon lizard

Over the past decade, evolutionary ecologists have begun to focus on the physiological mechanisms underlying trade-offs among traits. Since von Schantz et al.'s (1999) groundbreaking paper, oxidative stress (OS) biology has become a focal point in the integration of proximate mechanisms with ultimate explanations, and has been especially influential in the study of sexually selected condition-dependent traits. One area of research that has been left behind in the integration of evolution and OS biology is postcopulatory sexual selection—sperm competition and cryptic female choice. It is noteworthy that OS has been linked to infertility in human males for almost twenty years, but very few studies have addressed OS in the context of sperm competition. Here we present data on the effect of whole-body oxidative status on sperm traits and an interaction with a signal trait, brightly colored gular bibs, in painted dragon lizards, *Ctenophorus pictus*. Furthermore, we test for an interaction effect between exhaustive exercise and the possession of bibs on sperm traits. We demonstrate a link between a signal trait, sperm traits and activity levels.

57-1 FRITZSCHE MCKAY, A*; EZENWA, VO; ALTIZER, S; Odum School of Ecology, University of Georgia, Odum School of Ecology and Department of Infectious Diseases, University of Georgia; afritzsche@gmail.com

Does migratory flight alter immunity in monarch butterflies?

Migratory animals undergo extreme physiological changes to prepare for and sustain migratory movements such as flight. One of these changes is investment in immune defenses. Importantly, the intense energetic demands of migration can divert resources away from immunity, increasing susceptibility to parasites and pathogens. However, some migrants also atrophy reproductive organs, and these non-reproductive migratory animals could experience lower energetic costs during migration. In this study, we quantified the costs of flight for immunity in monarch butterflies and examined whether these costs further depend on reproductive investment by controlling whether or not monarchs were in a pre-migratory state of reproductive diapause prior to flight. Direct physiological linkages between flight and immunosuppression are poorly described in wild animal populations. We used a tethered flight mill apparatus to mimic the demands of powered flight and address several inter-related questions. First, we measured whether immunity differed in monarchs that were flown versus those that remained inactive. Second, we examined relationships between continuous measures flight performance and immunity. Last, we determined if reproductive investment compounds the cost of strenuous activity for immune defense, by comparing immune-flight relationships in reproductive and non-reproductive monarchs. Our work shows how multiple behavioral drivers affect immune defense, with the potential to identify the mechanisms and circumstances under which migratory species are most vulnerable to disease.

84-7 FUDGE, DS*; HUPE, A; CHAUDHARY, G; EWOLDT, RH; University of Guelph, University of Illinois at Urbana-Champaign, University of Illinois at Urbana-Champaign; dfudge@uoguelph.ca

Biophysics of gill clogging by hagfish slime

Hagfishes defend themselves from fish predators by releasing exudate from their slime glands when they are attacked. The slime exudate contains condensed mucus and protein threads, which combine with seawater and expand to form an ultra-dilute, viscoelastic material. Recent work has shown that slime release repels further attacks by fish predators by lodging in their gills and putting them at risk of suffocation. In this study, we explored the biophysical mechanisms that allow the slime to clog fish gills. Using a custom apparatus designed to measure the flow rate of test solutions through a screen, we found that the slime's ability to impede flow initially increased strongly and linearly as a function of concentration, and started to plateau at an optimal concentration of 45 mg/L of mucus. We performed similar trials with hydrogels formed from suspended xanthan gum and psyllium husk and found that hagfish slime is 120 and 130 times more effective at impeding flow than these materials, respectively. We found that the mucus alone has an optimal clogging concentration of 102 mg/L, suggesting that the mucus and threads act synergistically to disrupt flow and that the mucus is responsible for most of the clogging effect. We also tested the hypothesis that the threads perform a distinct function from the mucus, which is to allow the slime to catch on and persist on the gills. Flushing experiments were consistent with this hypothesis, with thread presence having a strong positive effect on the ability of the slime to impede flow after repeated flushing with seawater. Our results provide insights into the mechanisms of gill clogging by hagfish slime and raise new questions about how it performs so well at such low concentrations.

105-5 FUESS, LE*; PINZON, JH; WEIL, E; MYDLARZ, LD; University of Texas at Arlington, University of Texas Southwestern Medical Center, University of Puerto Rico; fuess@uta.edu
Comparison of immune phenotypes and changes in gene expression provides new insight into pathways of coral immunity
 Corals, which are the foundation of diverse coral reef ecosystems, are threatened by an increasing number of stressors, including disease. Still, knowledge of host response to disease is currently limited. This study employed novel network based approaches to better understand host immunity. Samples of the disease susceptible coral species *Orbicella faveolata* were exposed to immune challenge with bacterial LPS in a controlled laboratory setting. A combination of RNA sequencing and biochemical assays representing immune protein activity were used to characterize the holistic response of the corals to immune challenge. The data were analyzed using the R package, Weighted Gene Correlation Network Analysis (WGCNA), to build groups of coexpressed genes. These groups, as well as individual genes of interest, were then correlated to protein activity, measured by the biochemical assays, to identify genes which may contribute to phenotypic immune responses. Analysis revealed 371 differentially expressed genes following immune challenge, 77 of which were significantly correlated to one or more biochemical measures of immunity. Included in this group of 77 genes were members of each primary component of invertebrate immunity: receptors, signaling molecules, and effector molecules. Some of these differentially expressed genes with significant correlations to biochemical measures of immunity displayed dysfunctional patterns of expression during immune challenge. Genes such as green fluorescent protein, which has antioxidant properties and likely contributes to host immune response, decreased in expression following immune challenge. These counter-intuitive patterns of gene expression may help in part explain the well documented vulnerability of *O. faveolata* to disease.

34-3 GABOR, C. R.*; ROZNIK, E. A.; KNUTIE, S. A.; ROHR, J. R.; Texas State University, University of South Florida; gabor@txstate.edu
Does corticosterone mediate the negative effects of atrazine and *Batrachochytrium dendrobatidis* on growth and survival?
 Many of the adverse effects of anthropogenic changes on biodiversity might be mediated by their impacts on organismal stress levels. To test this hypothesis it is necessary to cross anthropogenic stressors with compounds that block the synthesis of stress hormones. As an example, the herbicide atrazine (ATZ) and the introduced fungal pathogen, *Batrachochytrium dendrobatidis* (Bd), both increase the stress hormone corticosterone (CORT) in amphibians. Additionally, both can have adverse effects on the growth, development, and survival of amphibians. We assessed how much CORT mediates these adverse effects of ATZ and Bd by exposing Cuban tree frog tadpoles, *Osteopilus septentrionalis*, to ATZ and the CORT synthesis blocker metyrapone (MTP, for six days in a fully crossed design) and then challenging tadpoles and metamorphs with Bd or not. MTP successfully countered the CORT elevation induced by ATZ and Bd. However, reductions in body condition and development caused by ATZ and Bd were not mediated by CORT because they persisted even when CORT was blocked. Additionally, MTP exposure did not significantly affect tolerance of Bd as tadpoles, but reduced tolerance as adults because adults previously exposed to MTP lost more weight per Bd zoospore than adults not previously exposed to MTP. ATZ exposure decreased Bd load in the absence of MTP but increased Bd load with MTP, a result that is consistent with intermediate CORT levels induced by ATZ enhancing immunity. Our results suggest that the effects of ATZ and Bd on amphibian growth and development, and the effects of ATZ on amphibian tolerance of Bd are not a function of their effects on stress hormones. Instead, these effects are likely a function of energy lost from 1) ATZ detoxification, 2) defense against Bd, and 3) repair from any damage caused by ATZ and Bd. Additional studies are needed to evaluate how often the effects of anthropogenic stressors are mediated by their impacts on stress hormones.

86-4 FUITEN, A.M.*; BASSHAM, S.L.; CATCHEN, J.M.; SMALL, C.M.; JONES, A.G.; CRESKO, W.A.; Inst. of Ecology & Evolution, Univ. of Oregon, Eugene, Dept. of Animal Biology, Univ. of Illinois, Urbana-Champaign, Dept. of Biology, Texas A&M Univ., College Station ; afuiten@uoregon.edu
Hox Cluster Annotation and Axial Elongation of the Gulf Pipefish
 The remarkable level of morphological diversity in Syngnathidae (pipefish, seahorses, and seadragons) makes this clade of fish excellent territory to explore developmental genetic processes underlying extreme morphological diversification. Conserved *hox* cluster genes are responsible for positional information in many early developmental processes, including specification of the anterior-posterior body axis in metazoans. Changes in these genes are hypothesized to underlie a significant amount of animal body plan diversity. We hypothesize that changes in *hox* genes organization, content or regulation in the syngnathid lineage may have contributed to the evolution of their elongated body axis. To test this hypothesis we sequenced, annotated and confirmed the orthology of 45 *hox* genes in the Gulf pipefish genome - the first syngnathid reference genome. We searched for *cis*-regulatory elements and miRNAs near *hox* genes by identifying conserved-noncoding elements co-localized within the *hox* clusters. Our results indicate that Gulf pipefish have the typical number of *hox* genes for teleost fish and have conserved coding sequences, but some intergenic noncoding elements missing in pipefish suggest regulatory regions may be altered. *HoxA7a*, which has been hypothesized to be associated with absence of ribs when lost, appears to have deteriorated independently in the tetraodontid pufferfish and the pipefish lineages. We conclude that although *hox* genes may be involved with the body axis diversification through differential regulation, a significant causative factor may be other downstream developmental genetic pathways.

76-5 GADOUAS, JA*; ZANI, PA; Univ. Wisconsin-Stevens Point; Joy.A.Gadouas@uwsp.edu
Environmental cues influencing winter activity behavior of lizards
 Surviving winter by retreating into hibernacula is a key aspect for many animal species' survival. However, animal behavior is usually studied during the growing season and is not well documented during winter. Previous research has suggested that reptiles remain inactive during the entirety of the winter with periodic arousals due to warm temperatures. In order to determine if lizard activity was related to thermal cues or other environmental variables (i.e., convection, radiation, or time of winter), we used wildlife cameras and temperature sensors to observe known hibernacula of side-blotched lizards (*Uta stansburiana*). We also acquired wind and irradiance data from nearby weather stations. Cameras took pictures regularly allowing us to score lizard activity, which was episodic throughout winter. These data allowed us to analyze winter emergence cues used by lizards. We found that lizards emerge from their hibernacula to bask when wind speeds were low, when irradiance was high, and when further from mid-winter. These results suggest that lizards are not relying strictly on temperature to cue winter activity, but rather also use other environmental variables.

59-4 GAFFNEY, AM*; WITT, CC; Univ. of New Mexico; arielgaffney@unm.edu

Experimental hypobaric alters inter-specific competitive dominance in elevational replacement hummingbird species

The role of hypoxia tolerance in limiting species elevational distributions is poorly understood. Distributions are predicted to shift upslope with warming, causing exposure to hypobaric hypoxia. Hummingbirds exhibit exceptional O₂ consumption rates which make them particularly susceptible to changes in PO₂. The lowland Black-chinned Hummingbird and montane Broad-tailed Hummingbird are elevational replacement species that compete for nectar resources at mid-elevations where they overlap. We captured adult males of both species in the zone of overlap and we used a hypobaric chamber to compare their responses to hypoxia. Specifically, we evaluated the effects of reduced pressure on activity levels and inter-specific competitive dominance. We asked 1) Do behavioral responses to experimentally reduced pressure differ between high and low elevation species? 2) Is competitive dominance by the low elevation species diminished at high simulated altitudes? We quantified activity level by examining the proportion of time spent in flight versus perching at multiple simulated elevations. To measure competitive dominance, naive adult males of each species were allowed to compete for perches of differing heights. Activity levels dropped at high altitude in both species, but the reduction was greater in the low elevation Black-chinned Hummingbird. Competitive dominance of Black-chinned Hummingbirds at simulated low elevations did not persist at simulated high elevations. These results suggest that differential adaptation to atmospheric pressure contributes to the maintenance of stable elevational replacement distributions in hummingbirds.

92-1 GALASKA, M. P.*; MAHON, A. R.; SANTOS, S. R.; HALANYCH, K. M.; Auburn University, Central Michigan University; mpg0009@auburn.edu

Comparative phylogeography of Antarctic ophiuroids *Ophionotus victoriae* and *Astrotoma agassizii*

The Southern Ocean is a unique ecosystem characterized by a highly endemic benthic fauna. Brittle stars or ophiuroids in particular are a highly abundant and conspicuous member of the benthic assemblage, often dominating in abundance at many sampling localities. Here we present a large scale phylogeographic analyses in the Southern Ocean comparing two highly abundant ophiuroid species, *Ophionotus victoriae* and *Astrotoma agassizii*. While these two species differ in reproductive strategy and feeding behavior, they both occupy extensive ranges throughout the Antarctic continental shelf post glacial maxims of the Cenozoic. *O. victoriae* is endemic to the Southern Ocean but *A. agassizii* is known to occur on both sides of the Antarctic Circumpolar Current, in the Southern Ocean and in the waters surrounding South America. In this study, we build upon the previous mitochondrial work for these two species but focus on 2b-RAD as a high resolution whole genome approach in efforts to recover genetic structure at a resolution that is not capable with traditional molecular markers. Through the use of 2b-RAD for phylogeographic analyses, we are assessing gene flow in both species and are particularly interested in the effects of Southern Ocean currents, breaks in the Antarctic shelf and open ocean barriers of dispersal have on genetic connectivity for these species.

13-7 GAGLIARDI, SF; DILLON, ME; COMBES, SA*; Univ. of California, Davis, Univ. of Wyoming; sacombes@ucdavis.edu

Do bumblebees carry loads for free?

Bumblebees are industrious foragers that routinely carry heavy loads during flight. Man made aircraft consume more fuel per unit time when they are heavily loaded, and aerodynamic theory suggests that this should be the case for flying animals as well. However, we have previously found that the rate of nectar consumption in bumblebees flying over long periods does not decrease as their nectar loads decline, and studies on metabolic rate in bees carrying loads have produced conflicting results. Honeybee studies are complicated by the fact that honeybees alter their flight kinematics for thermoregulatory purposes, and previous bumblebee studies are difficult to interpret because loads were altered by varying nectar consumption, which may have metabolic consequences unrelated to the mechanical demands of weight support. We examined the effects of loading on flight kinematics and metabolic rate in bumblebees (*Bombus impatiens*) by subjecting individual bees to two loading treatments: one in which bees consumed 20% of their body mass in nectar, and one in which they consumed the same amount of nectar and also had an exogenous load equivalent to another 20% of body mass attached to them. We flew bees in a chamber for 30 minutes, using acoustic analysis to measure flapping frequency, video analysis to calculate stroke amplitude, and flow-through respirometry to measure CO₂ production. There was no clear relationship between flapping frequency and flight metabolism, and no significant shift in metabolic rate when bees were carrying an exogenous load. These results suggest that bumblebees are capable of carrying loads during flight without incurring the energetic costs predicted by aerodynamic theory - a result with important implications for the design of micro aerial vehicles and for the economics of foraging in flying insects.

83-4 GANGLOFF, E.J.*; HOLDEN, K.G.; TELEMECO, R.S.; BAUMGARD, L.H.; BRONIKOWSKI, A.M.; Iowa State Univ., Ames, Univ. of Washington, Seattle; gangloff@iastate.edu

Hormonal and physiological responses to upper temperature extremes in divergent life-history ecotypes of the garter snake *Thamnophis elegans*

Extreme temperatures fundamentally constrain ectotherm physiology and have both acute and chronic effects. Both hormone-modulated stress response pathways and energetic trade-offs are important drivers of variation in life-history strategies. This study employs an integrative approach to quantify the physiological response to high temperatures in divergent life-history ecotypes of the Western Terrestrial Garter Snake (*Thamnophis elegans*). Using wild-caught animals, we measured oxygen consumption rate and physiological markers in plasma across five ecologically relevant temperatures (24, 28, 32, 35, and 38° C). We discovered that corticosterone, insulin, and glucose all increased with temperature. This indicates that, as seen in mammals, high temperatures can decouple the glucose regulatory mechanism of insulin, a pathway that has not been well-categorized in reptiles. We also determined that oxygen consumption increased without plateau with advancing temperature, but that lactate concentrations were not temperature responsive, challenging the recent hypothesis that oxygen limitation sets upper thermal tolerance levels. We did not find differences between life-history ecotypes in oxygen consumption rates, hormone concentrations, or glucose levels, perhaps indicating convergence of reaction norms in individuals maintained under long-term common garden conditions. The identification of hormonal-mediated response pathways is especially important given uncertainty around the mechanisms that set thermal limits in vertebrates which may soon experience increased frequencies of stressfully high temperatures in the wild.

34-7 GAO, S*.; SANCHEZ, CE; DAS, C; DEVICHE, P; Arizona State University, Tempe, Apeejay Stya University, India; sisi.gao@asu.edu

Corticosterone regulates stress-induced innate immunity in the male House Sparrow

The activation of the stress response can affect immune function in many species of free-living birds. It is unclear, however, if the direction of these effects depend on the duration of the stressor, how the stress response regulates immune function, and which components of the immune system are altered. We used adult male House Sparrows (*Passer domesticus*) to address these uncertainties. Specifically, we investigated 1) the interaction between an activated stress response and the innate immune response and 2) the possible roles of the stress hormone, corticosterone (CORT), over this interaction. We focused on the innate immune system because it is the first line of defense against pathogens. The stress response was induced by restraining birds for 10 minutes or 2 hours. The strength of the innate immune response was measured by how well its plasma components could recognize and lyse foreign cells (agglutination-lysis assay) and kill bacteria (bacterial killing assay). Innate immune measures were reduced by 10 minutes and remained low for 2 hours after the activation of the stress response. When birds were treated with mitotane to inhibit stress-induced (SI) elevation of plasma CORT, SI immunosuppression did not occur. In fact, mitotane-treated birds showed enhanced bacterial killing capacity relative to control birds. When birds were treated with RU486 to antagonize the glucocorticoid receptor, activation of the stress response did not decrease agglutination scores but still reduced bacterial killing capacity. These results suggest that SI levels of plasma CORT regulate the suppression of the innate immune response during the stress response, and that this regulation may be partially mediated through the glucocorticoid receptor. These studies were funded by CAP LTER, ASU Sigma Xi, and NSF IOB 1026620 to PD.

70-3 GARCIA, MJ*.; RODRIGUEZ, S; TAYLOR, RC; HUNTER, KL; Salisbury University, University of Texas, Austin; mjgarcia@salisbury.edu

Anthropogenic Effects on the Epigenome of the Túngara Frog (*Physalaemus pustulosus*)

Phenotypic responsiveness to changing environmental conditions is mediated, in part, by changes in gene expression due to epigenetic modification. Epigenetic modifications entail the addition of functional groups (e.g. methyl-groups) to the genome, which alter gene expression without directly altering the genome itself. With increasing anthropogenic disturbance such as habitat destruction and introduction of novel pathogens, it has become important to detail how animal populations respond to these changes. The túngara frog, native to Middle America, exhibits great adaptability to anthropogenic disturbances and the introduced, fungal pathogen *Batrachochytrium dendrobatidis*. We suspect this adaptability may be mediated, in part, by epigenetic modifications. Our study sought to examine epigenetic differences within and among four locales located in Gamboa, Panama, which vary in both their level of habitat disturbance and fungal prevalence. DNA samples (N=30 per local) were collected from amplexed pairs (male-female) and fine scale patterns in DNA methylation were analyzed using a methylation-sensitive amplified fragment length polymorphism (MS-AFLP) technique. An initial sampling (N=10 per local) revealed significant epigenetic difference among locales. Analyses of the entire dataset is underway with the goal of revealing whether individuals within and among locals vary in their epigenetic response to environmental perturbation. These data should provide for future work investigating that causal role epigenetics have in mediating phenotypic response to environmental perturbation.

89-2 GARCIA, A.*; PRIYA, S.; MAREK, P.; KRUMMEL, G.; Virginia Tech; ajgarcia@vt.edu

Understanding the Locomotion and Dynamic Controls for Millipedes: Part 2 - Dynamic Analysis of Millipede Traveling Wave Gait

There is a growing need in the development of locomotion techniques for miniature mobile robots for a wide range of applications that involve navigating through difficult scenarios, unknown terrains, and dangerous areas of interest. The efficient movements that arthropods exhibit have evolved over 500 million years, demonstrating effective kinematics and dynamics with respect to the surrounding environments. *Diplopoda* (millipedes), like other myriapods, have elongated bodies with numerous pairs of legs, which allow them to perform more adept maneuvers compared to other arthropods, such as cockroaches and beetles that have served as inspiration for many existing miniature ambulatory robots. Several interesting and relevant features specific to millipedes with respect to robotic applications include: (i) stable locomotion, (ii) ability to burrow through different substrates, and (iii) flexibility to traverse complex uneven terrains and right themselves swiftly when fallen over. These actions are performed by utilizing its myriapod morphology in combination with a unique traveling wave gait. An investigation of the locomotion biomechanics observed in millipedes is performed in order to provide a model that can be used to design a crawling miniature millipede-inspired robot (millibot). This study focuses on analyzing the dynamics of the effective traveling wave gait used in millipede locomotion, with interest in gait adjustments through wave modulations, implemented for different cases requiring more power such as burrowing and climbing. The ability to characterize its gait with the traveling wave properties of the aggregate behavior across all its legs, such as the wavelength, amplitude and velocity, would be desirable in developing a central robotic control scheme for a miniature platform.

90-6 GARCIA, S.M.*; KOPUCHIAN, C.; FUXJAGER, M.J.; MINDLIN, G.B.; GOLLER, F.; University of Utah, CECOAL-CONICET, Wakeforest University, FCEN-Universidad de Buenos Aires; Sarah.Garcia@utah.edu

Tracheophones revisited: The three sound source syrinx

Avian vocalizations are highly diverse, and arise from an interplay between morphology, aerodynamics and neuromuscular control. Although variation in the morphology of the vocal organ of birds, the syrinx, has been described, its functional role in generating vocal diversity is still poorly known for most bird taxa. Among Passeriformes, substantial differences in syrinx morphology exist between various suboscines, but their functional relevance has not been directly investigated. Here we illuminate the functional morphology of the syrinx in three "tracheophones", which are thought to generate sound with a prominent pair of membranous windows located in the distal end of the trachea (e.g. Ames, 1971, Peabody Museum of Natural History, Bulletin 37; King 1989, *Form and Function in Birds*, Volume 4; Beddard, 1898, *The Structure and Classification of Birds*). Using a fine optic fiber system inserted into the trachea, we identified the vibratory structures in the syrinx during induced phonation and found three possible sound sources: one pair of membranes in the distal trachea and one pair in each bronchus. We then tested the respective roles of these putative sound sources during spontaneously produced distress calls and induced phonation before and after experimental disruption of the tracheal membrane pair. Although the membrane windows can oscillate, they typically are not the main sound source. However, vibrations of the intact membranes are of low frequency and their disruption results in reduced amplitude and frequency modulation patterns. These data provide strong evidence that "tracheophones" likely use 3 sound sources. However, the role of the postulated "main" sound source, the tracheal membranous windows, is primarily that of modulating vibrations generated by the labial sound sources located in each bronchus.

32-6 GARDNER, C.E.*; BAIN, B.A.; GOVEDICH, F.R.; Southern Utah University; coralgardner1@gmail.com

Revision of *Colossendeis colossea* Wilson, 1881 (Pycnogonida: Family Colossendeidae)

Sea spiders (pycnogonids) are a small group of exclusively marine arthropods which resemble terrestrial spiders. One family, the Colossendeidae can grow to a very large adult size, much larger than any other pycnogonid. *Colossendeis colossea*, the largest known species, has a leg span of up to 70 cm and is found in both very deep ocean waters and shallower water in the Antarctic. Since it has been very difficult to obtain and study live specimens of this species, very little is known of their biology and natural history. We have obtained a number of preserved specimens, all labeled *C. colossea*, from the United States National Museum and are asking the question, are all of these specimens actually *C. colossea*? To answer this question, the specimens are being compared to syntypes from the Museum of Comparative Zoology and also to the original type description (Wilson, 1881). Based on previous scientific papers on *C. colossea* and closely related species, the following are used to separate species within this genus: relative proportions of terminal segments of walking leg and of pedipalp; location and number of eyes and shape of eye tubercle; proboscis shape and orientation; number of spine rows on terminal segments of oviger and shape of oviger terminal claw; abdomen size and orientation. Based on these, our preliminary results demonstrate that some of the United States National Museum specimens are not *C. colossea* since they differ from the syntypes and type description in several of the above characteristics.

56-8 GARLAND, JR., T*.; SALTZMAN, W.; GARLAND, Theodore; Univ. of California, Riverside; tgardland@ucr.edu

Hormones and the evolution of complex traits: insights from artificial selection on behavior

Although behavior may often be a fairly direct target of natural or sexual selection, it cannot evolve without changes in subordinate traits that cause or permit its expression. In principle, changes in endocrine function could be a common mechanism underlying behavioral evolution and, if so, then correlated responses in other aspects of behavior, life history, and organismal performance (e.g., locomotor abilities) should commonly occur because any cell with appropriate receptors could be affected. At the same time, because hormones are likely to affect multiple traits, including through early-life parental effects, they might be "used" routinely by selection to achieve (adaptively) correlated changes. Nevertheless, the seminal papers in modern evolutionary physiology scarcely mentioned the endocrine system. Ways in which behavior coadapts with other aspects of the phenotype can be studied directly through artificial selection and experimental evolution. Several studies have targeted rodent behavior for selective breeding and reported changes in other aspects of behavior, life history, and lower-level effectors of these organismal traits, including endocrine function. One example involves selection for high levels of voluntary wheel running in four replicate High Runner lines of mice. Circulating levels of several hormones (including insulin, testosterone, thyroxine, triiodothyronine) have been characterized, three of which - corticosterone, leptin, and adiponectin - differ between HR and control lines, depending on sex, age, and generation. Potential changes in circulating levels of other behaviorally and metabolically related hormones, as well as in other components of the endocrine system (e.g. receptors), have yet to be examined. Overall, results to date identify promising avenues for further studies on the endocrine basis of activity levels.

78-7 GARLAND, T; Univ. of California, Riverside; tgardland@ucr.edu

Born to Run: Artificial Selection Lab

Students rarely get opportunities for inquiry-based learning when they study evolution. Most hands-on learning experiences are simulations or involve reviewing data that has already been collected. In this lesson, students examine changes in dimensions of leg bones of mice from four replicate lines that have been selectively bred for high levels of voluntary wheel running. Wheel running can be viewed as a model of human voluntary exercise or of the daily movements that other animals exhibit in nature, so it has relevance for both applied and basic science. As the wheel-running behavior of the "High Runner" lines has evolved across tens of generations, many other changes have also been observed in the mice, encompassing other behaviors, physiology, and morphology. Students develop hypotheses and predictions about how the thigh bones (femurs) of animals that are good runners might be different from those that are not. They develop a protocol for testing their predictions by use of digital photos to measure femurs from generation 11. Measurements can be submitted through a Google form, which populates a spreadsheet that can be shared by the instructor, teaching assistant, and/or the students. This crowd-sourcing of morphometric data can also be used for research purposes, so the students get to participate in real science. The original middle-school version of the lesson, including supporting resources, can be accessed online at ENSI (<http://www.indiana.edu/~ensweb/lessons/BornToRun.html>) and a peer-reviewed publication is available (Radojicic, T., and T. Garland, Jr. 2014. Born to run: Experimental evolution of high voluntary exercise in mice. *Science Scope*, Summer 2014, pp. 3-12.). An online lecture giving the experimental background is available (http://idea.ucr.edu/documents/flash/born_to_run_stem_28_may_2013/story.htm). The procedures are easily scaled for high school or college, and I now use it in the undergraduate evolution course at UCR.

35-7 GARRETT, J.*; DAVALOS, R.; SOCHA, J.J.; Virginia Tech; jfg@vt.edu

Using inspiration and expiration from the hissing cockroach to design new microfluidics

Like all animals, insects depend on the internal movement of fluids to sustain life. Despite their small size, they use complex internal networks to efficiently transport gases, liquids, and food through their bodies. Previously, we studied respiratory patterns found in the Madagascar hissing cockroach (*Gromphadorhina portentosa*) to understand how abdominal pumping, tracheal compression, and spiracular valving are coordinated to produce airflows. Three key respiratory behaviors were identified: abdominal pumping, tracheal tube collapse, and spiracular valving. We found that the animal is able to control abdominal pumping and spiracular valving to compensate for changes in oxygen availability, such as increasing the pump frequency when exposed to hypoxic conditions. Here we explore how these behaviors are used to regulate internal flows using a computational fluid dynamics simulation, investigating the following parameters: branching schema, channel width, channel length ratio, pump frequency, pump amplitude, valve phasing, and valve locations. We varied these parameters through a range of values determined from previous animal experiments, as well as purely theoretical states not seen *in vivo*. Our preliminary results suggest a variety of parameter combinations that can be optimized for flow rate, shear stress on the channel walls, interior mixing, or interior diffusion. In addition to improving our knowledge about how the insect respiratory system coordinates flow production and valving, we aim to apply the results of this study toward developing low-power, small-footprint microfluidic systems for new engineered devices.

125-4 GEHMAN, A. M. *; HALL, R. J. ; BYERS, J. E. ; University of Georgia, Athens; alyssamina@gmail.com

High temperatures limit reproduction in an invasive castrating parasite

Temperature has predictable, often non-linear, effects on many biological processes. Parasites of ectothermic hosts may have similar non-linear responses to temperature, however the effects of temperature on parasites are less well understood compared to that of free-living animals. We conducted lab experiments developing thermal optimum curves for reproduction and mortality in the parasitic castrator *Loxothylacus panopaei* in its mud crab host *Eurypanopeus depressus*. Parasitized and unparasitized hosts were exposed for 209 days to a range of temperatures (5 to 35° C in increments of 5° C) commonly experienced in the field. All parasitic larvae released from crabs were collected, quantified and measured; survival was recorded for both hosts and parasites. Reproductive output of the parasite was maximized at 20° C, with frequency of larval release occurring approximately every 7 days at 20° C and above. Time between releases was longer for temperatures below 20° C. Survival of uninfected hosts was maximized at 20° C, whereas survival of parasitized hosts was maximized at 10° C, creating an offset in the optimum between uninfected and infected hosts. This work reveals that temperature has a non-linear effect on parasite rates of survival and reproduction, and will need to be explicitly included in future models to obtain accurate predictions of infection as a response to ecosystem change.

58-11 GIBBS, H. Lisle*; HOLDING, Matthew L.; SIMLEY, Sarah A.; Ohio State University; gibbs.128@osu.edu

Beak of the Snake: Conceptual Frameworks for Assessing Venom as an Adaptive Phenotype

Intraspecific variation in venom is hypothesized to be adaptive yet conceptual frameworks for testing this idea are lacking. Here, we draw on approaches developed in other fields of biology to develop these frameworks for functional tests of the functional and adaptive significance of (1) Individual protein composition of whole venom and (2) Widely-documented geographic variation in whole venom diversity. In terms of whole venom composition, we present a qualitative model of the "cabal" hypothesis for venom composition and draw on techniques developed for evaluating multi-drug antibiotic resistance in bacteria to propose how to experimentally assess functional interactions between individual venom proteins in terms of their effects on targets. To evaluate the evolutionary significance of geographic variation in venom, we argue that using a conceptual framework for evaluating local adaptation is essential. In particular, fully-crossed reciprocal comparisons of venom effectiveness on sympatric (local) and allopatric (non-local) targets are important because prey are key components of the environmental heterogeneity encountered by a venomous species. Variation in prey resistance may also be revealed in this way, extending this conceptual framework for the study of coevolutionary interactions between venomous animals and their prey. We provide examples of how these approaches can be applied from our own and published work.

34-2 GERVASI, S.S.*; BURGAN, S.C.; BURKETT-CADENA, N.; SCHREY, A.W.; HASSAN, H.; UNNASCH, T.R.; MARTIN, L.B.; University of South Florida; steph.gervasi@gmail.com
Vector preferences and host defenses in the West Nile virus system: A role for avian stress hormones?

Parasite transmission dynamics depend on interactions between host and vector traits within the context of the environment. For example, host behavior and physiology mediate parasite exposure, susceptibility and infectiousness, and vector feeding preferences can influence which individuals contribute most to the spread of infections. Importantly, host defenses and vector preferences might change plastically across an environmental gradient, for example, through effects of natural and anthropogenic change on the endocrine system. Glucocorticoid hormones profoundly affect vertebrate immunity and behavior and may thus influence how hosts encounter and respond to parasites and vectors. We investigated the role of stress hormones in mediating the enzootic cycle between mosquitoes and birds in the West Nile virus (WNV) system. Adult zebra finches (*Taeniopygia guttata*) were experimentally manipulated via corticosterone (CORT) implants to examine role of stress hormones in shaping (1) anti-vector behaviors of hosts (2) vector preferences for hosts and (3) WNV viremia profiles. Birds implanted with CORT did not display significant differences in anti-vector behaviors directed toward the southern house mosquito (*Culex quinquefasciatus*) compared to controls. However, implantation with CORT nearly doubled the chances that a bird was fed on by vectors. Additionally, mortality rate was increased in the CORT-treated birds compared to controls. Our findings suggest that corticosterone and other hormones may mediate plasticity in host traits, which could amplify the contributions of some individuals to transmission dynamics. Such effects might be especially common where anthropogenic stressors are concentrated such as cities and other highly-modified habitats.

14-6 GIDMARK, NJ*; GIAMMONA, F; KACZMAREK, E; ROBERTS, A; University of Chicago, Cornell University, University of Miami, Perdue University; gidmark@uchicago.edu

Muscle physiology and architecture as an axis of variation in functional diversity

Examining functional diversity and its evolutionary patterns requires quantification of a particular trait as a metric for disparity between species. Biomechanical models for force and displacement are a common tool in such studies, especially in feeding systems, and have elucidated countless insights into development, community composition, and ecology. Such models of feeding biomechanics primarily rely on metrics of jaw skeletal morphology such as the jaw adductor mechanical advantage. To accurately characterize the performance of a jaw system, however, both the skeletal leverage/linkage system and muscular actuation must be considered. Characteristics such as operating length (i.e. constraints of the force-length relationship), fiber angle, and ratio of muscle fiber strain to muscle-tendon-unit strain have at least an equivalent impact on organismal performance (arguably more) as skeletal morphology. Recent studies of ray-finned fishes have demonstrated that the force-length relationship of skeletal muscle constrains predator performance across prey sizes, fiber angle varies significantly across species, and the amount of muscle strain necessary for mouth opening can vary throughout ontogeny. Here, we demonstrate yet more functional diversity in fish feeding musculature by showing that: 1) the gape corresponding to optimal muscle force varies with feeding ecology in closely-related salmon species; 2) adductor muscle fiber architecture varies across salmon species; and 3) jaw skeletal morphology and Muscle fiber length evolve independently across sympatric sculpin species. Collectively, these data suggest the necessity of examining muscle morphology and physiology as axes of variation in functional diversity.

65-5 GIFFORD, ME*; CLAY, TA; Univ. of Central Arkansas, Univ. of Arkansas at Little Rock; megifford@uca.edu

The influence of internal and external conditions on offspring dispersal in free-ranging lizards.

Offspring dispersal is an important ecological process with implications for individual fitness. By dispersing, individuals provide a conduit between semi-isolated populations and maintain metapopulation structure, contribute to inbreeding avoidance, and influence population recovery after habitat fragmentation. Previous studies have identified a variety of intrinsic attributes and extrinsic conditions that influence the propensity of individuals to disperse. Because phenotypes related to dispersal can be induced or manifest at various stages of the life-cycle, dispersal itself might be highly variable and depend, to some degree, on the conditions experienced during development. In *Sceloporus consobrinus*, we examined the influence of incubation conditions on offspring phenotypes and combined this with a mark-recapture study of individual dispersal. We specifically asked whether individual variation in dispersal distance was associated with hatchling size, sex, and incubation conditions.

114-5 GILBERT, AL*; MILES, DB; Ohio University; anthony.gilbert09@gmail.com

Lability of thermal physiology revealed along an elevational gradient in *Urosaurus ornatus*

Species with broad geographic distributions often have populations inhabiting disparate habitat types that vary in thermal quality. Recent models suggest that differences in the thermal environment should lead to divergence in the thermal ecology of populations. Yet, evidence to date suggests thermal rigidity in key thermal traits, such as preferred temperature and field active body temperatures. Because one potential response to climate change is phenotypic plasticity, evaluating the potential for local adaptation to environmental gradients may enhance our understanding of how species may cope with altered thermal niches. Here we estimate the variation in thermal and physiological traits among populations of the lizard species, *Urosaurus ornatus* along an 1100 m elevational gradient in Arizona. We measured preferred temperature, critical thermal minima and maxima- the lower and upper thresholds for physiological function-, field active body temperature, and the thermal sensitivity of locomotor performance for low (750m), mid (1300m), and high (1850m) elevation populations of *U. ornatus*. Individuals at lower elevations had higher critical thermal maxima, whereas at high elevations they exhibited lower critical thermal minima. Preferred body temperatures declined with increasing elevation. The field active body temperatures of *U. ornatus* from low elevations were higher than those at higher elevations. The differences in thermal biology suggest that populations of *U. ornatus* along this gradient are locally adapted to specific thermal niches. The lack of thermal rigidity in these traits indicates that differences in thermal quality of habitats can lead to physiological changes within lizards. Physiological consequences due to thermal habitat selection may thus be severe as thermal niches change due to climate warming.

S10-1 GIGNAC, Paul M*; O'BRIEN, Haley D; Oklahoma State University Center for Health Sciences, Ohio University; paul.gignac@okstate.edu

Reliving the past: The ontogeny and evolution of crocodylomorph feeding success

It is largely assumed that the functional anatomy of adult forms tightly fits the adult niche. At odds with this precept are groups with resource dependent growth, whose ontogenies seemingly recapitulate adult morphologies of ancestral taxa. Integrated developmental-evolutionary histories can constrain maturing phenotypes, so much so that deviations may negatively affect clade persistence. Here we study the development and evolution of the suchian feeding apparatus to assess the impact of such ontogenetic inertia on clade dynamics. Regardless of niche-specific rostrudental phenotypes, modern adult suchians (Crocodylia) are robust, high-force biters and often capable of subduing large prey. Neonatal forms, on the other hand, are reminiscent of early suchians with lower bite forces, delicate dentitions, and relatively short jaws. Using biomechanical and evolutionary modeling techniques we formally investigate the occurrence and impact of such shifts in suchia. We examine total-morphospace evolution, clade-wide disparity, and convergence on functional phenotypes between stages of crocodylian ontogeny and suchian evolution. Our findings show that developmental patterns appear to broadly mirror the increasing size and robustness of the suchian jaw during its 240 million year history. The generalist life histories of neosuchians, in particular, appear to exemplify such coordination; however, the ecomorphological specializations of notosuchians inversely demonstrate a decoupling of such histories, precipitating reduced clade longevity. Our findings, therefore, demonstrate how visiting historical phenotypes during ontogeny can contribute to functionally important morphologies that aid individual and clade success without being strongly tied to their adult niche.

27-3 GILBERT, RR*; UETZ, GW; University of Cincinnati; gilbertrr@mail.uc.edu

Investigating the relationship between infection and sexual signaling in a wolf spider

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 examine the impact of bacterial infection on a terrestrial wolf spider species, *Schizocosa ocreata*. This species has energetically costly multimodal courtship, which has previously been shown to be negatively affected by bacterial infection as a juvenile. In the current study, we evaluated the impact of infection by a bacterial pathogen *Pseudomonas aeruginosa* as an adult on sexual signaling and mating success. We found that there is a correlation between tuft symmetry and intensity of infection, and that females may be able to detect whether males are infected. In addition, we found that infection as an adult did not impact mating success, but that there is evidence that infection can be transferred during copulation. This indicates that there may be complex direct and indirect relationships between sexual signaling and immunity in this species, and potentially a role for female mate choice to include the detection of infection.

126-6 GILMAN, SE*; ROGNSTAND, R; Pitzer College, Claremont McKenna College; sgilman@kecksci.claremont.edu

Effect of food supplementation on the growth and survival of the barnacle *Balanus glandula* under low tide stress

Rocky intertidal shores are characterized by vertical zonation, the distribution of species into distinct vertical band along the shore. Physiological stress has long been implicated as a cause of zonation, as higher shore sites have greater duration of low tide exposure and increased temperature and desiccation stress. Yet, high shore animals also have reduced opportunities for feeding and it is possible the energy limitation, rather than physiological stress, sets upper vertical limits. To test this hypothesis, we conducted a field manipulation of food supply on the barnacle *Balanus glandula*. We collected adult B. and attached them to ceramic tiles placed at one of 4 shore heights, hanging from an unused wharf in the Port of Los Angeles, CA USA. Tiles were grouped into three feeding treatments (fed, manipulated control, unmanipulated control). To feed barnacles, we removed tiles at high tide and placed them in coolers of seawater and brine shrimp. We followed growth and survival of the barnacles for 39 days, with supplemental food provided on 18 days. Survival was significantly greater at lower shore heights, but there was no effect of feeding on survival. Growth differed significantly among shore heights and feeding treatments. Food supplementation increased final mass by up to 36% over controls. The feeding effect declined with shore height. Our results suggest that barnacle growth is food-limited across its vertical range.

63-3 GOLDING, C.; KELLY, K.L.; LOCKE, B.R.; KINSEY, S.T.*; Florida State University, University of North Carolina Wilmington; kinseys@uncw.edu

The sensitivity of white muscle contractile function to the major components of the sarcomere calcium-cycling system

Muscle contraction is dependent on the release of Ca^{2+} from the sarcoplasmic reticulum (SR) followed by its binding to troponin-C (TnC), and relaxation requires the reuptake of Ca^{2+} by the SR, which drives its release from TnC. Quantitative analysis of this process requires detailed knowledge of the system components, which is often absent for comparative models. We therefore constructed a reaction-diffusion model of a fish white muscle sarcomere that comprised Ca^{2+} release, TnC binding, parvalbumin (Parv) binding, Ca^{2+} uptake, molecular diffusion and force production. We evaluated the sensitivity of force characteristics to these model components in an effort to define their functional ranges. The model compared well to force measurements in white muscle. Diffusion led to Ca^{2+} gradients along the sarcomere length that enhanced maximal force and generated a more rapid relaxation than the case where diffusion was infinitely fast. However, a modest increase in the sarcomere length or radius led to a decrease in maximal force. The model was highly sensitive to Ca^{2+} release and uptake. Lowering the release rate led to a lower maximal force, but increasing the rate led to only modest gains in maximal force while incurring much greater ATP costs associated with uptake, thus reducing contractile economy. Increasing the binding rate or concentration of Parv decreased maximal force but elevated rates of relaxation, and this effect was enhanced when Ca^{2+} uptake rates were lowered as may occur during fatigue. In general, these results show that a physiologically relevant set of parameters can be identified that lead to a functional sarcomere even when key experimental details are absent.

70-4 GLEASON, L.U.*; BURTON, R.S.; Scripps Institution of Oceanography, UC San Diego; Loyola Marymount University, Scripps Institution of Oceanography, UC San Diego; lani.gleason@gmail.com

Genomic evidence for ecological divergence against a background of population homogeneity in the marine snail *Chlorostoma funebris*

It can be difficult to resolve the balance between local adaptation and the opposing forces of gene flow and genetic drift, especially in marine invertebrates that can have extensive dispersal and fluctuating population sizes. The intertidal snail *Chlorostoma funebris* has pelagic larvae and previous work using mtDNA polymorphism reported no genetic population structure. Nevertheless, recent studies have documented differences in thermal tolerance and transcriptomic responses to heat stress between northern and southern California, USA, populations. To increase our understanding of the dynamics influencing adaptive divergence, we used double digest restriction site-associated DNA (ddRAD) sequencing to identify 2371 genome-wide, quality filtered single nucleotide polymorphism (SNP) loci for *C. funebris* collected from three northern and three southern California sites (15 individuals from each population). Considering all SNP loci, there was no evidence for genetic differentiation (average $F_{ST} = 0.0042$). However, separate analysis of the top ten percentile of SNPs based on F_{ST} (164 loci, average $F_{ST} = 0.11$) shows clear differentiation between geographic regions. This SNP subset includes several loci involved in ubiquitin protein degradation. Furthermore, outlier tests revealed 34 loci putatively under divergent selection between northern and southern populations. Three of these annotated outliers are known or hypothesized to be involved in cytoplasmic stress granule formation. This study increases our understanding of the factors constraining local adaptation in marine organisms, while nevertheless suggesting that ecologically driven, strong differentiation can occur at some relevant loci, even in a species with pelagic larvae.

118-2 GOMEZ, C.G.*; RICHARDS, J.G; University of British Columbia; gomezc@zoology.ubc.ca

Regulation of mitochondrial F_1F_0 -ATPase in the anoxia tolerant turtle, *Trachemys scripta*

The anoxia-tolerant turtle, *Trachemys scripta* is able to survive months buried in anoxic mud while overwintering in ice covered-ponds. In most vertebrates, anoxia leads to inner mitochondrial membrane depolarization causing the F_1F_0 -ATPase to run in reverse, hydrolyzing ATP, in an effort to restore membrane potential. This depolarization triggers a signalling cascade ending in cellular apoptosis or necrosis. Previous studies have shown that when *T. scripta* is exposed to anoxia, they severely down-regulate F_1F_0 -ATPase activity. The benefits of reducing F_1F_0 -ATPase activity during anoxia are clear, but the mechanisms responsible for inhibition remain unknown. Inhibitory Factor-1, a well-characterized mitochondrial ATPase inhibitor, is not responsible for the inhibition of F_1F_0 -ATPase in *T. scripta*. We predict that during long-term anoxia, the F_1F_0 -ATPase is inhibited via post-translational modification, which we investigated using proteomics approaches.

89-5 GONG, C.*; ASTLEY, H.; DALI, J.; MCLNROE, B.; SCHIEBEL, P. E.; TRAVERS, M.; GOLDMAN, D. I.; CHOSET, H.; Carnegie Mellon University, Pittsburgh, PA, Georgia Institute of Technology, Atlanta, GA, University of California, Berkeley, CA; chaohuigong@gmail.com

Geometric Mechanics: A Framework for Studying Animal Locomotion

We demonstrate the utility of geometric mechanics in studying various types of animal locomotion. Geometric mechanics offers a useful set of tools, including connection vector fields and height functions, for analyzing biological movements in an intuitive manner. These tools were conventionally applied to systems with only two internal degrees of freedom, but they can be modified to model locomotors that have many joints. We present case studies of two types of locomotions: crutching motion of mudskippers and sidewinding in sidewinder rattlesnakes (*Crotalus cerastes*). In the mudskipper study, geometric analysis shows tail usage can either be harmful, neutral, or beneficial depending on limb-tail coordination. This result shows control of limb-tail movement is crucial in achieving effective movements. *C. cerastes* moves by generating posteriorly traveling body waves in the horizontal and vertical directions with ± 90 degrees phase offset. Geometric analysis shows speed of sidewinding sensitively depends on wave kinematics. Subtle changes in kinematics can significantly change locomotion performance. Geometric analysis show the fastest sidewinding movement is achieved when the phase offset is equal to ± 90 degrees, revealing sidewinders use the set of wave kinematics which produces high locomotion speed. Together, these examples highlight the diversity of systems for which geometric mechanics can provide useful mathematical insights.

3-7 GORDON, JC; CARR, JA; BIEWENER, AA; DALEY, MA.*; Royal Veterinary College, University of London, Harvard University; mdaley@rvc.ac.uk

Intrinsic muscle dynamics power stability in the absence of autogenic proprioceptive feedback

Terrestrial vertebrates achieve agile and robust locomotion in the face of changing task demands and variable terrain; yet, the integration of sensory and biomechanical processes underlying this performance remains poorly understood. Here we investigate the relative roles of intrinsic mechanics and proprioceptive feedback in the modulation of muscle dynamics, using a novel bilateral self-reinnervation protocol to induce proprioceptive loss in the lateral gastrocnemius muscle (LG) of the guinea fowl (*Numida meleagris*). Previous studies of guinea fowl locomotion revealed that LG rapidly adjusts work output for stability in uneven terrain. However, reflex-mediated changes occurred concurrently with intrinsic mechanical effects, making their relative roles unclear. We measured *in vivo* LG force-length dynamics during running over level and obstacle terrain in guinea fowl lacking autogenic LG proprioception. Birds showed no consistent shifts in LG muscle electromyographic (EMG) activity during obstacle negotiation, yet, substantial shifts in LG force and work. The magnitude and pattern of work modulation matched that previously observed in 'intact' birds. In obstacle encounters, reinnervated LG exhibited higher muscle strain during force development, associated with higher total force and work output. The findings suggest that autogenic proprioception is not essential for regulating muscle dynamics during running. Instead, feed-forward control coupled to intrinsic mechanics can provide robust performance. We will discuss the likely roles of proprioception in light of this evidence, including provision of error signals to update internal models and optimising muscle strain for economy and injury avoidance.

67-3 GOODHEART, J.A.*; BAZINET, A.L.; COLLINS, A.G.; CUMMINGS, M.P.; Univ. of Maryland, College Park, Univ. of Maryland College Park, National Oceanic and Atmospheric Administration; GoodheartJ@si.edu

Phylogenomics of Cladobranchia (Mollusca: Gastropoda: Heterobranchia)

Cladobranchia (Gastropoda: Nudibranchia) is a diverse (~1000 species) but understudied group of sea slug mollusks. In order to fully understand the ecological and morphological character evolution as well as the importance of nudibranchs within Cladobranchia, a solid understanding of the evolutionary history of this group is necessary. This goal has yet to be achieved, as to date there have only been two direct attempts at resolving the evolutionary relationships of members within this group, with neither identifying a well-supported topology. Even at the most fundamental level, it is unclear whether the three traditional groupings within Cladobranchia (Arminida, Dendronotida and Aeolidida) are monophyletic. In our research, we have successfully addressed some of these long-standing issues in resolving the evolutionary history of Cladobranchia utilizing RNA-Seq data (transcriptomes). We sequenced 16 transcriptomes of cladobranchs from 16 different genera *de novo* and combined these with four transcriptomes from the NCBI Sequence Read Archive. Transcript assembly using Trinity and orthology determination using HaMStR yielded 839 orthologous groups for phylogenetic analysis under a maximum likelihood framework. These data provide a well-supported and almost fully resolved phylogenetic hypothesis of the sampled taxonomic groups in Cladobranchia. Our results support the monophyly of Cladobranchia and the sub-clade Aeolidida, and show that Dendronotida is paraphyletic. The data collected also resolve the position of problematic groups and revealed some interesting familial level relationships. However, broader taxon sampling will be necessary before we propose any taxonomic modifications within Cladobranchia.

68-3 GORSON, J.M.*; VERDES, A.; YEE, L.; SHIN, H.; KHAWAJA, S.; HOLFORD, M.; CUNY Graduate Center- New York, Hunter College, New York, Hunter College, New York; JMGORSON@GMAIL.COM

Characterizing the molecular diversity and function of Terebridae venom

This study investigates how venom genes evolved and the function of venom peptides in specific lineages of marine snails of the Terebridae. Terebrids, cone snails, and turrids make up the Conoidea superfamily of predatory marine snails. Terebrid venom peptides (teretoxins), are similar to the peptides of the more well studied sister clade, cone snails (*Conus*), but they also have distinct differences. Both Conidae and Terebridae produce highly diverse biologically active compounds that are undergoing rapid evolution. However, given that cone snails and terebrids diverged in the Paleocene era, their venom peptides are different, suggesting new possibilities for elucidating venom evolution in predatory snails of the conoidea. Here we performed a molecular ecology study of the Terebridae family using transcriptomics, proteomics and population genetic strategies to identify comparative features of terebrids and to elucidate novel neuropeptide compounds for investigating cell signaling. A comparative analysis of ten terebrid transcriptomes identified several novel terebrid venom gene superfamilies. Interestingly, distribution of teretoxin gene super families varied between a single species collected from different locations indicating that teretoxin genes are differentially expressed both inter- and intraspecifically. Additionally, novel teretoxins were chemically synthesized and analyzed for function using bioactive assays of potential prey species (polychaete worms and fish). Our results suggest that the diversity of toxin gene superfamilies has evolutionary implications and sheds light on novel compounds for manipulating cellular physiology as it pertains to drug discovery.

S10-5 GOSWAMI, Anjali; University College London; a.goswami@ucl.ac.uk

The macroevolutionary consequences of phenotypic integration: from development to deep time

Phenotypic integration is a pervasive characteristic of biological organisms. Interactions among morphological traits, termed phenotypic integration, can be readily identified through quantitative analysis of geometric morphometric data from living and extinct organisms. These interactions have been hypothesized to be a fundamental influence on morphological evolution on small to large time scales. Simulations using covariance matrices derived from 3-D landmark data for 97 living and extinct mammalian taxa confirm that trait integration can influence the trajectory and magnitude of response to selection. Phenotypic integration also produces both more and less disparate organisms than would be expected under random walk models by repartitioning variance in preferred directions, thereby increasing occupied morphospace range, but also homoplasy and convergence on macroevolutionary scales. The role of integration in shaping morphological evolution is particularly interesting when combined with the observation from many studies that cranial integration changes through ontogeny and that postcranial integration is correlated with reproductive strategy in mammals. If integration directs morphological variation, functional pressures at various points in ontogeny may differ in consequence depending in part on level and pattern of integration. For example, high integration in early postnatal ontogeny in marsupials, combined with strong functional pressures for crawling and suckling, may have contributed to the low variance observed in early postnatal marsupials and low disparity across marsupials, relative to placentals. Here, I discuss the macroevolutionary consequences of interactions among phenotypic integration, ontogeny, and function for morphological variance and evolution with comparative data from mammals and new data from amphibians.

61-1 GRAHAM, AM*; LAVRETSKY, P; MCCRACKEN, KG; Univ. of Miami; graham.allie@gmail.com

High-altitude adaptation and genetic divergence in Speckled Teal populations (*Anas flavirostris*)

Divergent selection pressures in heterogeneous landscapes can result in adaptive evolution to local environmental conditions. However, gene flow among populations experiencing different selection regimes can influence the propensity for local adaptation. Understanding such interactions between selection and gene flow can be achieved in systems that have more recently invaded novel/extreme environments. The Speckled Teal inhabits both low and high elevational habitat in the Andean mountain range, and while populations are thought to be largely allopatric, they are known to disperse long-distances, likely resulting in gene flow events up the altitudinal gradient. Although high-altitude Speckled Teal are believed to be locally adapted, it is unknown the extent to which gene-flow between the populations has maintained a heterogeneous genome. Therefore, we tested whether high and low elevation populations of this species are under divergent selection, as well as estimated gene flow across the genome (neutral SNPs vs. SNPs under selection), using 47,731 SNPs. In general, we find that adaptations to high-altitude environment are resulting in genomic divergence, despite high gene flow. We identified 356 SNPs as outliers under positive selection with allele frequencies strongly correlated with altitude. Among the markers under positive selection, we identified those involved in the insulin-like signaling pathway, bone morphogenesis, and blood coagulation; while markers under balancing selection were identified to be involved in metabolic processes. Ultimately, we provide the most comprehensive genomic study of this special Andean species, illustrating another example of how populations are able to adapt and invade novel, and sometimes, extreme habitats.

40-5 GRACE, M.S.*; MCLAMB, W.T.; Florida Institute of Technology; mgrace@fit.edu

What a Long Strange TRIP: Molecular and Neural Mechanisms of Thermal "Vision" in Pit Vipers and Pythons

Boid and crotaline snakes (boas, pythons and pit vipers) image their worlds simultaneously in two very different regions of the electromagnetic spectrum - visible light, and mid-to-long-wavelength infrared. This fascinatingly novel approach to targeting potential prey and predators and for locating appropriate refugia provides interesting opportunities to understand thermosensation and the evolution of imaging sensors in animals generally. In addition, analysis of this unique and rare sensory system may inform the development of new artificial thermosensors that could someday approach the sensitivity and effectiveness of those utilized by these snakes. Here we report a comprehensive analysis of transient receptor potential (TRP) ion channels as molecular thermosensors in the snake pit organ-based infrared imaging system. Immunofluorescence (including appropriate controls) and laser-scanning confocal microscopy revealed multiple TRP channels - particularly TRPA1 - in terminal nerve masses of snake pit organs in both pythons and pit vipers. Pharmacological manipulation of infrared-based thermal targeting through the use of a TRPA1 antagonist dramatically inhibited the ability of copperheads (*Agkistrodon contortrix*) to accurately and efficiently target warm objects. Finally, the same TRPA1 antagonist inhibited heat-induced, pit organ-mediated activity in the brain, demonstrated by functional magnetic resonance imaging (fMRI). The latter result provides not only physiological evidence for TRPA1 as the snake pit organ's molecular thermosensor, but also the first demonstration by real-time neuroimaging of the infrared imaging system's neural pathway in the snake brain.

125-6 GRAHAM, OJ*; HARGENRADER, K; EISENLORD, M; GRONER, M; University of Washington, Friday Harbor Laboratories, University of San Diego, CA, Cornell University, Ithaca, NY, University of Prince Edward Island, Charlottetown, PE, Canada; ojgraham@me.com

The severity and prevalence of eelgrass wasting disease in the San Juan Islands, WA

Seagrasses are marine angiosperms that are important primary producers in temperate estuarine and marine ecosystems worldwide, forming ecologically and economically valuable meadows. Of the five species found in the Pacific Northwest of the United States, common eelgrass (*Zostera marina*) is one of the most widely studied. A marine slime mold, *Labyrinthula zosterae* is the causative agent for eelgrass wasting disease and is one of the primary causes of declines in seagrass beds. *Labyrinthula* is an opportunistic pathogen that persists in eelgrass beds throughout the world, although it has primarily been studied in shallow, intertidal eelgrass beds. We conducted field and lab analyses to determine the prevalence and severity of wasting disease in intertidal and subtidal *Z. marina* beds from four sites throughout the San Juan Islands, Washington. By quantifying the diseased tissue on 417 intertidal blades and 480 subtidal blades, we found that subtidal beds had significantly more diseased eelgrass blades than intertidal beds. Furthermore, we determined that depths strongly influenced the severity of wasting disease. Collectively, these data suggest that subtidal beds are more conducive to *Labyrinthula* growth. This study highlights the need for further marine epidemiological studies to determine what factors may allow *Labyrinthula* to persist more in subtidal beds than in intertidal eelgrass beds.

82-2 GRAVISH, N*; MOUNTCASTLE, A.M.; CRALL, J.D.; WOOD, R.J.; COMBES, S.A.; Harvard University, Univ. of California, Davis; gravish@seas.harvard.edu
The role of roll: rapid collision avoidance in cluttered aerial environments

Foraging flight of bumblebees (*Bombus impatiens*) requires stable, coordinated movement in complex aerial environments. Through previous long-term observation of free-flight in cluttered environments, we have observed that bumblebees employ stereotyped flight kinematics to navigate around obstacles: bees engage in rapid lateral movements (0.27 ± 0.10 m/s) while maintaining fixed heading, rather than turning to avoid collisions. High-speed video reveals that rapid lateral maneuvers are initiated through body roll, and that even during extreme roll maneuvers (with the stroke plane tilted 45° from the horizontal), bees maintain a fixed horizontal head posture, or gaze. These observations present two complementary hypotheses for the role of lateral maneuvering. 1) Body dynamics favor rapid maneuvering along the body axis with the lowest moment of inertia, thus roll-based maneuvering maximizes rapid collision avoidance. 2) Roll-based lateral maneuvering allows for continuous visual feedback (through counter rotation of the head) while navigating through challenging environments. By performing free-flight perturbation experiments, we explored the relative roles of visual feedback and body dynamics in roll-based lateral maneuvering. Our experiments suggest that the flight strategies employed by bumblebees in cluttered environments optimize both flight dynamics and sensory processing.

73-4 GREAR, ME*; CROFTS, SB; COPPING, AE; SUMMERS, AP; DITSCHKE, P; University of Washington, Pacific Northwest National Laboratory; mgrear@uw.edu
Finite element material model of harbor seals' (*Phoca vitulina*) skin and blubber

New energy forms are needed to reduce CO₂ output and global warming. For much of the coastal United States, tidal turbines are being considered as a new form of energy. Therefore, the potential environmental consequences of installing tidal turbines must be investigated. The goal of this study is to quantify the soft tissue response to marine mammals like harbor seals (*Phoca vitulina*) from collision with a tidal turbine. The biomechanical properties of the seal's skin are needed to implement a finite element model determining the extent and severity of a tidal turbine blade strike. Skin samples were collected from stranded harbor seals postmortem. Two adult seals and one pup were investigated in this study. We performed tensile tests of both the skin and blubber layers to determine tensile stiffness and tensile strength, as well as the strain rate effects. The samples were taken in different orientations (0° , 45° and 90°) to the longitudinal body axis to investigate if anisotropy is present in the tissue. Both types of tissue exhibited a large plastic region, showing non-linear behavior with the amount strain expected in a turbine collision. The blubber and skin both showed strain-rate hardening. Neither the blubber nor skin exhibited anisotropy. Consequently, the material can be modeled as isotropic, but must be modeled non-linearly and as a rate-dependent material. Results were used to create a constitutive material model in an ABAQUS finite element analysis.

S5-7 GREDLER, M.L.; Univ. of Florida, Gainesville; mlgredler@ufl.edu

Developmental and Evolutionary Origins of Amniote External Genitalia

Amniote external genitalia vary significantly in form. Most amniote species have a single phallus, although some have paired hemiphalluses and others lack a phallus altogether. Intromittent amniote phalluses have either an open urethral groove or a closed urethral tube. This considerable degree of morphological variation has confounded our understanding of phallus evolution. To ask whether differences in adult phallus anatomy reflect distinct developmental and evolutionary origins, we compared external genital development in three reptiles with distinct external genital anatomies: the American alligator has a single phallus, the green anole has paired hemiphalluses, and the tuatara lacks a phallus. We find that in the alligator, anole, and tuatara, early stages of cloacal and external genital patterning include the formation of genital protuberances adjacent to the cloaca and developing hindlimbs. In the alligator, the genital tubercle, or embryonic penis and clitoris, forms from outgrowth of genital mesenchyme beneath the ventral body wall, adjacent to the cloacal membrane and medial to the hindlimb buds. The anole hemiphalluses initiate as genital buds at the ventral base of the hindlimb buds, yet these buds remain separate and mature into two distinct hemipenes in males and hemiclitoris in females. Histological analysis shows that, despite absence of an adult phallus, tuatara embryos develop paired genital eminences adjacent to the cloaca. Conservation in the events comprising early external genital development across amniotes supports the hypothesis that external genital anlagen are a shared, derived character of Amniota, and subsequent divergence in morphogenesis generates the variation observed in adult phallus morphology.

54-3 GREENE, MJ*; BUBAK, AN; RENNER, K; SWALLOW, JG; University of Colorado Denver, University of South Dakota; michael.greene@ucdenver.edu

Regulation of individual decision by pavement ants and the self-organization of wars between neighboring colonies

Social insect colonies are regulated as non-hierarchical, distributed systems in which ants must make individual decisions that are informed by local information cues. Changes in colony behavior occur collectively because of the many decisions of individuals. We report how brain monoamines affect the decisions of individual ants after detecting chemical cues during interactions with nestmate ants, fighting with non-nestmate ants, or exposure to nestmate and non-nestmate chemical cues during the self-organization of warfare by pavement ant (*Tetramorium caespitum*) colonies. Wars are hostile conflicts in which members of one society coordinate their efforts to kill or injure members or disrupt the normal functioning of another. The pavement ant is a tramp species well known for its ant wars in which thousands of workers from two colonies fight. Fighting is ritualized; ants fight by grabbing another ant's mandibles with its own and pairs undergo what can be described as a "push-of-war" while other ants recruit more workers to the battle and few, if any, ants die during the battle. What are the rules that influence the collective-organization of these "wars" and how are cooperative and agonistic behaviors modulated in individuals by brain monoamines? We report that serotonin (5-HT) levels were higher in ant brains after interactions with nestmate ants or their chemical cues. Dopamine levels were elevated only after interactions with live nestmate or non-nestmate ants. Brain octopamine levels were elevated in ants that fought non-nestmates. Increasing octopamine levels increased the probability that an ant will fight a non-nestmate ant.

88-3 GRESS, BE*; PITNICK, S; Syracuse University; begress@syr.edu

Size-dependent patterns of ejaculate investment and fertilization success between alternative mating environments in the yellow dung fly

Males are expected to alter resource allocation strategies to maximize fertilization success under sperm competition. In the yellow dung fly, *Scathophaga stercoraria*, larger males typically compete for gravid females on dung in cow pastures (low sperm competition risk), while smaller males primarily mate with non-gravid females at off-pasture feeding sites (high sperm competition risk). Theoretical models predict that when large males mate off pasture they should reduce ejaculate expenditure since such matings present lower potential for reproductive pay-off than a typical dung mating, whereas small males unable to compete on dung should increase investment at feeding sites due to the greater risk of sperm competition. Here, we quantified ejaculate investment and fertilization success of small and large field-caught males in both mating environments to test patterns of resource allocation. In non-manipulated field matings, we find that small and large males differentially invest in ejaculate expenditure between mating environments in a manner consistent with theoretical expectations. However, when mating environment was manipulated, no ejaculate tailoring occurred, suggesting that males are not adjusting expenditure based on environment per se, but rather investment reflects different physiological states of large and small males at feeding sites. These findings, combined with paternity data, will provide insight into the pay-off of this long-overlooked aspect of the yellow dung fly mating system.

81-1 GROGAN, KE*; SAUTHER, ML; CUOZZO, FP; DREA, CM; Emory University, University of Colorado, University of North Dakota, Duke University; kathleen.e.grogan@gmail.com
The Influence of MHC on Reproductive Success in Wild Ring-tailed Lemurs (*Lemur catta*)

Because Major Histocompatibility Complex (MHC) genes encode the proteins responsible for activating the immune system during infection, genetic variation at the MHC is critical for health and, by extension, survival and reproduction. MHC diversity or possession of a particular MHC allele can purportedly influence an individual's lifetime reproductive success (LRS) via energetic trade-offs between immunocompetence and reproduction. Although researchers have shown relationships between MHC variation and various proxies of fitness, e.g. health and survival, few have examined if the MHC is related to the ultimate measure of fitness, the production of offspring. Using wild, ring-tailed lemurs (*Lemur catta*) under long-term study at the Beza Mahafaly Special Reserve, Madagascar, we evaluated if LRS was correlated with maximal MHC diversity or the possession of specific MHC supertypes. Of 205 infants born to 62 females from 2005-2012, 130 were successfully weaned and 75 died prior to weaning. Although MHC diversity and LRS were uncorrelated, the possession of particular supertypes was correlated with offspring survival to weaning (z value=7.622, p value=0.000***). Other supertypes were associated with failure to give birth (z value=3.797, p value=0.000***) or offspring death before weaning (z value=3.932, p value=0.000***). Thus, an individual's specific MHC genotype strongly influenced LRS. These relationships disappeared, however, during two severe droughts in 2006 and 2010. As the climate of Madagascar is further altered by human disturbance, the disruption of selective pressure acting on genetic make-up and LRS might increase the threats from population fluctuations and resultant genetic drift. Funded by NSF and Duke University.

55-1 GROGAN, E.D.*; LUND, R.; Saint Joseph's University, Carnegie Museum; egrogan@sju.edu

Early Insights into How to Build a Gnathostome Cranium

Embryological studies of vertebrate development have culminated in a model of the cartilaginous units which collectively contribute to formation of the chondrichthyan cranium. Developmental studies of neural crest and mesodermal cell contribution to the cranium have enhanced the embryological data. Yet, how complete is our understanding of chondrocranial development? How does this influence our interpretation of chondrocranial evolution? Are we missing something? In this work, we present evidence of Paleozoic fish with cranial designs that challenge our perceptions of what the early chondrocranium was like. A number of Paleozoic elasmobranchs, in contrast to extant forms, are now known to exhibit a chondrocranium comprised of two moieties. New data is now presented for a discontinuous chondrocranial design in non-elasmobranchian fishes from the Bear Gulch Limestone of Montana (323myo). This information is discussed with reference to data from acanthodian and osteichthyan fishes. This data on cranial design offer challenges from a developmental and evolutionary perspective to our concepts of the stem chondrichthyan and stem gnathostome design.

71-3 GROOM, DJE*; TOLEDO, MCB; WELCH JR, KC; University of Toronto, Universidade de Taubate; derrick.groom@mail.utoronto.ca

Wingbeat frequency and flight kinematics in the largest hovering animals under flight challenge

Variation in wingbeat kinematics is necessary to sustain hovering flight in the face of changing requirements, such as body mass fluctuations or air density variation due to elevation. Previous work has shown that hovering animals primarily vary power output via changes in stroke amplitude (the angle swept by the wings). Changes in wingbeat frequency are typically not observed, or are small in magnitude, suggesting that high wingbeat frequencies are physiologically constrained. Variation in frequency during sustainable hovering has been seen at reduced air densities, when decreased profile drag and inertial requirements may explain increases in wingbeat frequency. However, the kinematic variation by the largest hovering hummingbirds has not been explored. Given their larger sizes and lower frequencies, we hypothesized that sustained frequency variation is a viable strategy for these hoverers. We quantified wingbeat frequency and stroke amplitude in three large-bodied hummingbirds using high-speed videography as they sustainably lifted masses or briefly lifted maximal masses at three elevations. As predicted, frequency was upregulated during weight lifting, independent of elevation, suggesting that hummingbirds have a reserve wingbeat frequency capacity when higher power outputs are required. The current paradigm of a fixed wingbeat frequency for hovering does not apply to the largest hovering animals, highlighting the importance of scaling on kinematics during locomotion.

SI2-4 GROZINGER, Christina; Penn State University;
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Cooperation and conflict in social insect societies: from genes to pheromones

While honey bee colonies are often thought of a harmonious "superorganisms", our studies of interactions among the queen, workers and drones have revealed a nuanced and sophisticated pheromone communication system that balances cooperation and conflict among members of the colony. Our studies provide novel insights into genomic, epigenomic, physiological and chemical mechanisms that regulate the variation in pheromone production and responses to these pheromones that shape social behavior in honey bees. We have extended these studies to other social insects (bumble bees, paper wasps, and fire ants) to begin to examine the evolution of the genomic pathways underpinning chemical communication and reproductive dominance and the interplay between social environment and individual behavior. Finally, our studies demonstrate the power of using genomic approaches to identify and characterize social cues and signals and their impacts.

79-6 GUIGUENO, MF*; MACDOUGALL-SHACKLETON, SA; SHERRY, DF; University of Western Ontario;
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Sex and seasonal differences in hippocampal volume and neurogenesis in brood-parasitic brown-headed cowbirds (*Molothrus ater*)

Brown-headed cowbirds (*Molothrus ater*; hereafter "cowbirds") show a reversal of sex-typical space use often seen in mammals. Females search for, revisit, and parasitize host nests and show greater spatial memory than males on some laboratory tasks. Previous research reported a female-biased sex difference in the volume of the hippocampus, a brain region involved in spatial memory. New neurons produced by neurogenesis may also help form new memories and replace old neurons that contain information from the past that cause interference. We tested for sex and seasonal differences in hippocampal volume and neurogenesis of cowbirds and the closely related non-brood-parasitic red-winged blackbird (*Agelaius phoeniceus*; hereafter "blackbirds") to determine if there were differences in the hippocampus that reflected space use in the wild. Females had a larger relative hippocampus than males in both species, but hippocampal neurogenesis, measured by doublecortin immunoreactivity (DCX+), was greater in female than in male cowbirds in the absence of any sex difference in blackbirds, supporting the hypothesis of hippocampal specialization in female cowbirds. Cowbirds of both sexes had a larger relative hippocampus and greater hippocampal DCX+ than blackbirds, indicating that sex-specific selection on female cowbirds may have indirectly affected males. Relative hippocampus volume remained stable between breeding and post-breeding conditions for both species. However, DCX+ in cowbirds was greater in post-breeding condition, which suggests old memories are lost through hippocampal reorganization following breeding. Our results support, in part, the hypothesis that the cowbird hippocampus is specialized for brood parasitism.

101-3 GUINDRE-PARKER, S.*; RUBENSTEIN, D.R.; Columbia University; slg2154@columbia.edu

Integrating proximate and ultimate costs of reproduction in cooperatively breeding superb starlings

All sexually reproducing organisms are faced with a fundamental decision: to invest valuable resources and energy in reproduction or in their own survival. This trade-off between reproduction and survival represents the 'cost of reproduction' and occurs across a diverse range of organisms. The costs of reproduction are thought to underlie a number of behavioral adaptations, including the evolution of mating and social systems. Although it is widely assumed that cooperative breeding behavior in vertebrates results in part from costly parental care the costs of reproduction in social species have rarely been quantified. We examine the costs of reproduction in a free-living population of cooperatively breeding superb starlings (*Lamprolaima superbus*), combining proximate and ultimate levels of analysis. Specifically, we show that costs of reproduction have a measurable impact on superb starling fitness, where birds investing in reproduction more frequently throughout their lives have a shorter lifespan (i.e. breeding superb starlings have shorter lives than helpers at the nest, who invest less in caring for young). To better understand the costs of reproduction, we are further examining the physiological mechanisms that link reproduction and survival over a shorter time frame. Specifically, we focused on whether oxidative stress, glucocorticoids, or immune function could play a role in linking reproduction and survival in superb starlings. Preliminary results show that oxidative stress increases with reproductive workload, suggesting that this physiological trait may play a part in linking reproduction to reduced survival. This research demonstrates the importance of integrating across behavioral ecology, endocrinology, immunology and physiology to further understand the costs of reproduction.

130-4 GUNDERSON, A.R.; San Francisco State University;
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A conceptual framework for understanding thermal constraints on ectotherm activity

Activity budgets influence the expression of life-history traits as well as population dynamics. For ectotherms, a major constraint on activity is environmental temperature. Nonetheless, we currently lack a comprehensive conceptual framework for understanding thermal constraints on activity, which hinders our ability to rigorously apply activity data to answer ecological and evolutionary questions. Here, I integrate multiple aspects of temperature-dependent activity into a single unified framework that has general applicability. Examples of the implementation of this framework to address fundamental questions in ecology relating to climate change vulnerability and species' distributions are given, using empirical data from a tropical lizard.

11-2 HADFIELD, M.G.*; NEDVED, B.T.; University of Hawaii at Manoa; hadfield@hawaii.edu

The Bacterial Basis of Larval Settlement

Bacteria and archaea have profusely colonized the earth for more than 3.5 billion years, forming dense microbial biofilms on virtually all marine surfaces. The first evolving animals, arising around 700 million years ago, adapted to the microbial world in many ways. One major animal adaptation is the use of biofilm bacteria or their products as signals for recruitment by larvae from at least seven marine invertebrate phyla. We have investigated the settlement biology of one such species, the circum-tropical serpulid polychaete *Hydroides elegans*. In-depth studies on larvae of *H. elegans* have revealed that its metamorphically competent larvae settle selectively in response to specific biofilm-dwelling bacterial species. The strongly inductive bacterium *Pseudoalteromonas luteoviolacea* produces complex clusters of bacteriocins, multi-protein structures evolutionarily derived from phage-tail elements, which induce metamorphosis of *H. elegans*. However, at least three other bacterial species isolated from biofilms and found to induce settlement of *H. elegans* lack the genes for bacteriocins. Among these, *Cellulophaga lytica* produces abundant outer membrane vesicles (OMVs) in culture, and cell-free suspensions of OMVs induce metamorphosis of *H. elegans*. To determine whether it is compounds in the bacterial membrane that surrounds both intact cells and OMVs or OMV contents that induce settlement, we isolated major membrane lipopolysaccharides from *C. lytica* and purchased bacterial peptidoglycan and found them not to be inductive when tested separately or in combination. This suggests it is "cargo" in the OMVs that is the inductive element. Knowledge of the precise inductive elements will allow us to explore the mechanisms by which larvae respond with the profound developmental events of settlement and metamorphosis.

38-1 HALANYCH, KM; Auburn University; ken@auburn.edu
Worms and trees: The Fauchald push to annelid phylogenetics

In 1997, seminal papers were published by Kristian Fauchald and Greg Rouse that help clearly define families of polychaetous annelids and provided an overarching phylogenetic hypothesis that helped focus systematic research within the group. Fostered by this work, understanding of annelid phylogeny has changed dramatically. Molecular and genomic tools were used to test many hypotheses laid out in the 1997 papers. Sipunculids, echiurids, vestimentiferans, pogonophorans, and myzostomids all used to be considered separate phyla and are now known to be nested within annelids, and clitellates are recognized to be derived polychaetes. Here I will discuss recent and novel transcriptomic data in reference to higher-level annelid phylogeny, as well as the role transcriptomics and genomics has played in bringing about this new understanding. Discussion will be focused on placement of groups that were traditionally placed outside of "Polycheata". Magelonidae and Owenidae are sister to all other annelids and clitellates are allied with terebelliform annelids. Interestingly, the non-segmented sipunculids are sister to the homonomously segmented amphinomid. This novel understanding has profound implications for how we view segmentation across animal groups. Although, segmentation used to be considered a character of considerable phylogenetic value, it is an evolutionarily plastic feature that is likely dictated by functional constraints.

70-5 HAGUE, MTJ*; BRODIE JR., ED; BRODIE III, ED; University of Virginia, Utah State University; mh6nf@virginia.edu

Repeated adaptation to dangerous prey through a predictable molecular pathway in the garter snake *Thamnophis sirtalis*

Adaptive evolution may proceed down a predictable molecular path when functional constraints or pleiotropy restrict molecular evolution to a limited number of amino acid positions. We found convergent, adaptive changes in the sodium channel protein of the common garter snake (*Thamnophis sirtalis*) in response to its poisonous prey, the Pacific newt (*Taricha* spp.). These newts possess tetrodotoxin (TTX), a lethal neurotoxin that blocks nerve and muscle sodium channels and prevents the propagation of action potentials. The toxin deters most predators; however, key amino acid replacements in the pore region of the Na_v1.4 skeletal muscle sodium channel of *T. sirtalis* inhibit toxin binding and confer large increases in TTX resistance. We constructed a Na_v1.4 gene tree and surveyed TTX resistance alleles across western North America where the predator and prey co-occur. We found that TTX resistance likely evolved independently in two separate coevolutionary hotspots: central California and the Pacific Northwest. In each instance, adaptive amino acid replacements occurred in the same specific pore region of the Na_v1.4 channel. Population frequencies of these TTX resistance alleles were also tightly correlated with sympatric levels of newt toxicity. The occurrence of repeated adaptive changes within a single species suggests that convergent molecular evolution may not be uncommon, particularly when the availability of beneficial mutations is limited by functional constraints like the maintenance of sodium channel function.

S7-11 HALL, RJ*; BROWN, LM; ALTIZER, S; Univ. of Georgia; rjhall@uga.edu

Modeling Vector-borne Disease Risk in Migratory Animals under Climate Change

Recent theory suggests that animals that migrate to breed at higher latitudes may benefit from reduced pressure from natural enemies, including pathogens ("migratory escape"). The distribution and activity period of arthropod disease vectors in temperate regions is expected to increase under climate change, which could lead to a longer pathogen transmission window and reduce the potential for migratory escape. However, climate change could have the opposite effect of reducing transmission if shifting host migratory strategy reduces overlap with vectors in space and time. Here we develop a simple model to explore the influence of climate change on vector-borne disease dynamics in a migratory host. We investigate support for two mechanisms by which migrants might experience reduced disease risk under climate change: (i) poleward shifts in host breeding latitudes that increase migration distance cause infected hosts to experience higher migratory mortality ("migratory culling") and (ii) vectors respond more rapidly to changing environmental conditions in the breeding range than migrants, causing peak susceptible host density and peak vector emergence to diverge ("migratory mismatch"). This model provides a useful framework for understanding how migratory populations will respond to environmental change and emerging disease threats.

15-1 HANAUER, RE*; ABOLINS-ABOLS, M; KETTERSON, ED; Indiana University; rhanauer@indiana.edu

Adapting to human disturbance: physiological flexibility in adults of a common songbird

Some bird species are colonizing urban habitats, indicating their ability to adapt to altered light, noise, food resources, and disturbance. Urban birds' corticosterone (cort) responses to acute stressors differ in magnitude from non-urban conspecifics in many species. In the dark-eyed junco (*Junco hyemalis*), individuals residing in urban areas have a lower cort response to capture and handling stress than non-urban birds during the early breeding season. This urban phenotype could be the result of past selection, developmental plasticity, or physiological flexibility. To determine whether physiological flexibility could account for observed patterns, we tested whether exposure to frequent disturbance could induce an attenuated cort response over a short time frame in captive adult dark-eyed juncos derived from a non-urban population. Experimental subjects experienced 30-minute psychological stressors four times per day for 21 days; controls were disturbed only during animal husbandry. This treatment occurred during the springtime period of gonadal recrudescence and migration, which is critical in preparing for a successful breeding season. We found that frequently disturbed birds had a lower acute cort response, and some of the difference between groups was due to the seasonal increase in cort response in control birds. Baseline cort did not differ between groups. On average all birds gained weight over the course of the experiment, but frequently disturbed birds gained less weight. We conclude that adult juncos are capable of expressing an attenuated acute cort response in an environment with high frequency of disturbance, which may help to account for their ability to colonize urban habitats. We discuss these results in the context of large-scale field observations of urban and non-urban juncos.

118-5 HANNAN, KD*; JEFFREY, JD; WRIGHT, A; HASLER, CT; SUSKI, CD; University of Illinois, Urbana-Champaign; kelly.hannan3@gmail.com

The physiological effects of exposures to elevated CO₂ on freshwater unionid mussels

The movement and spread of invasive fish species is a topic of recent concern. In the Midwestern US, Asian carp are an invader of particular concern due to the recent expansion of their populations. Gas barriers aimed at deterring fish movement, such as CO₂, are gaining in popularity as areas of elevated CO₂ have been shown to be effective at deterring fish movement. However, little research has investigated potential consequences of these barriers on non-target species, such as mussels. Freshwater mussels are one of the most imperiled animals worldwide, and have some of their highest diversity in North America, and zones of high CO₂ have potential to impact these organisms. The goal of the current study was to quantify the impacts of short-term, chronic, and fluctuating exposures to elevated CO₂, and subsequent recovery, on freshwater mussels. Hemolymph ions such as, Ca²⁺, Cl⁻, Mg²⁺, and Na⁺ were measured along with hemolymph glucose, body condition indices, and metabolic rate. Results from these studies indicate that freshwater mussels experienced physiological disturbances related to acid base disturbance following CO₂ exposure, but body condition is unaffected, and there is evidence of recovery following removal of the CO₂ challenge. Results are further discussed in the context of how CO₂ barriers may impact non-target organisms.

66-2 HANEY, WA*; CLARK, AJ; UYENO, TA; Valdosta State University, College of Charleston; wahaney@valdosta.edu

Knotting Characteristics of the Pacific Hagfish

Hagfish are jawless, invertebrate chordates that may compensate for a lack of opposable jaws by employing leverage created by forming and manipulating body knots during feeding. Hagfish can also use knots to clean off mucous and to escape confined spaces. The mechanical characterization of knotting has not been well described because it is difficult to consistently control and stimulate this behavior experimentally. Here we study the knots formed by *Eptatretus stoutii* (Lockington, 1878) through the use of a custom jig that holds a sedated hagfish securely using an elastic membrane. Once the hagfish awakens it attempts to escape by rolling and swimming backwards. To escape however, the animal consistently forms a figure 8 knot and works it anteriorly to leverage its head out. We use this setup to a) identify common steps in knotting, b) describe knotting physical characteristics, including handedness and radii of loops, c) record three-dimensional kinematic parameters, and d) estimate head retraction forces. This behavior was recorded using two high-speed cameras (Phantom Miro320; Wayne, NJ; 350Hz) that were set at 90° from each other. After the kinematic analysis of video frames from 22 knotting events performed by 11 animals (using Tracker V. 4.90), we found that *E. stoutii* preferentially form right-hand knots (77%) and that the knotting process could be decomposed into 13 characteristic steps. We were able to record some preliminary measurements of head retraction force; it is highly variable (0.8-9 N, 17-41 N/kg body weight), and, interestingly, much lower than what is required to pull a semisolid plug of similar diameter from the membrane (28N). Further investigations are required to assess whether these knotting characteristics are species specific or represent generalized hagfish behavior.

105-7 HANSEN, VL*; SCHILKEY, FD; MILLER, RD; University of New Mexico, Albuquerque, National Center for Genome Resources, Santa Fe; vhansen@unm.edu

Immune regulation during pregnancy in a model marsupial, the gray short-tailed opossum *Monodelphis domestica*

Marsupials are a lineage of viviparous mammals that last shared a common ancestor with eutherians (placentals) over 148 million years ago. Marsupials are distinct from eutherians in that they give birth to highly altricial young after a short gestation. Whether or not there is regulation of maternal immune responses during marsupial pregnancy has been debated for decades. Indeed, the evolution of short gestation times has been attributed to a lack of immune regulation during marsupial pregnancy. Alternatively the maternal immune system may be entirely unaware of the presence of the fetal allograft in marsupials due to lack of a highly invasive placenta. To investigate this further, transcriptome analysis of uterine immune gene expression during pregnancy was performed in the gray short-tailed opossum, *Monodelphis domestica*. Gene expression profiles from pregnant and non-pregnant uterine tissues were generated using both NextGen sequencing and quantitative PCR. Analyses revealed expression of pro-inflammatory cytokines remained relatively low during pregnancy, even at implantation, but increased dramatically immediately preceding birth, peaking within twelve hours prior to parturition. These results contrast the two spikes of inflammation seen in eutherian pregnancy, first at implantation and second at parturition. Inflammation at terminal pregnancy in marsupials may be indicative of a parturition mechanism. Our results are consistent with the marsupial immune system being "aware" of the allogeneic fetus but under regulation.

96-4 HANTAK, M.M*; KUCHTA, S.R.; Ohio University ;
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Color Polymorphism in the Eastern Red-backed Salamander (*Plethodon cinereus*): How Morphs are Seen Through the Eyes of Visual Predators

Color polymorphism is the presence of two or more discrete, genetically determined color morphs in a population. In many cases, the ecological and evolutionary dynamics maintaining polymorphisms are not well understood. One hypothesis is that polymorphism is maintained by interactions with visual predators, either by way of apostatic selection, or by being differentially camouflaged in different microhabitats or seasons. In general, organisms that better blend into their background have an increased chance of survival. The Eastern Red-backed Salamander, *Plethodon cinereus*, contains two common color morphs, a striped morph and an unstriped morph. Presently, it is not known which of these two morphs is more cryptic, or if the answer to this question is context dependent. To address this question, we are studying three populations in Ohio: a monomorphic striped population, a monomorphic unstriped population, and a polymorphic population. For this study, we gathered information on whether the two morphs differ in their relative camouflage across seasons, light conditions, and habitats. A spectrometer was used to collect reflectance measurements from color patches, providing measures of brightness, hue and chroma. Ambient light from each location and from different times of the day was also measured, as the quality of available light impacts perceived color. We are running this data through mathematical models of the avian and mammal visual system to quantify how well each morph blends into the background. Overall, this study will provide essential data for better understanding the adaptive basis of the polymorphism, and what evolutionary and ecological dynamics might be involved in its maintenance.

112-3 HARDY, A.R.*; STEINWORTH, B.M.; HALE, M.E.; Univ. of Chicago, Whitney Laboratory for Marine Biosciences;
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Pectoral fins of the catfish *Pimelodus pictus* can function as passive touch sensors

Mechanosensation is fundamental to many tetrapod limb functions yet remains largely uninvestigated in the paired fins of fishes, limb homologs. Despite the diversity of pectoral fin functions across taxa, research has focused on species whose fins experience significant deflections during locomotion or active foraging. Here we examine whether fins may function as passive sensory structures for touch sensation in the absence of extensive fin ray movement. To test this idea, we investigated the pectoral fins of the pictus catfish (*Pimelodus pictus*), a species that lives in close association with the benthic substrate. The fins have a robust leading edge spine and kinematic analysis showed that the spine and trailing fin rays are played at a consistent angle relative to the body axis during routine swimming and thus do not appear to be used to generate propulsive force. The fins are highly innervated with nerves running from the base of the fin to near the fin rays' distal tips and antibody staining suggests the presence of mechanoreceptors at nerve fiber endings. To test for the ability to sense mechanical perturbations, fin ray nerve fiber activity was recorded in response to touch and bend stimulation. Afferent nerves from the pectoral fin responded to touch stimuli with little or no observable fin ray bending. Both pressure exerted perpendicular to the dorsal fin ray surface and brushing along the ray generated afferent nerve spiking. Fin ray nerves also responded to deflections of the rays. These data indicate that the pectoral fins of *P. pictus* can function as passive mechanosensory surfaces, providing feedback on benthic surface features and other aspects of the physical environment.

105-2 HARDWICK, KM*; PERKIN, LC; SCHLENKE, TA;
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Transcriptional response of *Drosophila melanogaster* to infection by ten different species of parasitic wasps

The success of a parasite depends on its ability to suppress or evade the immune system of the host. Parasitic wasps, which lay their eggs in the body cavities of host insects, inject venom proteins to modulate the host immune response. Previous research indicates that the venom proteins injected by different wasp species vary in their effects on the host immune system such that even closely related wasp species use divergent strategies to achieve successful infection. To investigate the evolution of immune evasion/suppression strategies in parasitic wasps, we conducted an RNA-Seq experiment with wasp-infected *Drosophila melanogaster*. *D. melanogaster* is an ideal host for studying virulence evolution because it is parasitized by several wasp species in nature, is a model system for the study of innate immunity, and has a well-characterized transcriptome. We infected *D. melanogaster* individuals with one of ten different wasp strains, and examined the transcriptional response to each infection over time. We found that wasp strain had a significant effect on the number and identity of genes differentially expressed between infected and control *D. melanogaster* individuals. We discuss connections between wasp host specialization, venom composition, and venom effects on host transcription, as well as the importance of phylogenetic relatedness among wasp strains.

81-5 HART, MW*; STOVER, D; MOZAFFARI, SV; OBER, C;
MUGAL, CF; KAJ, I; Simon Fraser Univ., Arizona State Univ., Univ. of Chicago, Univ. of Chicago, Uppsala Univ.; mwhart@sfu.ca
Selection on coevolving human gamete recognition genes

Coevolution of pairs of gamete recognition genes expressed on sperm and eggs can account for variation in reproductive compatibility between mates and the evolution of reproductive differences among populations. We fit branch-sites codon models to 1000 Genomes data to identify candidate sites under positive selection for high rates of amino acid substitution in the human egg coat genes *ZP2* and *ZP3*, and in the sperm *ZP* receptor gene *C4BPA*. Six lines of evidence indicated that these candidate sites are coevolving under selection at fertilization. (1) The candidate site in each *ZP* gene occurred in the known sperm-binding domains. (2) The candidate site in *C4BPA* was the same coding sequence SNP identified as coevolving with *ZP3* in a previous study using different methods and data. (3) All candidate sites distinguished two common haplotypes, with unusually high minor-allele frequencies. (4) Two candidate sites (in *ZP2* and *C4BPA*) were correlated with variation in family size and birth interval lengths among Hutterite couples, and (5) were in linkage disequilibrium in the same Hutterite study population. (6) The same polymorphisms at these candidate sites are known from Neanderthal or Denisovan genomes (consistent with long-term balancing selection). This evidence supports a previously proposed hypothesis of selection on coevolving combinations of egg- and sperm-expressed alleles (in *ZP3* and *C4BPA*), and point toward specific genetic variants that are the targets of selection, explain the coevolution of these three genes due to their epistatic interactions, underlie natural reproductive variation, and could be associated with clinical infertility.

127-1 HARVEY, R.J.*; BUSE, C; ROSKILLY, K; HUBEL, T.Y; WILSON, A.M; Royal Veterinary College; *rjharvey@rvc.ac.uk*
Calibration of natural terrain and collection of locomotor data on free ranging animals using a low cost UAS platform

UAS technology is progressing rapidly whilst still remaining relatively low cost. Remote survey using drones has become widely available and commercial software is available to produce high accuracy three-dimensional surface models. We have used these modalities to develop a new method for collecting locomotor data from free running wild animals remotely and also overlay this on surface models. Using a DJI Phantom 3 and Pix4D mapper software we were able to create three-dimensional (3D) geo-referenced terrain models from which we can extract ground control points. These ground control points can be used to remotely calibrate an area of interest, even after a free running animal has been filmed in the area. Using video footage of animal locomotion and calibration data speed, track and acceleration can be measured as well as visualising the 3D path of the animal(s). In order to validate these methods we surveyed ground control points with dual-frequency GPS, measured distance between obvious landmarks using a laser range finder and compared tracked positions of a dog running in the subject area wearing a dual-frequency GPS-IMU system.

126-7 HASLER, CT*; TIX, J; JEFFREY, JD; SUSKI, CD; University of Illinois; *cthasler@gmail.com*

Short-term impacts to freshwater fish movement and alarm cue response

Future levels of pCO₂ in the freshwater environment may rise as a result of climate change, and may also increase for brief periods of time because of human actions (e.g., CO₂ is being tested as a non-physical barrier to prevent fish movement). The objectives of this study were to expose freshwater fish species to elevated pCO₂ and monitor different ecologically relevant behaviors, such as movement and alarm responses. Movement behaviors were measured for Largemouth Bass (*Micropterus salmoides*) using acoustic telemetry in a small pond setting, and responses to alarm cues were measured for Fathead Minnow (*Pimephales promelas*) using video analysis. Largemouth Bass exposed to higher pCO₂ and monitored for two weeks were found to move less than fish exposed to normal pCO₂ levels, but only during the fourth day post-release. Turning angles and linearity ratios did not differ, indicating that fish were not disoriented. Fathead Minnow exposed to high pCO₂ demonstrated fewer predator avoidance behaviors than fish not exposed to elevated pCO₂, but recovery may be possible. Overall, there may be limited negative consequences for short-term exposure to elevated pCO₂. Future work will include a fine scale assessment of movement in Largemouth Bass and potential changes in personality traits of Bluegill (*Lepomis macrochirus*) exposed to elevated pCO₂.

88-1 HARVEY, TA*; SCHOLLES, E; BOSTWICK, KS; LAMAN, TG; MARSCHNER, S; Yale University, Cornell University, Harvard University; *todd.harvey@yale.edu*
From microscopic feather structure to whole-organism display behavior: Uncovering the private courtship signals of *Parotia wahnesi*

Characterizing the appearance and signaling performance of the courtship display of *Parotia wahnesi* is challenging due to its directional and temporal attributes. We used vouchered behavioral specimens in the form of field-generated video-recordings, in combination with reflectance measurements from a museum specimen in the lab to reconstruct the "anatomy" of the extended courtship phenotype of the male *Parotia wahnesi*. We investigated 4 fundamental components of its directional signaling: (1) the direction of light illuminating the male in his court, (2) the morphology of the male's iridescent ornamental plumage over a hierarchy of structural scale, (3) the direction and color of the reflectance from the male's iridescent plumage, and (4) the position and orientation of the ornaments with respect to the female during display. We show how plumages are tightly aligned at multiple structural scales to maximize the effectiveness of visual signals. In a highly choreographed performance, ornamental plumages entice females through contrasting shape, intensity, and color, while ancillary plumages construct a backdrop framing those ornaments. We present evidence that the male leverages the geometry of his court and lighting environment to gain additional directional advantages. Every attribute, whether intrinsic or extrinsic to the male himself, hones signal production to generate spectacular but private displays intended for visiting female birds, unobservable from other vantage points.

11-5 HATLEBERG, WL*; DEGNAN, SM; DEGNAN, BM; Univ. of Queensland; *williamhattleberg@gmail.com*

One genome, two body plans: how do larval and adult gene expression profiles differ in the sponge *Amphimedon queenslandica*?

The widely-distributed pelagobenthic life cycle, comprised of a dispersive pelagic larva and a reproductive benthic juvenile/adult form, is an excellent model for one of the most fundamental questions in evolutionary biology: what is the genomic basis for the origin of new phenotypes? Using replicated transcriptome data from two pelagic and two benthic stages of the sponge *Amphimedon queenslandica*, we examine what gene expression profiles can reveal about how the genome produces two clearly distinct body plans. We focus on the 14,699 (32.9%) genes that are significantly differentially expressed (DE) between at least two of the following stages: larval (precompetent and competent), 3 day old juvenile, and reproductive adult stages. PCA analysis of all genes confirms that the two larval stages are more transcriptionally similar, and the greatest transcriptional differences lie between larval and juvenile/adult samples, consistent with the hypothesis that distinct gene regulatory networks underpin pelagic and benthic body plans. Contrary to this, DE genes in the juveniles show more similarity in gene age to DE genes in larvae than those in the adult. Specifically, phylostratigraphy reveals that genes differentially upregulated (DU) in larval and juvenile stages are predominantly of pre-metazoan and metazoan origin, whereas genes DU in the benthic adult body plan tend to be younger, lineage-specific innovations. This is supported by orthology analyses, which indicate that the well-recognized and conserved metazoan genes are primarily DU in larval and juvenile stages but not the adult. Here, we discuss the implications of these results in the context of larval biology and historical embryological theory and suggest that future comparative analyses of additional life cycle transcriptomes in eumetazoans may help to address some the long-standing debates in the field.

91-3 HAVIRD, J.C.*; SLOAN, D.B.; Colorado State University; justin.havird@colostate.edu

Coevolution between nuclear and mitochondrial genomes

A mitochondrial genome is retained in all eukaryotes with a functional electron transport chain. However, in order for the mitochondria to meet the energy needs of eukaryotic cells, genetic products from the mitochondrial genome must interact intimately with those encoded by the nuclear genome. Because mtDNA is inherited differently (uni- vs. bi-parentally) and can evolve at a different rate than nucDNA, one hypothesis posits that nucDNA gene products (i.e., N-mt genes) coevolve with the mtDNA gene products they interact with in order to compensate for metabolic instability induced by mtDNA mutations. To evaluate this hypothesis, we examined rates of molecular evolution, protein structural characteristics, and expression levels in mtDNA- and nucDNA-encoded gene products in plants, since rates of mtDNA evolution and gene transfer to the nucleus are variable in different plant species. We tended to focus on closely related species in the genus *Silene* which vary drastically in their mtDNA substitution rates. d_N/d_S ratios of N-mt genes were elevated in *Silene* species with fast-evolving mtDNA, and substitutions in N-mt genes occurred most frequently at residues that contacted mitochondrial residues that had also undergone a substitution, providing support for the nuclear compensation hypothesis. However, the finding that N-mt genes recently transferred from the mito- to nuclear genomes have decreased expression provides support for an alternative, constraints-based hypothesis, which has been championed previously based on data from animals. We argue that both hypotheses likely contribute to observed patterns of mitonuclear evolution. These results have implications for recent theories of speciation and the evolution of sex that invoke nuclear compensation in mitonuclear genomic evolution.

108-7 HAWKINS, C.A.*; PHAN, T.; SANFORD, E.; SOKOLOVA, I. M.; Univ. of North Carolina at Charlotte; C.Hawkins@unc.edu
Effect of hypercapnia and metal exposure on intracellular metal distribution and metabolic activity in *Mercenaria mercenaria*

Rising atmospheric CO₂ levels leads to shifts in the carbonate chemistry and pH of marine waters, potentially changing the bioavailability of trace metals such as cadmium (Cd) and copper (Cu) to marine organisms with implications for metal toxicity. We determined the interactive effects of elevated P_{CO₂} levels and Cd or Cu exposure on intracellular metal distribution and metabolic efficiency of the hard clams (*Mercenaria mercenaria*). Animals were exposed to clean artificial seawater (ASW) or ASW supplemented with 50 µg L⁻¹ Cd or Cu at P_{CO₂} concentrations corresponding to IPCC present day levels, and projections for years 2100, and 2250 (~400, 800 and 2000 ppmv) for 28 days. Cu exposure did not cause significant Cu accumulation in clams indicating tight regulation of this essential metal. In contrast, Cd strongly bioaccumulated in biologically active fractions including mitochondria, lysosomes and high molecular weight cytosolic proteins, but only small fraction of the intracellular Cd burden partitioned to metallothioneins. Cd bioaccumulation in mitochondria and cytosolic proteins was enhanced by hypercapnia. Hypercapnia caused significant (P<0.02) decreases in specific activities of pyruvate kinase, PK, and phosphoenolpyruvate carboxykinase, PEPCK (enzymes that channel glycolytic substrates to aerobic and anaerobic pathways, respectively), indicating metabolic depression. Cd exposure in present-day conditions significantly (P<0.1) decreased PK activity. No significant differences in PK/PEPCK ratio were seen in any treatments, but a trend of lowered anaerobic capacity was detected in response to moderate hypercapnia and Cd exposure, which merits further inquiry. These findings aid our understanding of the long-term effects of increased CO₂ levels and pollution on the health of a keystone species and indicate that hypercapnia has a more negative impact on the metabolism of the hard clam than exposure to Cu and Cd at low, environmentally realistic concentrations.

S11-9 HAVIRD, J.C.*; MITCHELL, R.T.; HENRY, R.P.; Colorado State University, MedStar Union Memorial Hospital, Auburn University; justin.havird@colostate.edu

Gill-specific salinity response in the blue crab and developing a comprehensive multi-species gill transcriptome

The multi-functional crustacean gill acts as the primary site for regulation of many physiological processes that allow for the wide environmental plasticity observed in crustaceans. Specifically, gills are the major organs responsible for osmoregulation, which allows euryhaline crustaceans to maintain elevated internal osmolality in dilute waters. In brachyuran decapods only the posterior gills are specialized for osmoregulation; anterior gills are undifferentiated and function in gas exchange. However, the molecular basis underlying this specialization is poorly understood. Furthermore, examination of salinity-induced gene expression in the gills is typically restricted to known ion transporters (e.g., Na⁺/K⁺-ATPase). Here we use an RNA-Seq based approach to characterize gene expression in response to salinity transfer in anterior and posterior gills of the blue crab (*Callinectes sapidus*), a well-studied model for crustacean osmoregulation. While confirming previous patterns of gene expression consistent with salinity transfer, we identified novel differentially expressed genes (DEGs) involved in ion transport, hormonal regulation, and energy metabolism/mitochondrial function in the posterior gills. Anterior gills were characterized by high levels of structural proteins such as actin, but showed few DEGs associated with osmoregulation. Publically available crustacean gill transcriptomes were also investigated in order to identify a "core" crustacean gill transcriptome. Finally, we use a subsampling strategy to make a recommendation as to the minimum number of reads necessary in studies of crustacean gill transcriptomics and ecophysiology. Results described here demonstrate the ease of applying transcriptomics to species with little or no available sequence data.

S4-5 HEATH-HECKMAN, Elizabeth/A.C.*; PEYER, Suzanne; MCFALL-NGAI, Margaret; University of California, Berkeley, University of Wisconsin, Madison, University of Hawaii; heathheckman@berkeley.edu

Bacterial regulation of host cryptochrome expression in a squid photophore

Nonvisual photoreceptors have been studied for their ability to allow organisms to interact with their external environment, but their role in host-symbiont communication is not well known. We studied the involvement of bacterial partners in regulating host transcription of putative circadian photoreceptors in the light-organ symbiosis between the squid *Euprymna scolopes* and its luminous symbiont *Vibrio fischeri*. This binary model for bacterial colonization of a host organ is characterized by daily transcriptional rhythms in both partners, as well as by daily rhythms in symbiont luminescence and host-cell morphology. Two transcripts encoding cryptochromes (*escry1* and *escry2*), blue-light receptors that entrain circadian rhythms, were identified in the host. Whereas transcription of both cycle in the head with a pattern suggesting entrainment to environmental light, *escry1* cycles in the symbiont-colonized light organ with an 8-fold upregulation coincident not with environmental light but with the rhythms of bacterial luminescence. Manipulating the colonization process revealed that *escry1* transcription patterns in the light organ were dependent upon the presence of symbionts. Mutants of *V. fischeri* defective in luminescence failed to induce *cry1* expression to wild-type levels, providing evidence that bacterial luminescence entrains host cryptochrome expression. This study demonstrates that bacterial symbionts have the potential to be active participants in the setting of host biological rhythms. The conservation of both bacterial-epithelial interactions and circadian gene regulation across the metazoa suggests that symbiont-induced circadian rhythms may be widespread.

62-8 HEATH-HECKMAN, E.A.C.*; PELLEGRINO, M.; DE MIGUEL, F.F.; BAUTISTA, D.; WEISBLAT, D.A.; University of California, Berkeley, Universidad Nacional Autonoma de Mexico; heathheckman@berkeley.edu

Using leeches to identify molecular mechanisms mediating cellular responses to touch

Mechanotransduction, the mechanism(s) by which cells convert mechanical stimuli into electrical activity, is a process conserved across all domains of life and is a necessary facet of our interaction with the world. However, despite its ubiquity and importance, mechanotransduction is not well understood at a molecular level. Leeches in the genus *Hirudo*, commonly known as medicinal leeches, have been long used as a model system for neurobiology. As a result the characteristics of the neurons in the segmentally iterated ganglia of the ventral nerve cord have been well established, including three classes of mechanosensory neurons that can be distinguished by their responses to light touch (T cells), pressure (P cells), and noxious (potentially damaging) chemical and mechanical stimuli (multimodal N cells). To determine what genes might mediate the differences among these and other neurons, we carried out a transcriptomic analysis of pooled sets of four different cell types. My analysis revealed distinct transcriptional profiles for each cell, including robust differences between the three types of mechanosensory neurons. Some of the most highly regulated transcripts correspond to genes encoding ion channels and their modulators that may mediate the detection of mechanical stimuli, suggesting that my analysis may let us identify new mechanosensory channels and pathways by which mechanosensation is achieved. Future directions include: 1) determining the effect of the loss of these channels on neuronal function; 2) describing the developmental trajectory and organismal relevance of these genes; and 3) directly determining whether a subset of these channels confers mechanosensitivity in mammalian cell culture.

5-2 HEINEN-KAY, JL*; NOEL, HG; LAYMAN, CA; LANGERHANS, RB; North Carolina State University; justa.heinenkay@gmail.com

Human-caused habitat fragmentation can drive rapid divergence of male genitalia

The aim of this study rests on three premises: (i) humans are altering ecosystems worldwide, (ii) environmental variation often influences the strength and nature of sexual selection, and (iii) sexual selection is largely responsible for rapid and divergent evolution of male genitalia. While each of these assertions has strong empirical support, no study has yet investigated their logical conclusion that human impacts on the environment might commonly drive rapid diversification of male genital morphology. We tested whether anthropogenic habitat fragmentation has resulted in rapid changes in the size, allometry, shape, and meristics of male genitalia in three native species of livebearing fishes (genus: *Gambusia*) inhabiting tidal creeks across six Bahamian islands. We found that genital shape and allometry consistently and repeatedly diverged in fragmented systems across all species and islands. Using a model selection framework, we identified three ecological consequences of fragmentation that apparently underlie observed morphological patterns: decreased predatory fish density, increased conspecific density, and reduced salinity. Our results demonstrate that human modifications to the environment can drive rapid and predictable divergence in male genitalia. Given the ubiquity of anthropogenic impacts on the environment, future research should evaluate the generality of our findings and potential consequences for reproductive isolation.

S10-8 HEERS, A.M.; American Museum of Natural History; ashmheers@gmail.com

Building a Bird: Ontogenetic and Evolutionary Construction of the Avian Body Plan

Developmental and evolutionary origins of avian flight involve some of the greatest transformations in vertebrate history. Flight is the most power-demanding mode of locomotion, and volant species have many anatomical features that presumably help meet these demands. However, juvenile birds, like early winged dinosaurs, lack many hallmarks of advanced flight capacity. Instead of large wings they have small "protowings", and instead of robust, interlocking forelimb skeletons their limbs are gracile and their joints less constrained. Such features are often thought to preclude extinct theropods from powered flight, yet young birds with "dinosaur-like" anatomies flap-run up slopes and even briefly fly, thereby challenging longstanding ideas on skeletal and feather function in the theropod-avian lineage. To address this discrepancy and assess how ontogenetic changes in anatomy effect improvements in locomotor performance, I constructed three-dimensional musculoskeletal models of a precocial ground bird (*Alectoris chukar*) (Software for Interactive Musculoskeletal Modeling) and simulated flapping behaviors at different ontogenetic stages (OpenSim). Aerodynamic measurements, *in vivo* kinematics and model simulations collectively suggest that immature birds have excess muscle capacity and are limited most by feather morphology, which they compensate for by using their wings and legs cooperatively until the wings can fully support body weight during flight. These results help elucidate the ontogeny and evolution of avian locomotion by (i) establishing how muscular and aerodynamic forces interface with the skeletal system to generate movement in morphing juvenile birds, and (ii) providing a benchmark to inform biomechanical modeling and simulation of extinct theropods with similar anatomies.

30-5 HELLMANN, JK*; LIGOCKI, IY; O'CONNOR, CM; REDDON, AR; GARVY, KA; MARSH-ROLLO, SE; GIBBS, HL; BALSHINE, S; HAMILTON, IM; The Ohio State University, McMaster University, McGill University, Duke University, McMaster University; jehellmann45@gmail.com

Reproductive sharing in relation to group and colony-level attributes in a cooperative breeding fish

The degree to which group members share reproduction is dictated by both within-group (e.g. group size and composition) and between-group (e.g. density and position of neighbors) characteristics. While many studies have investigated reproductive patterns within social groups, few have simultaneously explored how within-group and between-group social structures influence these reproductive patterns. We investigated how group size and composition, along with territory density and location within the colony, influenced parentage in 36 wild groups of a colonial, cooperatively breeding fish *Neolamprologus pulcher*. Dominant males sired 76% of offspring in their group, while dominant females mothered 82% of offspring in their group. Subordinate reproduction was frequent, occurring in 47% of sampled groups. Subordinate males gained more paternity in groups located in high-density areas and in groups with many subordinate males. Dominant males and females in large groups and in groups with many reproductively mature subordinates had higher rates of within-group parentage loss, but only at the colony edge. Our study provides the first comprehensive quantification of reproductive sharing among groups of wild *N. pulcher*, a model species for the study of cooperation and social behavior. Further, we demonstrate that the frequency of extra-pair parentage differs across small social and spatial scales.

80-8 HELM, BR*; BALDWIN, MD; RINEHART, JP; YOCUM, GD; BOWSER, JH; GREENLEE, KJ; North Dakota State University, USDA-ARS Insect Genetics and Biochemistry, USDA-ARS Insect Genetics and Biochemistry; bryan.r.helm@ndsu.edu

Causes of metamorphic induction and consequences for adult phenotypes in solitary bees

Variation in body size, a central theme for integrative organismal biology, influences fitness and shapes ecological and evolutionary interactions. In insects, body size is a product of growth rate and the factors that regulate metamorphic induction late in larval development, such as attainment of a critical weight, a terminal growth period, and growth cessation. However, the generality of these factors/mechanisms for different insect species is an open question. We examined causes of metamorphic induction and consequences on adult size variation in the solitary bee, *Osmia lignaria*. We found that this species used absence of food provisions as a cue for metamorphosis rather than a critical weight. In addition, excess provisions caused a delay of metamorphosis, suggesting that multiple cues and/or mechanistic interactions regulate metamorphosis in this species. Approximately 90% of body size variation in adults was due to differences in the timing of metamorphic induction. Manipulation of food provisioning induced more than a ten-fold mass difference between the smallest and largest adult bees. When we examined body plan morphologies, we found that allocation to flight structures, but not reproductive structures, was different in small and large bees. These results imply that mechanisms shaping size variation and consequences for individuals are diverse among different insects and reflect the environmental context for each species.

131-5 HENDERSON, LJ*; COCKCROFT, RC; KAIYA, H; BOSWELL, T; SMULDERS, TV; Newcastle University, UK, National Cerebral and Cardiovascular Center, Japan; lindsayhenderson@hotmail.com

Peripherally injected ghrelin and leptin reduce food hoarding and mass gain in the coal tit (*Periparus ater*)

The hormonal control of feeding and hoarding behaviour in mammals is reasonably well characterized. Contrary to mammalian studies, the hormones that regulate appetite and consumption, ghrelin and leptin, both cause a reduction in consumption in birds. To date, the role of these hormones in the regulation of hoarding behaviour in birds has not been examined. To investigate this we injected wild caught coal tits (*Periparus ater*) with high-dose ghrelin (0.25 nmol), low-dose ghrelin (0.05 nmol), leptin (10 µg) and a saline control in the laboratory. We then measured hoarding activity and mass gain, as a proxy of food consumption, every 20 mins for two hours post injection. We found that both the ghrelin-high and leptin injection significantly reduced hoarding behavior and mass gain compared to controls. But the ghrelin-low injection did not differ from controls for hoarding or mass gain. The results are consistent with previous findings from birds that show both leptin and ghrelin cause a reduction in consumption and mass gain. Unlike hoarding mammal species, where ghrelin promotes hoarding and leptin reduces hoarding; our results provide the first evidence that hoarding behaviour is reduced by both leptin and ghrelin in a passerine bird. These findings add to evidence that the hormonal control of consumption and hoarding in avian species differs from that in mammals. Furthermore, food hoarding and consumptive behaviours consistently show the same response to leptin and ghrelin, which suggests that the hormonal regulation of hoarding behaviour has evolved from the consumption regulatory system.

107-6 HEMMERT, H. M.*; BALTZLEY, M. J.; Western Oregon University; hhemmert10@wou.edu

Scaling and Velocity Correlations Between Horizontal and Vertical Crawling in *Cornu aspersum*

Across various modes of locomotion, body size and speed of locomotion are well correlated. Body size and crawling speed are also thought to be correlated in terrestrial snails and slugs, but existing data is ambiguous. We tested this hypothesis by examining the relationships between body size and crawling speed in the terrestrial snail *Cornu aspersum*. We also examined the relationships between wavelength and wave frequency on crawling speed. We recorded snails crawling on both horizontal and vertical surfaces. We did not find a correlation between foot length and speed. We found that there was a correlation between wave frequency and speed on vertical surfaces. Weight and shell length had no correlation with speed when snails were crawling horizontally, but we found a negative correlation when snails were crawling vertically. Interestingly, we found a positive correlation between wavelength and foot length for snails crawling on both vertical and horizontal surfaces. We also found a negative correlation between wave frequency and foot length for vertical crawling. These observations suggest that foot length does not predict crawling speed. There may be a trade-off between wavelength and frequency for snails crawling on vertical surface; as foot length and wavelength increase, wave frequency decreases and the overall crawling speed does not change.

48-6 HENSCHEN, A.E.*; WHITTINGHAM, L.A.; DUNN, P.O.; Univ. of Wisconsin, Milwaukee; hensche9@uwm.edu

Parasitism and ornamentation: a within-individual study in the common yellowthroat

Elaborate ornaments are hypothesized to honestly signal individual quality, including the ability of an individual to combat parasitic infection. Although there have been many studies of this hypothesis, the results of these studies have been mixed. One explanation for these varying results is that measures of ornaments and parasitic infection intensity are typically obtained only once for each individual. Therefore, correlations between ornamentation and parasitic infection intensity do not consider within-individual relationships, which may differ from between-individual relationships. We examined the relationship between ornaments and intensity of infection by haemosporidian parasites within individuals (using data from two breeding seasons) in the common yellowthroat, *Geothlypis trichas*. Male common yellowthroats have two ornaments, a melanin-based (black) mask and a carotenoid-based (yellow) bib, and in our study population females prefer to mate with males that have larger black masks. In addition, mask size is positively correlated with antibody production, body condition, survival, resistance to oxidative stress, and immune gene variation (major histocompatibility complex, MHC). Of the males analyzed over two years, 89.3% were infected with haemosporidian parasites during at least one breeding season. Interestingly, we found a positive within-individual relationship between mask size and infection intensity, but no relationship across individuals. This result is potentially explained by the high costs of immune response, which may outweigh the benefits of parasite clearance.

80-5 HERAS, J.*; AGUILAR, A.; University of California, Irvine, California State University, Los Angeles; herasj@uci.edu
Analysis of multiple transcriptomes to identify adaptive evolution in rockfishes (*Sebastes*) subgenus *Pteropodus*
 The genetic mechanisms that contribute to adaptation and speciation are not completely understood, especially within marine ecosystems. These evolutionary processes can be elucidated by directing attention to adaptive radiations, because they provide replicates of divergence within a given environment or time-frame. Marine rockfishes (genus *Sebastes*) are an exemplary demonstration of adaptive radiations and unique model system for studying adaptive evolution, because of the extensive diversity found within this group which include morphology, ecology, and a broad range of life spans. Brain transcriptomes were sequenced via RNA-Seq from three species within the subgenus *Pteropodus* (*S. carnatus*, *S. nebulosus*, and *S. maliger*) and a pair of related congeners to *Pteropodus* in order to find repeated patterns of adaptive evolution. De novo assemblies from these transcriptomes were used to identify 3,867 orthologous clusters, and 866 genes were subject to positive selection based on site models. Genes under positive selection belonged to a variety of gene functions that include sensory perception, growth, and metabolism. By using branch-site models, we found 686 genes subject to positive selection that were restricted to *Pteropodus* in comparison to closely related congeners. Genes under positive selection within *Pteropodus* were associated with visual perception, regulation of cell proliferation, and response to stimulus. These candidate genes will provide a better understanding of how this subgenus radiated and adapted to their respective habitats within the Northeast Pacific, and as more genetic patterns are identified with multiple species within *Sebastes*, we can make stronger inferences about adaptation and speciation.

S10-11 HERREL, A; CNRS/MNHN; anthony.herrel@mnhn.fr
Do adult phenotypes reflect selection on juvenile performance? A comparative study on bite force and head morphology in lizards.
 When competing for food or other resources, or when confronted with predators, young animals may be at a disadvantage relative to adults because of their smaller size. Additionally, the ongoing differentiation and growth of tissues may constrain performance during early ontogenetic stages. However, juveniles must feed before they can become reproductively active adults and as such the adult phenotype may be the result of an ontogenetic filter through selection on juvenile phenotype and performance. Here I present ontogenetic data on head morphology and bite force for different lizard species. I test whether adults reflect selection on juveniles by comparing slopes of growth trajectories before and after sexual maturity in males and females. Next, I test whether phylogenetic history drives the observed patterns by comparing ontogenetic trajectories both within and between two clades: lacertids and *Anolis* lizards for both sexes. Next, I test whether dietary specialization has an impact on the ontogenetic trajectory of head morphology and bite force by including data on dietary specialists. Finally, I compare the data for lizards to data on other vertebrates and discuss the generality of the observed patterns.

117-4 HERMANSON, J.W.*; DZAL, Y.A.; ORR, T.J.; YORK, J.M.; CZENZE, Z.J.; PARSONS, S.; Cornell Univ., Ithaca, Univ. of British Columbia, Vancouver, Univ. of Massachusetts, Amherst, University of Auckland, Queensland Univ. of Technology, Brisbane; jwh6@cornell.edu

The Efficiency of Bounding Vampires

Vampire bats, *Desmodus rotundus*, maximize their feeding cycle of one meal per day by being efficient in stalking and acquiring their food. Riskin and Hermanson studied the running gait of *D. rotundus* and observed long stride lengths and decreased stride frequencies. We measured the gait of 14 *D. rotundus* maintained for up to 10 minutes on a treadmill at speeds ranging from 0.23 to 0.74 m/s, which spanned from walking to running gaits. Bats transitioned between gaits at about 0.40 m/s. There was no significant change in stride duration or frequency with an increase in speed. The switch to bounding gait reduces the need for an increase in stride frequency. We measured O₂ consumption and CO₂ production both before running, and 1 and 5 minutes after exercise, and found that O₂ consumption increased 1 minute and 5 minutes after exercise. CO₂ levels increased significantly from baseline to 1 minute after exercise, but tended back towards pre-exercise level after 5 minutes. We measured body temperatures prior to and immediately after exercise. Baseline temperatures were about 38° C and increased to as much as 41.7° C suggesting bats were not able to maintain their baseline body temperature while running with the wings folded. In summary, we studied the unique bounding gait of *D. rotundus* and observed an increase of metabolism about 1.5 times greater than pre-exercise levels. While some running terrestrial mammals increase metabolism 6-8 fold, the running gait of vampires appears to be more efficient because of its low stride frequency and the use of relatively long thoracic limbs.

45-1 HESSEL, AL*; NISHIKAWA, KC; Northern Arizona University, Flagstaff AZ; alh385@nau.edu
Stretch shortening cycle protocols demonstrate the difference in eccentric properties of EDL and soleus muscles from wild type and mdm mice.

During animal movement, muscle length oscillations are common. We used a stretch-shortening cycle (SSC) protocol that stimulated muscles over the first third of lengthening to determine eccentric contraction properties during cyclical length changes. Mouse extensor digitorum longus (EDL, fast twitch) and soleus (slow twitch) muscles were used in the experiments. Additionally, due to the attenuation of eccentric contraction properties in mdm mice, these muscles were evaluated under the SSC protocol and results compared to wild-type muscles. We calculated the rate of force development (RFD) during eccentric contractions and total work. The results indicate that the RFD is larger in the EDL than the soleus, while both have larger RFDs than isometric contractions. Both EDL and soleus display large negative work, showing their absorptive properties during eccentric contractions. It is apparent that the EDL and soleus differ in muscle deactivation rates; the soleus maintains force well after stimulation ends while the EDL drops in force immediately after deactivation. We suggest that this is caused by the differences in calcium uptake rates. These results suggest that the soleus functions as a spring, while the EDL functions as a shock absorber. Mdm muscles showed reduced RFD and negative work compared to wild-type muscles, suggesting that a key component of the eccentric contraction mechanism is lost by the mdm mutation. The mdm mutation involves a deletion in part of the N2A region of titin, which could be involved in titin activation - a prediction of the winding filament hypothesis. Taken together, the SSC approach used here appears to be a good strategy to study and compare mechanics of different muscles with varying fiber types and functions.

83-7 HEWS, D.K.*; SEDDON, R.; ZÚÑIGA-VEGA, J.J.; VITAL-GARCIA, C.; MARTINS, EP; Indiana State University, Terre Haute, Universidad Nacional Autónoma de México, Mexico City, Universidad Autónoma de Ciudad Juárez, México, Indiana University, Bloomington; diana.hews@indstate.edu

Phylogenetic analyses of Sceloporus lizards reveal that species with abdominal blue patches have higher plasma testosterone levels

In *Sceloporus* lizards, male blue abdominal patches are ancestral while absence of blue patches is derived and has evolved independently several times. In the several species that have been studied, early exposure to androgens hormonally organizes the skin and blue patches are permanently expressed in adult males. The blue is exposed with specific postural displays used during male-male aggression. Hence expression of male blue in a given species is likely to often be associated with higher levels of territorial display behavior and activity, both of which are androgen-mediated behaviors. We test the hypothesis that males in blue species will have higher breeding-season levels of testosterone than males in non-blue species. We selected blue-loss species and a closer blue relative of each, in several clades within *Sceloporus*. Analyses controlling for phylogeny (using phylogenetically independent contrasts and phylogenetic generalized least squares) revealed that, in species in which males are blue (*grammicus*, *parvus*, *graciosus*, *occidentalis*), both males and females have significantly higher plasma testosterone than the comparable sex in species in which males have lost the blue patches (*megalapidurus*, *cozumelae*, *siniferus*, *virgatus*). Hence breeding-season levels of testosterone appear to co-evolve with the presence of blue abdominal patches in males, and females may show correlated responses.

55-5 HIERONYMUS, TL; NEOMED; thieronymus@neomed.edu
Hand skeleton and wingtip evolution in coraciiform and piciform birds

Differences in avian wingtip shape have well-characterized relationships to flight performance, migratory behavior, and feeding ecology. Kingfishers, woodpeckers, and their kin (Coraciimorphae) display a broad range of wingtip shapes, as well as a range of flight behaviors (including intermittent flight and flexed-wing upstroke) that cannot, as of yet, be clearly identified as adaptive responses to flight performance demands. These taxa also possess an unusual suite of morphologies in the forelimb skeleton at sites of flight feather attachment and articulation. This study examines the relationships between feeding and migration ecology, distal primary feather lengths, and forelimb musculoskeletal characters. Exploration of these relationships was conducted using phylogenetic co-inertia analysis on matrices of feeding and migratory behaviors (13 binary characters), lengths of primaries VI-X, and musculoskeletal morphology (79 categorical characters) for 65 Coraciimorph taxa. Coraciimorph birds maintain a relationship between pointed wingtip morphology and migratory behavior/aerial foraging that is consistent with other avian clades. The analysis of co-inertia between ecological characters and musculoskeletal characters points to several hot-spots of morphological variation, most notably the joint surfaces and muscle attachments of the carpometacarpus and digits II - III. A prominent and recurring pattern within piciform birds, with parallel occurrences in Bucerotiformes, involves a shift in joint surface conformation of the proximal phalanx of digit II, together with the formation of a deep sulcus in the joint surface for digit III and the elongation of the digit III phalanx. This morphology may be tied in to producing tip washout, a spanwise twist in the wing that may be advantageous for flight at low advance ratios

11-4 HIEBERT, T.C.*; MASLAKOVA, S.A.; Univ. of Oregon, Oregon Institute of Marine Biology; terrah@uoregon.edu

Evolution of lecithotrophy among nemertean pilidium larvae

The nemertean pilidium larva, produced by members of the clade Pilidiophora, is generally known to be planktotrophic and comes in many distinct forms. The typical pilidium is characterized by a large inflated episphere, a tucked-under hyposphere and lobes and lappets along the margin. It resembles a deer-stalker cap and feeds on unicellular algae using a ciliated band spanning its lobes and lappets. Pilidial development epitomizes maximally-indirect development: the juvenile arises from several independent rudiments within the larval body, and emerges during catastrophic metamorphosis, devouring the larval body. Other nemerteans (including the Hoplonemertea and the basal Palaeonemertea) develop more or less directly, producing uniformly ciliated superficially planula-like larvae, which may be non-feeding or macrophagous, i.e. feeding on macroscopic prey, such as other invertebrate larvae. Intriguingly, some pilidiophorans have superficially planula-like or trochophore-like larvae that are lecithotrophic. Recent studies by us and others suggest that at least 17 pilidiophoran species exhibit or are expected to have lecithotrophic development. Despite superficial resemblance to planuliform larvae of other nemerteans, or trochophores of other spiralian, these still develop via imaginal discs and undergo dramatic metamorphosis, thus retaining important features of pilidial development. Here we present our data on the larval forms of numerous pilidiophoran species, identified through DNA-barcoding, or embryologically. By placing this information into a phylogenetic context we show that lecithotrophy evolved many times independently within the Pilidiophora. Convergent evolution of non-feeding planuliform and trochophore-like larvae in nemerteans underscores the success of this body plan and life history.

55-2 HILL, JJ; University of Bristol ; jjhill100@gmail.com

Evolution of the Lower Jaw of Gnathostomes

The origin of the lower jaw is a key innovation that underpins the adaptive radiation of gnathostomes. 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. Changes in jaw shape and structure may have facilitated the emergence of different feeding behaviors. Here we present an analysis to deduce the timing (geological time) and tempo (evolutionary rates) 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. Outline analysis and extended eigenshape analysis were used to mathematically quantify variation in lower jaw morphology for four hundred lower jaw specimens spanning three major evolutionary transitions: the origin of Osteichthyes, Amniota and Mammalia. According to Principal Component Analysis (PCA), 22.4% of lower jaw shape variation is attributable to overall length of the dentary bone and/or the configuration of the bones located posteriorly. 16.6% of the variation is attributable to the robustness of the lower jaw, while the relative thickness of the dentary bone and the angle of the bones located posteriorly account for 11.9% of variation. Initial taxonomic group patterns illustrate that fish (including chondrichthyans and osteichthyans) are the most disparate group; birds show little variance in comparison to mammals except for the overall curvature of the mandible and thickness of the (fused) dentary bone. Squamates have less morphological diversity than mammals, but comparable disparity to birds whereas snakes have restricted morphospace occupation. From these results, it is likely that both ecological and functional consequences affect lower jaw shape variation and that transformation in lower jaw shape allowed different feeding behaviors to emerge.

33-2 HILL, A*; SCHENKELAARS, Q; HALL, C; QUINTERO, O; FIERRO-CONSTAIN, L; RENARD, E; BORCHIellini, C; University of Richmond, Virginia, Aix-Marseille University, Marseille, France; ahill2@richmond.edu

Role of the Rho/Rock pathway in sponge morphogenesis

The Rho associated protein kinase (ROCK) plays crucial roles in development across bilaterians including initiation of epithelial morphogenesis and regulation of cell shape and movement through action on the cytoskeleton. The Rho/Rock pathway is regulated, in part, by noncanonical Wnt signaling in complex animals. We studied the Rho/Rock pathway in the early branching freshwater sponge, *Ephydatia muelleri*. We demonstrated that *Ephydatia* ROCK protein exhibits Rho-kinase specific activity and is inhibited by two different commercially available inhibitors. We found that inhibition of ROCK activity prevented establishment of a functional aquiferous system (i.e., oscula and canals did not develop) and resulted in sponges forming unique outgrowths in the basal pinacoderm layer. We also found that *cyclin D* and *DNA methyltransferase 1* were over-expressed during outgrowth formation while key genes in the Wnt pathway were moderately down-regulated. These data imply that Rho/Rock signaling may have conserved roles in morphogenesis across animal evolution.

104-2 HIRAMATSU, L.*; GARLAND, JR., T.; Univ. of California, Riverside; lhira001@ucr.edu

Can a hybrid line break a selection limit on voluntary wheel running in mice?

An ongoing selection experiment for increased voluntary wheel running resulted in four replicate high runner (HR) lines that run ~3-fold more revolutions per day than do four non-selected control lines. A previous study showed that the 4 HR lines, and both sexes within lines, differed in the rate as well as the total amount of response to uniform selection, and in the number of generations to reach selection limits (V. Careau, et al. 2013. *Evolution* 67:3102-3119), which suggests that somewhat different genetic (and behavioral or physiological) factors underlie wheel running for the two sexes and in replicate lines, i.e., multiple solutions have evolved. A study on thermoregulatory behavior in mice showed that selection limits in replicate lines for nest building could be overcome with continued selection on hybrid lines for 10 generations (A. Bult and C. B. Lynch. 2000. *Behav. Genet.* 30:193-206). Therefore, in an attempt to break the wheel-running selection limit in the HR lines, we crossed two HR lines and continued selection on this hybrid line concurrent with the parental lines. As in a previous line-cross study (R. M. Hannon, et al. 2011. *Behav. Genet.* 41:615-624), male hybrids, but not female hybrids, showed heterosis in the F1. With continued selection for 6 generations, there is no clear indication that the hybrid line will break the selection limit, but more generations are forthcoming. Interestingly, both male and female hybrids ran faster than the pure parental lines in every generation, but running duration was intermediate or reduced in the hybrid line, suggesting a possible trade-off in running duration versus average speed. Further analyses will incorporate estimates of heritability and genetic correlations from an "animal model," accounting for the full pedigree of the three lines.

S7-10 HILL, Nichola J.*; MA, Eric J.; MEIXELL, Brandt W.; LINDBERG, Mark; BOYCE, Walter M.; RUNSTADLER, Jonathan A.; Massachusetts Institute of Technology, Cambridge, U.S. Geological Survey, Alaska, University of Alaska, Fairbanks, University of California, Davis; nhill@mit.edu

Evidence of seasonality in a host-pathogen system: Influenza across the annual cycle of wild birds

Influenza A Viruses (IAV) in nature must overcome shifting transmission barriers caused by the mobility of their primary host - migratory wild birds, which changes throughout the annual cycle. Using a phylogenetic network of viral sequences from North American wild birds, we demonstrate a shift from intraspecific to interspecific transmission that along with reassortment, allows IAV to achieve viral flow across successive seasons from summer to winter. This study supports a model of intense, short-chain transmission during summer breeding with minimal reassortment. As birds migrate from breeding sites to lower latitudes they become involved in transmission networks with greater connectivity to other bird species, with interspecific transmission of reassortant viruses peaking during the winter. We propose that switching transmission dynamics may be critical for the circulation of pathogens that infect mobile hosts in temperate climates with a strong seasonal signal. Understanding how transmission patterns vary seasonally may prove instructive for predicting how diseases spread after introduction into a migratory population and informing surveillance efforts.

52-6 HO, WW*; RIFFELL, J; University of Washington, Seattle; wwho@uw.edu

Scents of North American Pitcher plants (Sarraceniaceae) may mediate plant-insect interactions

Carnivorous plants attract insects to fulfill both reproductive and nutritive functions. This can lead to a potential trade-off that can be particularly acute for pollen-limited plants, because any nutritional benefits come at the cost of consuming pollinators. One way to alleviate this pollinator-prey conflict is for flowers and traps to produce divergent scents, in order to attract and specialize on separate classes of insect prey and pollinators. We examined the North American pitcher plants (Sarraceniaceae) to explore the suite of volatile compounds produced by trapping leaves and floral organs, and to test the hypothesis that scent might play a role in mediating pollinator-prey conflict. Volatiles from each pitcher plant species were captured using a combination of dynamic headspace sampling and solid phase microextraction (SPME), and analyzed using coupled gas chromatography and mass spectrometry (GCMS). Floral scents in the Sarraceniaceae were rich in mono- and sesquiterpenes, some of which were highly conserved across the family. Trapping leaves were also highly scented, and consistent with flower mimicry, traps produced a number of floral-typical odors. Nevertheless, relative proportions of odor compounds could be quite distinct across traps and flowers, and as were total volatile emissions. These results have implications for understanding the role of scent in mediating complex plant-insect interactions.

53-6 HOBBS, N.V.S.*; COBB, J.S.; THORNBUR, C.S.; Univ. of Rhode Island; nvshobbs@uri.edu

Conspecific tolerance and heterospecific competitiveness as a mechanism for invasion success.

The success of the invasive Asian shore crab, *Hemigrapsus sanguineus*, now commonly found along the rocky shores of the northwestern Atlantic and elsewhere, includes the ability to exclude other species from preferred rocky and cobble intertidal habitat. This study sought to test preference and competition for habitat types (cobble vs. sand) for *H. sanguineus* and two competitor species; the resident green crab, *Carcinus maenas*, and the native rock crab, *Cancer irroratus*. We paired similarly sized heterospecifics and conspecifics from each species, and also grouped combinations of *C. maenas* and *H. sanguineus* in sets of four, to test intra- and inter-specific competition at different densities. In individual controls, all three species significantly preferred cobble substrate. With paired conspecifics, both *H. sanguineus* individuals significantly preferred cobble, whereas *Carcinus* and *Cancer* individuals each excluded conspecifics from cobble. Similarly, *H. sanguineus* significantly excluded heterospecifics from cobble. In larger assemblages, *H. sanguineus* preferentially grouped under cobble, whereas *C. maenas* were more evenly distributed among habitat types. These patterns illustrate a clear mechanism for changes in distribution and habitat use among nearshore crab species following the introduction of *Hemigrapsus* in New England coastal systems.

80-7 HODIN, J.*; FERNER, M.C.; NG, G.; LOWE, C.J.; GAYLORD, B.; UW Friday Harbor Labs, SF National Estuarine Research Reserve, UC Davis Bodega Marine Lab, Hopkins Marine Station, UC Davis Bodega Marine Lab; hodin@uw.edu

Tumbling Paradigms: Brief turbulence exposure causes long term shifts in larval life history

Seashore marine organisms with a planktonic dispersal phase can release millions of offspring in their lifetimes, a tiny fraction of which survive to become juveniles back on the seafloor. One notable bottleneck in such life histories for benthic animals and algae is for the larva or dispersive stage to locate an appropriate place to settle into the benthos. Therefore, we predict that planktonic stages are under significant selection pressure to acquire the capacity to respond to any environmental signal that may indicate suitable benthic habitat. We have previously shown that one such signal for nearshore sea urchin and sand dollar larvae is fluid turbulence, which increases in intensity near coastlines, and exposure to these increased levels propels larvae from a non-responsive *pre-competent* period into a *competent* stage, where the larvae can respond to local cues and settle. Nevertheless, many such species exist as adults in highly specific benthic habitats that are far more rarely encountered than the associated turbulence conditions, which characterize broader habitat scales. Here we provide an account for this apparent mismatch in signal consonance at different scales: turbulence exposure seems to cause sand dollar (*Dendraster excentricus*) larvae to permanently shift from pre-competence to competence. This observation suggests a scenario where turbulence can activate a temporally extensive search image in larvae over a broad habitat range, a plausibly adaptive feature for larvae entering dynamic coastal environments. We also describe preliminary results indicating that sand dollars show population level variation in larval responsiveness to turbulence, thus suggesting scope for adaptation at this crucial planktonic-to-benthic transition.

S5-3 HOCH, JM*; SCHNECK, DT; NEUFELD, CJ; Nova Southeastern University, Quest University; jhoch@nova.edu
Ecology and evolution of phenotypic plasticity in the penis and appendages of barnacles

Barnacles, crustaceans of the order cirripedia, typically reproduce via pseudocopulation. Because they are sessile, their penis is long and flexible, capable of stretching to an impressive distance to reach mates. It is generally accordion-like in structure, inflated with hydrostatic pressure and controlled by longitudinal muscles. The penis is lined with setae that are likely used as chemosensory organs during the search for mates. Size, flexibility and setae patterns are all variable among species and are variable within many species in response to environmental conditions. For many barnacles, penis form is phenotypically plastic and may change form in response to waves, hydrodynamic forces or local population density. For others such variability is lacking. Species that have a distinct breeding season rapidly grow a penis in anticipation, only to cast it off with a molt shortly afterward. We will review the functional morphology of penises among the barnacles, discuss how environmental and social factors affect it and explore how this varies among different cirripede taxa. We will also consider the implications that variation in penis form has for mate competition, sex allocation, and population growth and spread.

77-6 HOEPFNER, A.R.*; MORROGH-BERNARD, H.; HUSSON, S.; HARRISON, M.; GOLLER, F.; University of Utah, Orangutan Tropical Peatland Project, Orangutan Tropical Peatland Project, University of Exeter, Orangutan Tropical Peatland Project, Orangutan Tropical Peatland Project, University of Utah; amanda.hoepfner@utah.edu

Social and environmental influences on long call behavior of male orangutans

Long-distance communication in primates is often examined in light of social influences, and less attention has been paid to environmental factors. Given the costly nature of vocal communication, examining environmental influences can help us understand proximate and ultimate mechanisms shaping the use of vocalization for social behavior. Male orangutans produce a long distance call, the long call, which indicates location, direction of travel, caller identity, etc. Multiple social factors may influence calling rate, however, it is not known to what degree environmental factors, such as food availability and weather conditions influence long call behavior. We tested the effects of environmental and social factors on long call rates of Bornean orangutans (*Pongo pygmaeus wurmbii*) in Central Kalimantan, using long-term behavioral data (2003-2012). We discovered that plant phenology (flowering and fruiting) was the most significant predictor of calling rate. Furthermore, forest productivity, assessed as litter fall data, was significantly correlated with male calling behavior. For social factors, the number of heard long calls influenced calling rate. "Winning" an interspecific conflict greatly increased male long call rate compared to those of individuals that recently "lost" a conflict. In addition, males increased their call rate prior to and during encounters with a female. These data show a clear influence of environmental factors on long calling behavior of orangutans and therefore highlights the importance of examining environmental variables along with social factors in affecting long call behavior.

29-4 HOFFMAN, S.K.*; SEITZ, K.W.; SANTOS, S.R.; Auburn University; ski0003@auburn.edu

The microbial biodiversity of Hawaii's anchialine habitats

The Hawaiian Islands are home to the greatest concentration of anchialine (landlocked coastal pools of brackish water) habitats in the world, but little has been done to characterize the endemic microbial communities inhabiting them. To this end, water column and benthic samples were collected from nine anchialine habitats on three islands (Oahu, Maui and Hawaii) in Summer 2010. To elucidate general trends in microbial diversity and community structure, the prokaryotic-specific V6 and eukaryotic-biased V9 regions of small subunit (SSU) rRNA were amplified and resulting products sequenced using high-throughput microbiome profiling by Illumina sequencing. The dataset encompassed 19,806,349 demultiplexed Illumina V6 reads in each paired-end direction and 13,128,796 V9 reads. These grouped into 1,776 and 1,337 operational taxonomic units (OTUs), respectively, using the QIIME open reference OTU algorithm. Taxonomic identities were assigned using the GreenGenes 13.8 database for V6 reads and the Silva 111 database for V9 reads. Overall prokaryotic and eukaryotic diversity indices and community characteristics will be discussed.

18-2 HOFMEISTER, N.R.*; RUBENSTEIN, D.R.; Columbia University; nrh44@cornell.edu

Environmental variability influences the evolution of the glucocorticoid receptor in African starlings

As climate change increases globally, vertebrates must cope with increasingly variable and unpredictable environmental conditions. The glucocorticoid stress response enables vertebrates to adjust their behavior and physiology to these changes in the environment, but organisms can respond to environmental stressors only when circulating hormones bind to the glucocorticoid receptor. A variety of environmental stressors influence glucocorticoid receptor expression, but DNA sequence variation in the glucocorticoid receptor gene (Nr3c1) also affects hormone binding affinity and transcriptional activity. Genetic variation in the HPA axis and particularly in the glucocorticoid receptor may facilitate adaptation to changing conditions. Here we examined signatures of selection in the glucocorticoid receptor in African starlings (Family: Sturnidae). African starlings occupy a range of environments that vary in precipitation across seasons and years, and many species may be behaviorally and physiologically adapted to environmentally unpredictable habitats. We sequenced Nr3c1 in 27 species of African starlings to investigate whether vertebrates cope with changing environmental conditions via adaptive genetic variation. Although we found low levels of sequence variation in Nr3c1 across species and populations of African starlings, substitution rate (dN/dS) is correlated with variance in precipitation. This relationship suggests that environmental variation does influence evolution of the glucocorticoid receptor in African Sturnidae. During the radiation of African starlings, fluctuating selective pressures as a result of environmental variability may have enabled these birds to adjust their stress response to particular environments.

102-4 HOFFMANN, S. L.*; PORTER, M. E.; Florida Atlantic University; shoffmann2014@fau.edu

Comparative axial musculature across shark families: implications for cephalofoil lift generation

Hammerhead sharks are known for their unique, dorso-ventrally compressed head called a cephalofoil. Due to its aerodynamic shape and anterior location, previous researchers hypothesized that the cephalofoil acts as lifting body, increasing the maneuverability of hammerhead sharks. Observational studies also show that scalloped hammerheads are actively moving their head approximately 10 degrees in volitional swimming, suggesting a degree of muscular control over the cephalofoil. Previously, it has been shown that scalloped hammerheads have significantly more axial muscles in the anterior trunk region than compared to the pointy nosed Galapagos reef shark. This allowed for a greater range of dorso-ventral movement of the cephalofoil. Here, we examine the hypaxial and epaxial muscles of three species of hammerhead shark (Sphyrnidae) in comparison to three species of pointy nosed sharks (Carcharhinidae). We hypothesized that hammerhead sharks would have more axial musculature in the anterior trunk region and that hypaxial muscles would originate more anteriorly in the hammerheads. We found significantly more axial muscle in the two more ancestral hammerhead species (scalloped and great), although the most derived bonnethead shark did not fall into this pattern. However, hypaxial musculature was present at the first gill slit in all hammerhead species and absent in the pointy nosed sharks. We predict that the farther anterior presence and greater mass of hypaxial and epaxial muscles in the anterior trunk region of hammerhead sharks correlates to the increased range of motion of the cephalofoil and, in turn, greater maneuverability of these sharks.

SI-4 HOKE, K.L.*; FISCHER, E.K.; GHALAMBOR, C.K.; STYNOSKI, J.L.; Colorado State University, Harvard University; kim.hoke@colostate.edu

Plasticity, homeostasis, and evolution across timescales

A long-standing debate revolves around whether phenotypic plasticity facilitates or slows evolution in new environments, yet we largely lack empirical evidence about the relationship between environmental influences on phenotypes and the evolutionary trajectories of populations. We recently showed that traits exhibiting non-adaptive plasticity were the first to adaptively evolve following an experimental introduction of Trinidadian guppies, *Poecilia reticulata*, that replicated natural colonizations. Specifically, these results demonstrated an overall discordance between the direction of ancestral plasticity and short-term evolution of gene expression levels in the brain. However, here we report that longer-term evolution in similar environments shows the opposite pattern, with the direction of plastic and evolved shifts in brain gene expression levels largely concordant. We argue that these brain transcriptome patterns reflect homeostasis within neural circuits that maintain coherent behavioral outputs despite varied neural states. We summarize how stochastic changes in neural mechanisms in response to novel environments affect the earliest stages of evolution, and contrast that with subsequent evolution that reshapes homeostatic and compensatory mechanisms to stabilize developmental processes and to produce integrated behavioral phenotypes.

68-5 HOLDING, M. L.*; BIARDI, J. E.; GIBBS, H. L.; Ohio State University, Fairfield University; matthewholding28@gmail.com
Snakes win: Coevolution of venom function and prey resistance in a rattlesnake-squirrel arms race

The concept of a coevolutionary arms race has been widely-used to account for paired trait variation in vertebrate predators and their prey yet empirical confirmations of this explanation are few. Here we examine the applicability of the arms race analogy to interactions between venomous Northern Pacific Rattlesnakes and their main prey California ground squirrels by assessing evolutionary causes of parallel variation in snake venom activity and prey resistance across 12 snake and prey populations. We used in-vitro assays of venom protein function and resistance factor effectiveness to show that: 1) there is substantial geographic variation in both venom enzymatic activity and resistance factor effectiveness consistent with coevolutionary dynamics across geographically distinct populations in these traits. 2) Statistical analysis of local adaptation shows evidence of the effectiveness of snake venom to overcome squirrel resistance but not of squirrel resistance to snake venom composition. 3) The local adaptation of snakes to squirrels has a strong environmental component in that it only occurs between snakes and squirrels in populations at different elevations, demonstrating the possible contributions from local adaptation analyses that incorporate environmental structure into statistical models. Our results support the coevolutionary arms race as a general explanation for geographic variation in both animal venoms and prey resistance, because variation in squirrel resistance is likely responsible for variable selection on venom phenotypes, suggesting a tight evolutionary relationship between the two species. Adaptation by predators to environmentally-determined physiological variation in prey needs to be considered as a mechanism for the evolutionary diversification in predatory traits such as venom at the molecular level.

45-4 HOLT, NC*; AZIZI, E; UC Irvine; natalie.c.holt@gmail.com
The effect of activation level on in vivo muscle lengths and velocities: do fibers always operate at their optima?

Skeletal muscle fibers can only generate high forces and powers over a narrow range of lengths and velocities. Many morphological and physiological properties of muscle are thought to have evolved to allow fibers to utilize these optimal lengths and velocities across a broad functional range. However, these optima are not constant; but rather depend on the activation state of the muscle. This study used the cane toad plantaris muscle to determine if and how muscle lengths and velocities changed with activation level *in vivo*, and how this related to changing optima. Muscle ergometry was used to determine the effect of activation level on force-length and power-velocity relationships. Electromyography and sonomicrometry were used to determine operating lengths and velocities at a range of *in vivo* activation levels. Operating velocities decreased in line with decreased optimal velocities; suggesting that operating velocity can be modulated and optimal velocities used at all activation levels. However, fiber operating lengths did not increase in line with increases in optimum length. At the highest *in vivo* activation levels, fibers shortened over the plateau of the maximally activated force-length relationship. However, at lower *in vivo* activation levels, fibers appeared to operate entirely on the ascending limb of sub-maximally activated force-length relationships. This suggests that the ability to change operating lengths is constrained, and that muscles are tuned to produce maximal performance when demand is highest. This study provides insight into the factors which have shaped muscle performance, and informs our understanding of how muscle operating lengths and velocities are modulated during locomotion.

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Mollusks to Medicine: Discovering novel therapeutics from the venom arsenal of predatory marine snails of the Terebridae

Venom peptides from predatory organisms are a resource for investigating evolutionary processes such as adaptive radiation or diversification, and exemplify promising targets for biomedical drug development. Using a venomomics approach, we identified novel terebrid venom peptides, teretoxins, and characterized their function as anti-cancer agents. The most common treatment for patients with liver cancer, hepatocellular carcinoma (HCC), is chemotherapy with doxorubicin, 5-fluorouracil or cisplatin, or targeted therapy with sorafenib. Compared to traditional cancer treatments, such as chemotherapy or radioactive treatment, peptidic compounds with high specificity for cancer cells provide a route of killing cancer cells while protecting normal cells. There is an urgent need to find novel therapies for HCC that are selective to liver and lead to better clinical outcomes. Venomous peptides are an innovative arena for investigation of novel cancer therapies. Most venomous snail peptides are antagonists that inhibit the function of their target ion channel. Membrane ion channels play an important role in cell proliferation and the development of cancer. We examined the cytotoxic and anticancer properties of novel teretoxin Tv1 from *Terebra variegata*. Results indicate Tv1 is highly specific in inhibiting liver cancer cell lines, preventing tumor cell migration using an apoptotic cell death pathway. We have identified a potential mechanism of action for Tv1 using migration assays, mouse models, and immunoblotting of certain key factors. The virtues and versatility of venom peptides have propelled them to the top of diagnostic and therapeutic arenas. Newly identified teretoxins, such as Tv1, have the potential to significantly advance the creation of dual purpose, targeted imaging agents and therapeutics for cancer cells.

85-2 HOLT, A.L.*; SWEENEY, A.M.; University of Pennsylvania; alisonsw@physics.upenn.edu

Light guides and open water camouflage in Galiteuthis

The midwater squid *Galiteuthis* has prominent photophores on the ventral surfaces of its eyes. These photophores presumably function in counter-illumination, a common strategy for camouflage from predators looking up for shadows in the strongly downwelling radiance of this habitat. The *Galiteuthis* photophore organ consists of densely-packed, fiber-like cells with a complex semi-coaxial geometry of repeating, dense layers. The layers are made of densely-packed protein surrounding a core of active cytoplasmic and have previously been suggested to function as light guides. Here, we computationally modeled light transmission through *Galiteuthis* photophores using the finite difference time domain (FDTD) method. We found that the cells are capable of guiding light, but we also observed a surprising degree of variation in both *Galiteuthis* light guide geometries and in the relative efficiencies of these cells in guiding light. Many of the most common geometries in the eye result in "leaky" light guides, however efficient light guides are also observed less frequently. When we placed these light guides in the context of the radiance distribution where *Galiteuthis* lives, we gained insight into a possible adaptive reason for this inefficiency. At the depths where *Galiteuthis* is found (250 - 600 m), the angular distribution of light is surprisingly variable both with depth and the content of the water column above the animal. Our calculations show that the light guides in *Galiteuthis* subocular photophores are able to recapitulate this variation in angular distribution of light. We suggest that by selectively activating geometrically distinct populations of its light-guiding cells for bioluminescence at different depths, the animal would be able to reproduce the environmental angular distribution of light at all positions in its habitat.

69-8 HOLT, A.L.*; SWEENEY, A.M.; University of Pennsylvania;
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Micro-PAM in clams: A system for single-cell-scale spatial resolution of photosynthetic efficiency

We recently described a "solar transformer" in photosymbiotic tridacnid giant clams, an evolved system that functions to redistribute solar flux incident on the clam's mantle to spatially patterned *Symbiodinium* algae within the mantle tissue. Our measurements and models suggest that even at the most extreme solar fluxes experienced in shallow tropical water near the equator, all *Symbiodinium* cells within the clam system could function at maximum photosynthetic efficiency, while all incident solar flux is used for photosynthesis. To gain further insight into the clam system and understand whether a synthetic algal culture system based on clam principles may be industrially useful, we sought to directly measure photosynthetic efficiency of *Symbiodinium* with single-cell spatial resolution within the clam. Typically, measurements of photosynthesis are made with pulse-amplitude modulated (PAM) fluorimeters that average the efficiency of hundreds or thousands of photosynthesizing cells over a large area on or close to the surface of an organism. To measure efficiency at small spatial scales and depths of millimeters within the highly absorbing and structured clam tissue, we developed a PAM instrument that has micron-scale spatial resolution. We modified our existing optical microprobe technique for measurements of scalar irradiance to mount two pulled optical fibers in the same ~50 μm scattering sphere. One fiber emits pulsed blue light, and the other is coupled to a spectrometer to measure chlorophyll fluorescence response - light both enters and exits the scattering sphere and our probe can "see" 10's of cells within the clam system. We will present proof-of-concept data from the instrument and initial estimates of photosynthetic efficiency from the interior of the clam system.

16-4 HOPKINS, W.A.*; FALLON, J.; BECK, M.; COE, B.H.;
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Hematological and immunological characteristics of eastern hellbenders infected with endo- and ecto-parasites

Disease is among the leading causes of global amphibian population declines. In North America, parasites are among the factors implicated in precipitous population declines of the giant hellbender salamander (*Cryptobranchus alleganiensis*), but the incidence of infections and their responses to infections remain poorly studied. We document the prevalence of leech and trypanosome infections in a population of eastern hellbenders and describe hematological and immunological characteristics of hellbenders with these infections. We hypothesized that hellbenders parasitized by trypanosomes would be anemic, that individuals infected with either or both parasites would exhibit shifts in white blood cell counts, and that hellbenders infected with leeches would exhibit altered plasma bactericidal capacity. We found that 24% and 68% of hellbenders were infected with leeches and trypanosomes (respectively), and 20% were co-infected. We found no evidence suggestive of anemia. However, hellbenders infected with either or both parasites exhibited marked shifts in circulating white blood cells that were consistent with adaptive responses to infection. In addition, we found that hellbenders harboring leeches had much higher plasma bactericidal capacity than individuals without leeches, and we offer multiple potential mechanistic explanations for this observation. We also found evidence that cellular and serological immune responses to parasites were less robust in juvenile than adult hellbenders. This finding warrants further investigation in light of the demographic characteristics, specifically the scarcity of juvenile age classes, of hellbender populations where disease is a possible contributor to declines. Our study provides fundamental insights into how hellbenders respond physiologically to endo- and ectoparasites, which could prove useful for their conservation.

48-2 HOOD, WR*; MOWRY, AV; KAVAZIS, AN; Auburn University, Auburn University ; wrhood@auburn.edu

Tissue-specific variation in mitochondrial function and implications for the costs of reproduction

A central tenet of biology is that the costs of reproduction contribute to reduced future fecundity and earlier senescence, but the mechanisms that underlie such a tradeoff are unclear. We reasoned that this tradeoff is driven, in part, by variation in energetic responses of different organs to the demands of reproduction. Mitochondria are the major source of ATP production in the body, but during OXPHOS mitochondria also emit ROS. Thus, we predicted that differences in mitochondrial bioenergetics and redox state would influence both the amount of resources that a female can allocate to current reproduction and the relative cost of current reproduction to future reproduction and survival. To this end, we evaluated changes in liver and skeletal muscle mitochondrial function between non-reproductive and lactating house mice. We found that skeletal muscle of lactating house mice displayed substrate-sparing strategies, including a more efficient basal respiration rate, reduced antioxidant production, and fewer mitochondrial subunits. The liver of lactating mice, however, showed a mix of costly and substrate-sparing changes. Measured costs included increased tissue synthesis, increased basal respiratory rate, and greater lipid peroxidation. Substrate-sparing strategies included reduced antioxidant production and a higher maximum respiratory rate. These findings suggest that adaptations by both the skeletal muscle and liver are likely to play important roles in supporting nutrient allocation to the developing young. Because the strategy for supporting reproduction differs between organs, the costs of reproduction also appear to vary between organs. Based on our findings, the long-term impact of reproduction on skeletal muscle is predicted to be minimal, while damage incurred by the liver may contribute to the tradeoff between reproduction and longevity.

S3-5 HOPPER, JV; Univ. of California, Berkeley;
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Parasites and Hosts in Motion: Two Case Studies from California

In an era of global warming, ecological communities are increasingly influenced by species invasions and shifting species ranges. To predict and mitigate potential negative impacts, it is important to understand how interactions with natural enemies can impact the distribution and abundance of species in motion. Shifting geographic ranges may allow hosts either to escape from natural enemies, such as parasites, parasitoids and predators, or to experience biotic resistance from novel resident enemies in their new range. In addition, whether the losses or gains of natural enemies during a range shift will affect the population abundance of a species in motion will depend on its abiotic tolerances. Here, I present two case studies examining the influence of natural enemies on host species following a range shift. In the first study, I examine the abundance and diversity of parasites of a large marine snail, Kelle's whelk (*Kelletia kelletii*), throughout its historical and expanded range in coastal California. Expanded-range populations of Kelle's whelk experienced substantially lower parasite abundance and diversity than the historical-range populations, perhaps due to the limitations resulting from complex parasite life cycles and a major biogeographical boundary. In the second study, I examine the abundance and diversity of parasitoids and pathogens of the light brown apple moth (*Epiphyas postvittana*), a highly polyphagous leafroller that recently invaded California from Australia. Although this leafroller continues to increase its range in coastal California, an initial increase in abundance in San Francisco and Santa Cruz has been followed by a subsequent decline. Constraints imposed by both abiotic factors and natural enemies are considered in the unusual decline of this exotic pest in California.

S7-5 HOYE, Bethany J*; BAUER, Silke S; Deakin University, Geelong, Australia, Swiss Institute for Ornithology; bethany.h@deakin.edu.au

How does infection alter animal migrations?

Migratory animals are thought to play a unique role in parasite dynamics and disease epidemics, both within and between resident communities. The importance of migration in disease ecology is, however, neither well established nor straightforward. Critically, the role of migrants may be complicated by the infection process itself, as animals must become infected prior to departure and be able to migrate successfully whilst infected in order to transport a parasite from one location to another. Adding to limited empirical data on the effects of infection on animal migrations, we show that Bewick's swans naturally infected with avian influenza virus delayed departure and traveled shorter distances during spring migration compared to uninfected individuals. Similarly, monarch butterflies infected with a protozoan parasite exhibited shorter flight distances, slower flight speeds, and lost proportionately more body mass for the distance flown; and during spring migration, passerines passing through a stop-over site later showed higher intensities of haemosporidian parasite infection. These disparate examples indicate that parasitic infections may alter migratory behavior through several potentially overlapping mechanisms. Infection may increase the cost of movement through changes to physical resistance or aerobic capacity; it may reduce the rate of energy accumulation prior to migration through decreased assimilation efficiencies and loss of appetite; or it may increase the rate of energy consumption during migration, with resources diverted to either the parasite or to the immune system. By incorporating these processes into a mechanistic model, we assess the degree to which different types of parasites may alter animal migrations.

10-5 HU, Y.*; DETRICH, H.W.; ALBERTSON, R.C.; University of Massachusetts Amherst, Northeastern University; yinan@cns.umass.edu

Craniofacial integration and evolution in an extreme environment: The adaptive diversification of Antarctic notothenioids

Antarctic notothenioid fishes offer a rare example of an extensive adaptive morphological radiation in an extreme environment. During a series of cooling events over the past 40 million years, the dramatic drop in water temperature of the Southern Ocean has led to the local extinction of most near-shore fish lineages. However, the evolution of anti-freeze glycoproteins in notothenioids enabled these ancestrally benthic fishes to survive and adapt in the sub-zero temperatures. The evolution of "secondary pelagicism", the reinvasion of the pelagic foraging niche, has fostered their morphological evolution, as they diversified to fill the newly available pelagic habitats. In this study, we used a 3D-morphometrics approach to investigate patterns of morphological variation in the craniofacial skeleton, and show that variation in head shape aligns well with niche partitioning among notothenioid fishes, highlighting a key role for divergent selection with respect to foraging niche in this group. We document further the evolution of morphological integration among notothenioids, and show that the evolution of exceptionally high levels of integration coincides with an accelerated rate of morphological evolution in the icefish family Channichthyidae. Taken together, we propose that shifts in integration can be considered as a key innovation in this group, and may have facilitated their radiation into the pelagic feeding habitats.

100-6 HRISTOV, NI*; SCHMIEDER, D; ALLEN, LC; BORISOV, I; SIEMERS, BM; Winston-Salem State University, NC, Max Planck Institute, Germany; hristovn@cdiunc.org

Turning Behavior and Flight Performance in European Horseshoe Bats

Prey capture for aerially hawking bats in or near dense vegetation is a difficult task. On the other hand, such environments attract abundant insect prey. To explore this resource, bats need to overcome sensory difficulties like avoid call masking and flight challenges by being able to fly slow, hover and turn aggressively. In Southeastern Europe all five European horseshoe bat species occur sympatrically - they forage within or close to different kinds of vegetation. Field studies indicate that the species differ in diet and hunting strategies to some extent, but they also show considerable overlap. How can several of these species share the same habitats and to what extent does niche partitioning occur? We set out to understand by testing the flight maneuverability in the three European Rhinolophid species (*R. euryale*, *R. ferrumequinum* and *R. mehelyi*) that best represented the range of body sizes. Minimum turning radius has been used previously as a measure of flight maneuverability. Therefore we tested the maneuverability of the 3 species by measuring their minimal turning radius along with other flight parameters during turning and obstacle avoidance under controlled laboratory conditions. We employed 3D, high-speed, motion-capture with synchronized sound-recording to study the evasive maneuvers of the bats. Three-dimensional reconstructions of the bats' flight trajectories indicate that there are no significant differences between the maneuverability of the three species as measured by their minimum turning radius. Other behavioral or ecological factors likely contribute to the realized niche partitioning presumed for these closely related and ecologically similar species.

42-3 HUANG, V*; LUBIN, F; University of Alabama at Birmingham; victoriahuang@uab.edu

Latent effects of environmental experience on learning and memory in zebrafish (*Danio rerio*)

A period of environmental experiences can influence an individual's brain and behavior, such as the capacity to retain memory, long after the insuring experience. Zebrafish (*Danio rerio*) have distinct behavioral, physiological, and neuronal responses to stressors. Though epigenetic changes such as histone modifications and DNA methylation have been shown to be responsive in the mammal brain, it is less known how these capabilities influence learning and memory in adult zebrafish, let alone these behaviors after stress experience. The extent of regenerative capacity of the zebrafish as a potentially mitigating response to chronic stress can be examined in learning and memory, in which cumulative stress effects can manifest. To address this question, we chronically stressed adult zebrafish with unpredictable environmental changes, and subsequently compared learning behavior and memory capabilities to those of unstressed zebrafish. In addition to behavior, we compared gene expression and analyzed associated epigenetic modifications such as histone methylation related to the aforementioned behaviors, as well as stress, in the telencephalon. These findings elucidate the capacity of a teleost species to learn and remember a novel association after a chronic stress experience. Focusing on epigenetic transcriptional regulation of gene expression changes in the telencephalon will contribute to a better understanding of mechanisms of neural gene regulation associated with learning and memory formation that are susceptible to stress.

39-7 HUBBARD, A.H.*; TREIBLE, W.R.; BOMHOFF, M.D.; DAVIS, R.V; LYONS, E; SCHMIDT, C.J.; University of Delaware, University of Arizona, University of Arizona; *allenhub@udel.edu*
fRNAkenseq: a Powered-by-iPlant RNA Sequencing Analysis Platform

We present fRNAkenseq: a novel, server based software platform for integrating various RNA sequencing analyses into a single powered-by-iPlant tool. fRNAkenseq is a complete analysis package, using iPlant compute resources to facilitate RNAseq analysis in a continuous workflow from FastQ file to enrichment analysis. fRNAkenseq implements a lightweight user interface and requires no prior computational experience. fRNAkenseq has access to the 20,000+ genome files (FASTA and Annotation) compiled by iPlant, from sources as diverse as NCBI, BGI, JGI and Ensembl, with the option for users to upload their own draft genome through another powered-by-iPlant tool, CoGE. fRNAkenseq is ideal for storage and access of boutique or draft genomes with an emphasis on downstream RNAseq analysis. This is made possible by iPlant's data storage system. Using iPlant's computational resources and existing powered-by-iPlant platforms, fRNAkenseq leverages the Tuxedo pipeline and several R Bioconductor packages into a scalable workflow that requires no prior computational experience. Thus, it is an ideal tool for biologists and biostatisticians working with large-scale data. Capitalizing on its integration with the Powered by iPlant Program and use of iPlant APIs, fRNAkenseq allows access to thousands of curated annotation and FASTA files of all species from the NCBI database, making them easily available for RNA seq analysis. To aid the transition from data to insight, fRNAkenseq employs the visualization abilities of cummeRbund and access to pathway resources. By combining multiple analyses in a scalable fashion, fRNAkenseq provides a functional tool that enables researchers to select the most promising genes for further investigation from mRNA sequencing as well as manage the challengingly large sequence files.

96-5 HULETT, R.E.*; GOSLINER, T.M.; California Academy of Sciences/San Francisco State University, California Academy of Sciences; *ryanehulett@gmail.com*

Spots, stripes, and slugs: Insight into color and biogeography of tritoniid nudibranchs

Nudibranchs offer a fascinating system to investigate biogeography and color evolution due to their ranges and mesmerizing pigmentation. The overall lack of a fossil record requires the use of morphological and molecular data to piece together this group's enigmatic history. The family Tritoniidae (Nudibranchia: Cladobranchia: Dendronotidae) is often cryptic on their octocoral prey, brilliantly mimicking their shape and color. The family has a murky evolutionary history; limited morphological and molecular work has been previously performed to resolve these relationships. This study examines the phylogeny of the two largest genera, *Marionia* and *Tritonia*, by the concatenation of four gene fragments (16S+28S+COI+H3). Maximum likelihood and Bayesian inference analyses shed new light onto the evolutionary relationships of these groups and an ancestral area reconstruction provides insight into biogeographic origins. *Marionia* and *Tritonia* are returned as well-supported, monophyletic groups with ancestral origins in the Indo-Pacific. The importance of color is reiterated in *Marionia*, which is divided into three clades defined by striping pattern, spots, and translucence. The discovery of these well-supported clades and biogeographic origins stresses the importance of color in nudibranchs and the breadth of biodiversity found in the Indo-Pacific.

127-2 HUBEL, TY*; BARTLAM-BROOKS, HLA; BENNITT, E; EVANS, H; WILSON, AM; Royal Veterinary College, UK, University of Botswana, Okavango Research Institute Gaborone, Botswana; *thubel@rvc.ac.uk*

Comparison of energetics and athletic performance of three large African herbivores

Zebra (*Equus quagga*), wildebeest (*Connochaetes taurinus*) and tsessebe (*Damaliscus lunatus*) are large African herbivores in the Okavango Delta ecosystem. Zebra and wildebeest are known for the ability to cover long distances and in some ecosystems seasonally migrate, while tsessebe are often described as the fastest antelope species. We collared eight members of each species with high resolution GPS/IMU collars to gain insight into their daily energy expenditure and the extent of their ranging and running performance. Our study animals are almost exclusively permanent residents of the study area, with the exception of two zebra that participated in the seasonal migration between the Delta and Makgadikgadi Pans National Park, the second longest known migration route. Resident zebra traveled distances of up to 35 km per day on multiple occasions. All zebra frequently achieved speeds above 6 m/s, often multiple times per day with no diurnal pattern in when runs occurred. Energy expenditure was calculated from daily distances travelled, speed and size derived cost of transport. High speed running events are examined in regards of speed, acceleration and maneuverability (turning radius and centripetal acceleration).

S10-4 HULSEY, C. Darrin*; MEYER, A.; Univ. of Konstanz; *darrin.hulsey@uni-konstanz.de*

Evolutionary consequences of modularity in vertebrate dentitions at multiple levels of biological design

Modularity at multiple levels of the genotype to phenotype map can influence the adaptive evolution of teeth. From ecology to genomics, teeth provide an integrative link between virtually every discipline in the biological sciences. Using examples from a wide array of vertebrates but with a bias towards studies of cichlid fishes, I will discuss how understanding modularity in teeth provides exceptional insight into processes such as correlated evolution, the importance of gene duplication, convergence, the primacy of protein coding versus regulatory changes, as well as many-to-one mapping during adaptive radiation.

11-3 HUNT, M*; MASLAKOVA, SA; Oregon Institute of Marine Biology, University of Oregon; mhunt@uoregon.edu
Development of a non-feeding trochophore-like pilidium
 The pilidium larva is an idiosyncrasy defining one nemertean clade, the Pilidiophora. It forms the juvenile from a series of isolated rudiments called imaginal discs, then erupts through and eats the larval body in a catastrophic metamorphosis. A typical pilidium is planktotrophic and looks like a hat, but pilidial diversity is much broader than previously imagined. One of the most intriguingly recently discovered larval types is the lecithotrophic, superficially trochophore-like *pilidium nielsenii* of an undescribed species. *Pilidium nielsenii* bears two circumferential ciliary bands evoking the prototroch and telotroch of a trochophore larva, found in related Spiralian phyla. One might interpret *pilidium nielsenii* as a reversion to the ancestral condition, or as an example of convergence upon a successful body plan. The typical pilidium is already a highly derived larval form within Nemertea, so a reversion seems unlikely. To more definitely establish *pilidium nielsenii* as an instance of convergence and determine how much of the pilidial developmental pattern is conserved, we describe and illustrate its development with confocal microscopy and compare it to that of a typical planktotrophic pilidium. Their development is strikingly similar; the juvenile develops via three paired imaginal discs and two unpaired rudiments, then emerges in a catastrophic metamorphosis. *Pilidium nielsenii* even develops transient lobes and lappets in early stages, re-creating the hat-like appearance of a typical pilidium. It does diverge from typical pilidial development in the orientation of the anteroposterior (AP) axis of the juvenile to the AP axis of the larval body, and juvenile development is markedly accelerated. This is the first modern description of development of a pilidiophoran with a free-swimming lecithotrophic larva.

46-4 HUNT, K.E.*; BURGESS, E.A.; ROLLAND, R.M.; New England Aquarium; huntk@neaq.org
Beyond just cort: fecal aldosterone as a complementary measure of adrenal activation in North Atlantic right whales (*Eubalaena glacialis*)

There has been great interest in fecal glucocorticoids (fGCs) as a measure of stress in large whales, and elevated fGCs have been shown to correlate with stressors such as entanglement and ocean noise in North Atlantic right whales (*Eubalaena glacialis*, NARW). However, fGCs can reflect numerous different influences besides anthropogenic stressors. Additionally, some glucocorticoid assays have mild cross-reactivity with fecal metabolites of reproductive steroids, and it is unclear to what extent such cross-reactivity might influence fGC data. Fecal mineralocorticoids (fMCs, aldosterone and its fecal metabolites) may offer a complementary measure that could help identify true adrenal activation. The mineralocorticoids are also released from the mammalian adrenal gland and typically rise in parallel with GCs during a physiological stress response. To assess feasibility of fMC assays for large whales, we tested three commercial aldosterone immunoassays with pooled NARW fecal extract. All three assays demonstrated good parallelism and accuracy, indicating that aldosterone fecal metabolites are likely present in NARW feces and are readily measurable with aldosterone antibodies. We then applied the most sensitive of these assays to 324 NARW fecal samples, assessing relationships of fMCs with existing fGC data and with reproductive steroids from the same samples. As predicted, fMCs were strongly correlated with fGCs, though the aldosterone antibody had no detectable cross-reactivity to reproductive steroids and extremely low cross-reactivity to glucocorticoids. fGC data therefore appear to primarily reflect adrenal activity. Addition of fMCs to a fecal endocrine panel shows potential for identification of cases of true adrenal activation, and may potentially help disentangle the various causes of fGC elevations.

50-6 HUNT, K.S.; LINDSAY, S.M.*; University of Maine, Orono; slindsay@maine.edu
Do nuchal organs aid navigation? Assessing polychaete responses to subsurface chemical cues

In marine sediments, burrowing and feeding by infauna (e.g. polychaetes, burrowing shrimp) result in sediment mixing and benthic-pelagic exchange of solutes, and such bioturbation plays a key role in benthic ecosystem dynamics. Although many infaunal taxa are equipped with chemosensory structures (e.g. polychaete nuchal organs), little is known about how infaunal burrowers detect and respond to chemical cues below the sediment surface. In a series of behavioral experiments, we examined responses of the polychaete *Alitta virens* to subsurface chemical cues. Using time-lapse photography and time-resolved, digital, particle-imaging velocimetry (PIV), we tracked worms' positions relative to the position of clam juice injected into the sediment (no-flow experiments), or released via subsurface drip (flow-through experiments). In no-flow experiments, worms with blocked (super-glued) nuchal organs did not respond positively to the cue, but intact worms (control) and worms with superglue on the 3rd chaetiger (glue control) did. These results support the hypothesis that nuchal organs mediate subsurface responses to chemical cues. PIV provided information about worms' subsurface activity and revealed subtle differences in burrowing dynamics for intact worms responding to a subsurface drip of seawater or clam juice in flow-through experiments. More worms increased average path speed in response to clam juice than in response to seawater, but overall, mean path speeds were not significantly different. Worms responding to clam juice had straighter paths (i.e., net-to-gross-displacement ratio closer to 1) compared to those responding to seawater. Supported by NSF grant OCE0851172 to P.A.Jumars and SML.

46-5 HUNT, K.E.*; ROBBINS, J.; ROLLAND, R.M.; New England Aquarium, Center for Coastal Studies; huntk@neaq.org
Development of fecal hormone techniques for assessment of reproduction and stress in humpback whales (*Megaptera novaeangliae*)

Fecal hormone analysis shows potential for noninvasive assessment of population-level patterns in stress and reproduction in large whales. However, data are lacking on collection methodology and assay validations for most species, particularly those mysticetes that have variable diets and highly liquid feces. We tested fecal-collection techniques for humpback whales (*Megaptera novaeangliae*), followed by assay validations for five hormone classes (progesterins, estrogens, androgens, glucocorticoids, thyroid hormones) and comparisons to known sex and reproductive state where possible. 55 humpback fecal samples were collected at sea during 2012-2013, of which 48 were large enough to assay for multiple hormones and 43 were from known whales. All five hormone assays were successfully validated with parallelism and accuracy tests. Calf samples had much higher fecal hormone content than samples from other whales, potentially due to ingestion of maternal steroids via milk fat. Females resighted with a calf the next year (e.g. definitely pregnant) had significantly higher fecal progesterins ($P=0.0021$, t-test) than females resighted but with no calf (e.g. probably nonpregnant). One potential case of calf loss was noted. Males had significantly higher fecal androgens than nonpregnant females ($P=0.0396$, t-test). The only sample from an entangled whale had fecal glucocorticoids more than two standard deviations above the population mean. Fecal estrogens and fecal thyroid hormones showed no obvious trends, though sample size was low. Despite the challenges of sample collection and despite low sample mass, fecal sampling appears viable for humpback whales and produces biologically relevant data that could be useful for assessment of pregnancy, calf loss, other reproductive parameters, and stress physiology.

130-2 HUNT, EM*; MILLER, LP; DENNY, MW; ALLEN, BJ; California State University Long Beach, Hopkins Marine Station of Stanford University; elizabethhunt0524@gmail.com
Recent thermal history determines microalgal response to acute temperature stress on rocky shores

In addition to higher average temperatures, global climate change is also resulting in higher temperature variability, increasing the risk that species' tolerance limits will be exceeded. Our study was designed to determine how prior thermal history and the intensity of an acute high temperature challenge might affect post-stress photosynthetic performance of microalgae on rocky shores. We manipulated temperature variability on artificial substrata in the mid-intertidal zone, allowing microalgae to settle under low, natural, or high variation for at least one month. We then measured community-level net photosynthetic rate (NPR) for each experimental plate under benign conditions with a LICOR LX-1600, before and after exposure to one of five peak temperatures (18, 24, 28, 32, or 36 °C) during a 4.5-hour simulated low tide. The more extreme the acute temperature challenge, the more negative the effect on post-exposure NPR. More surprisingly, microalgae grown on low variation plates in the field were twice as vulnerable as microalgae on normal and high variability plates. We are using scanning electron microscopy (SEM) and high-performance liquid chromatography (HPLC) to analyze changes in the identity and relative abundances of microalgal taxa for indications of variation in microalgal functional group composition and diversity.

33-3 HUSSAIN, Y*; GUASTO, J.S.; ZIMMER, R.K.; STOCKER, R; RIFFELL, J.A.; University of Washington, Seattle, Tufts University, Medford, MA, University of California, Los Angeles, ETH Zurich, Switzerland; hyasmeen@uw.edu
Individual fertilization success in sea urchins is dependent on sperm chemotaxis

Reproductive success fundamentally shapes an organism's ecology and evolution. A critical component of individual fertilization success is a sperm's ability to out-compete the sperm of other males to locate a conspecific egg. Sperm chemotaxis, the ability of sperm to navigate towards eggs using chemical signals, has been studied for over a century, but studies of chemotaxis have long assumed that chemotaxis improves individual male fitness without explicit evidence to support this claim. Here, we use a chemoattractant-digesting peptidase and a microfluidic device coupled with fertilization assays to assess the effect of sperm chemotaxis on individual male fertilization success in the sea urchin *Lytechinus pictus*. We show that removing chemoattractant from the gametic environment decreases fertilization success. We further find that individual male differences in chemotaxis to a well-defined gradient of species-specific attractant correlate with individual male differences in fertilization success. These results conclusively demonstrate that sperm chemotaxis is an important contributor to individual reproductive success.

115-4 HURLESS, V.; PICKETT, C.J.; ZELLER, R.W.*; San Diego State University; rzeller@mail.sdsu.edu

Evolutionary similarities between the peripheral nervous system of the ascidian larva and vertebrate sensory hair cells

Metazoan ciliated sensory neurons and derivatives, such as the hair cells found in the vertebrate inner ear are hypothesized to share a common evolutionary origin. In the ascidian larva, the peripheral nervous system (PNS) consists of a series of ciliated epidermal sensory neurons (ESNs), which primarily run down the dorsal and ventral midlines of the tail. Our lab has shown that at least four transcription factors and at least one microRNA operate downstream of a Notch-Delta mediated mechanism which specifies PNS neurons from the midline epidermal cells. These molecules share conserved roles with the specification of vertebrate hair cells, supporting the hypothesis of a common evolutionary origin. Here we report on the identification of large numbers of genes that are shared between ESNs and hair cells as revealed by comparative RNA-SEQ of wild type and transgenic ascidian larvae. Our preliminary analysis identified multiple structural genes expressed in ascidian ESNs that are known components of the stereo cilia found in vertebrate hair cells including proteins found within the cilia, proteins that form tip link and ankle link connections and proteins which regulate ion homeostasis. In addition, we found that numerous mechanosensory channel proteins known to be expressed in hair cells are also expressed in the PNS ESNs. The ESNs are assumed to be mechanosensory, but this is the first direct molecular evidence that they express multiple proteins known to be required for such a function. Our results provide insight into the novel innovations that evolved within vertebrates to generate hair cells.

14-1 HUTCHINSON, J.R.*; ELLIS, R.G.; RANKIN, J.W.; Royal Veterinary College, UK; jhutchinson@rvc.ac.uk

Predicting greyhound sit-to-stand muscle dynamics using computer simulation

Despite being a critical daily activity for many mammals, how species transition from supine to standing postures is not clear. Only human sit-to-stand (STS) movement has been studied extensively: the movement has been shown to be a demanding task, presumably due to the unique musculoskeletal demands associated with the motion. However, how demanding this movement is for other tetrapods is unclear. For example, cursorial-limbed animals such as the greyhound have adaptations for running, which uses small joint ranges of motion when the limb is loaded most. In contrast, the STS movement constitutes a postural change that requires large joint angle excursions and muscle force generation occurs over a wide range of limb configurations, including those with poor mechanical advantage. We aimed to determine whether, like in humans, STS transitions in cursorial mammals are highly demanding. We combined a musculoskeletal model of a greyhound hindlimb with experimental data to generate computer simulations of the STS movement and quantify muscle activity and fibre length changes. Simulations revealed that Mm. biceps femoris, gastrocnemius, and extensor digitorum longus activity remained high throughout the first half of the motion when joint angles deviated most from "normal" locomotor angles. Hip adductor muscle activity was also high; hence, greyhounds may compensate for limitations in sagittal plane muscle capacity by recruiting non-sagittal hip muscles. Although limb forces are less than those experienced in running during STS, substantial forces from the limb muscles are still required due to unfavourable mechanical advantage - these demands are further amplified by muscle fibres operating at suboptimal lengths over much of the motion.

82-4 INGERSOLL, R.*; LENTINK, D.; Stanford University; riversi@stanford.edu

Symmetric aerodynamic power in hovering hummingbirds requires extreme muscle output

Hummingbirds have the unique ability to continuously hover, which aerodynamically distinguishes them from other birds. The near kinematic symmetry between the upstroke and downstroke allows hummingbirds to generate aerodynamic lift force during both phases of their wingbeat to support their weight. We have developed a novel aerodynamic force platform to measure these aerodynamic lift forces noninvasively *in vivo*. By combining these wingbeat resolved forces with detailed 3D wing kinematics and applying an improved quasi-steady power model, new insight into how hummingbirds power their flight within a wingbeat are made, and muscle physiology consequences are determined. We also demonstrate our new method can be used to measure aerodynamic bodyweight support of voluntary participating hummingbirds freely fly into the setup to feed from an artificial flower. The new method is applicable to measure forces of flying animals and robots in general.

12-3 IRSCHICK, D.*; CROSBY, A; FEDERLE, W; University of Massachusetts at Amherst, Cambridge University; irschick@bio.umass.edu

A broad perspective on the evolution of geckos: Form, function, and ecology

Geckos are renowned for their diverse ecology and morphology. However, the vast majority of work on this group has centered either on the anatomy or function of their toepads, or on their phylogenetic relationships. However, relatively little effort has been devoted to synthesize how their toepads, toepad function, body form have co-evolved in a macroevolutionary framework. Over several years, our laboratories have been synthesizing ecological, functional, and morphological data, and evolutionary analyses show new insights into how the complex behavior of geckos has evolved. On the one hand, mechanics may explain much of the increase in adhesive ability both among and within species, and also, the radiation into key habitats (e.g., rocks) may have led to new adhesive abilities. Finally, the evolution of gecko feet is noted by remarkable convergence and evolutionary lability, which has followed to a large extent the evolution of body shape. Together, these data point towards a complex view of a dynamic and changing lineage.

89-6 ISAACS, M.R.*; WARD, J.; MCGOWAN, C.P.; LEE, D.V.; University of Nevada, Las Vegas, SpringActive Inc., Tempe, AZ, Univ. of Idaho; isaacsm@unlv.nevada.edu

Walking dynamics and speed effects in persons wearing a passive foot-ankle prosthesis

This research compares healthy unilateral transtibial amputees utilizing passive-elastic foot-ankle prosthesis and control subjects walking at normalized dimensionless speeds to assess collision-based angles, a set of kinetic parameters that relate supporting ground reaction forces (GRFs) and center of mass (CoM) oscillations. The persons with amputees (PWAs) tested in this study demonstrate a unique condition characterized by a complete biological foot-ankle and a mechanically constrained prosthetic which influences the dynamics of the human walking gait. The study design tests our hypothesis that walking dynamics, especially during double stance, have the potential for higher costs of mechanical transport (CoT_{mech}), as determined by collision-based analysis, due to changes in the step-to-step transition for subjects employing an unactuated, spring-driven passive foot-ankle prosthesis. Our approach looks to gauge the effectiveness of the passive devices in restoring walking gait dynamics and assesses the importance of the step-to-step transition. Our examination of the kinetic relationship of the subject's CoM and GRFs of discrete footfalls reveals the cooperative effort of the opposing lower limbs that generate resultant forces that redirect the CoM in a mechanically efficient manner from one step to the next. The relationship we typify in this study proposes reduced CoT_{mech} due to the step-to-step transition that would otherwise be higher if the two steps were not contemporaneous. The collision-based angle approach we present contrasts the traditional understandings of the walking gait as an out-of-phase exchange of potential and kinetic energy system to one that demonstrates reduction in the ratio of actual to potential collision costs of the system.

37-1 IVANINA, A; HAIDER, F; SOKOLOVA, I*; University of North Carolina at Charlotte, University of the Basque Country; isokolov@uncc.edu

The role of mitochondrial resilience and oxidative stress in hypoxia tolerance of marine mollusks

Marine bivalves are champions of hypoxia tolerance commonly exposed to hypoxia due to the tidal, diurnal and seasonal oxygen cycles. Mitochondria are a hub of hypoxic damage in sensitive species, and it remains unknown how mitochondrial functions are preserved during hypoxia-reoxygenation in mollusks. We found that hypoxia and reoxygenation stimulate activity of mitochondrial electron transport chain in a hypoxia tolerant species, clams *Mercenaria mercenaria* but lead to mitochondrial deterioration and loss of OXPHOS capacity in hypoxia sensitive scallops *Argopecten irradians*. Hypoxia-reoxygenation led to upregulation of the mitochondrial heat shock protein HSP60 indicating damage to mitochondrial proteins in scallops but not in clams. Activities of proteasome and mitochondrial Lon protease were suppressed and phosphorylation of the elongation factor 1 elevated during hypoxia in clams indicating downregulation of the protein turnover in hypoxia-tolerant species. Unlike scallops, clam mitochondria respired ~3 times faster with succinate than pyruvate and were less sensitive to accumulation of bicarbonate and low pH commonly occurring during hypoxia. Fast oxidation of succinate may allow for rapid generation of ATP and restoration of acid-base balance by removing accumulated succinate during post-hypoxic recovery in clams. Mitochondrial ROS production was significantly higher in clams than in scallops, but no oxidative damage to mitochondrial lipids was observed in either species indicating that oxidative stress plays no role in species-specific resilience to oxygen fluctuations. Thus, mitochondrial adaptations in hypoxia-tolerant mollusks involve high capacity to oxidize anaerobic end products, tolerance to bicarbonate and low pH, enhanced protein homeostasis and reduction of the protein turnover during hypoxia.

7-5 IVANOV, B.M*; SELZNICK, L.A.; JOHNSON, M.A.; Trinity University; bandre@trinity.edu

What does it mean to be green? Body color and social interaction in the green anole lizard

Color can communicate complex social information, particularly in animals that have the ability to change color rapidly. One example of this phenomenon occurs in *Anolis* lizards, which can change their dorsal coloration between their base color and dark brown within seconds. While color changes occur frequently during anole social interactions, it is not fully understood what color communicates. To determine whether male and female green anoles (*A. carolinensis*) use color similarly in social interactions, and to determine if lizard behavior and morphology are associated with body color, we collected 12 lizards of each sex. We first performed daily color checks to establish whether an individual's predominant color was green or brown. Next, in a series of behavioral trials, lizards were paired with a lizard of the opposite sex for two weeks, and then a novel lizard of the opposite sex or a familiar lizard of the opposite sex (i.e., the original pairing) for one day. Finally, lizards were sequentially paired with four same-sex lizards in a series of dominance trials. Results showed that females were green in 40-87% of color checks, while males were green 13-100% of the time, and that no morphological trait was associated with this variation. However, when paired with females, males with a predominant green color were more likely to perch in open areas, suggesting that green color indicates a bolder personality. Predominantly green males also displayed more often and won more dominance trials when paired with other males. While female color was not associated with behavior in same sex trials, females were more likely to be green in a trial with a novel male than a familiar one. These results suggest that body color plays different roles in male and female social interactions.

1-1 JAGNANDAN, K*; HIGHAM, T.E.; University of California, Riverside; kevin.jagnandan@email.ucr.edu

The ups and downs of tail autotomy: Assessing the effects of tail loss on incline and decline locomotion

Tail autotomy is the voluntary shedding of the tail, which is often used to distract a predator or escape its grasp. While this increases the likelihood of survival during the encounter, the morphological change accompanying this escape strategy can significantly alter locomotor performance and mechanics. Although previously described on level and vertical substrates, it is unclear how autotomy impacts locomotion on uphill and downhill slopes. In their natural environment, terrestrial animals frequently move over complex terrain, and these sloped surfaces alter the demand on the musculoskeletal system. Similarly, tail autotomy alters locomotor demand due to the rapid loss of mass, cranial shift of the center of mass, and loss of tail function. Therefore, we hypothesize that shedding the tail will impact the kinematic adjustments that lizards make as they move up and down different inclines. Video was obtained for ten leopard geckos (*Eublepharis macularius*) walking on five inclines: level (0°), up (30° and 60°), and down (-30° and -60°) before and after the tail was autotomized. Three-dimensional kinematics of the body, fore- and hind limbs were assessed for 3-5 strides per individual for each combination of treatments. Compared to level locomotion, walking uphill or downhill resulted in reduced speed and stride length, increased stance time, and increased flexion of the joints. Autotomizing the tail negated these changes (excluding joint flexion) when walking uphill, but not downhill. On all inclines, flexion of the joints was more prominent in post-autotomy trials. These results suggest that autotomy may augment uphill locomotion, but moving downhill remains problematic. Supported by NSF IOS-1147043 and the UCR Newell Fund.

93-4 JACKSON, BE*; MUNSON-CATT, AC; Longwood Univ.; jacksonbe3@longwood.edu

Dog-fighting bees: 3D tracking of nest defense flight performance in eastern carpenter bees, *Xylocopa virginica*

Aggressive conspecific interactions offer unique opportunities to examine animal locomotion at the edge of the performance envelope, and may provide insight to mechanical limitations on, and energetic costs of, animal behavior. Female eastern carpenter bees (*Xylocopa virginica*) are large pollinators that bore into wooden structures to build nesting tunnels, which they vigorously defend from other carpenter bees nesting in the same structure. We used three GoPro cameras to record (120 Hz) wild bee behavior as they built and defended nests in the author's porch in Charlottesville, VA, USA. Videos were synchronized, calibrated, and analyzed using the new open-source Argus package and custom Matlab auto-tracking scripts to generate 3D paths. Over two recording days we recorded over 1200 flight paths, each lasting 1-10 s, by an estimated 25 individual bees. Paths were designated as non-chases or chases, which involved two to four bees at least temporarily in close proximity (< 20 cm) and following distinctly similar 3D trajectories. Non-chasing bees spent more time (~30%) than chasing bees (~10%) of their flights at near hovering speeds (< 0.5 ms⁻¹). Bees involved in chases flew faster (median > 2 ms⁻¹) and with greater acceleration (> 11 ms⁻²) than bees flying solo (1 ms⁻¹; 4 ms⁻²). However, both chasing and non-chasing bees reached similar maximal horizontal velocities (10 ms⁻¹). Surprisingly, some chases occurred at low speeds (< 2 ms⁻¹), suggesting that not all chases were aggressive, or that velocity is not the principle factor in competitive flights during nest defense. Supported by LU-PRISM.

25-8 JAMES, WR*; MCCLINTOCK, JB; Univ of Alabama at Birmingham; wrxjames@uab.edu

Do conspecific chemical cues from prey groups influence individual phenotypic plasticity in response to predators?

Predators have been widely demonstrated to influence the developmental plasticity of prey. For example, crustacean amphipods may attain smaller body size and associate with structure to reduce predation by visual fish predators. However, to date, no studies have investigated the role of conspecific cues on the induction of an individual's anti-predator response. The present study investigated the growth of individual and groups of juveniles of the freshwater amphipod *Hyaella azteca* chronically exposed to chemical cues from a sympatric sunfish predator (*Lepomis megalotis*). Amphipods were placed in containers either individually or in groups of three and exposed to sunfish chemical cues or a control for 30 days. On day 35, amphipods were further tested for behavioral responses to a structural refuge following acute exposure to sunfish cue. Image analysis revealed that individuals held in groups chronically exposed to sunfish cue attained body sizes that were significantly smaller than amphipods in groups chronically exposed to controls. However, solitary individuals exposed to sunfish cue did not differ significantly in size to controls. Behavioral trials revealed that pre-exposure to sunfish cues had no significant effect on use of structural refuge. To test if the reduction in size seen in the grouped amphipods exposed to sunfish cue was due to a conspecific chemical cue, individual amphipods in opaque bottles were placed into containers containing three or no amphipods and exposed to sunfish cues or control for 30 days. The bottle openings were covered with mesh to only allow for the passing of sunfish and conspecific chemical cues. The results will be interpreted based on our hypothesis that individuals require conspecific cues in combination with sunfish cues to induce a plastic response to reduce predation.

58-3 JANSÁ, S.A.*; DRABECK, D.H.; DEAN, A.M.; VOSS, R.S.;
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Adaptive evolution of genes involved in venom resistance in mammals

The rapid evolution of venom toxin genes is often attributed to an arms race between venomous animals and their prey, implying that the trophic role of venom is central to its evolution. However, several species of mammals - including honey badgers, opossums, hedgehogs, and mongooses - regularly prey on venomous snakes and appear to be immune to the toxic effects of their venoms. The molecular basis of venom resistance is complex and is only beginning to be understood. Some toxins are neutralized by proteins that are present in mammalian serum, but these venom-neutralizing factors can only account for resistance to a few kinds of toxins. Other toxins have apparently lost their effect due to rapid adaptive evolution of venom-targeted molecules. Here, we present two examples of rapid adaptive evolution of mammalian genes that are targeted by snake venom toxins. The first involves adaptive changes in a blood coagulation protein - von Willebrand Factor - that may account for the ability of some opossum species to survive envenomation by pitvipers. The second involves convergent evolution of a venom-targeted neuroreceptor - the muscular nicotinic cholinergic receptor - that accounts for the ability of mongooses, hedgehogs, pigs, and honey badgers to survive envenomation by elapids. These examples suggest that molecules involved in venom resistance are also evolving rapidly, and that the role of venom in predator defense may be just as important in venom evolution.

108-5 JEFFREY, JD*; HANNAN, KD; HASLER, CT; WRIGHT, A; SUSKI, CD; University of Illinois, Urbana-Champaign;
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The impact of elevated carbon dioxide on genes associated with shell growth and the stress response in a freshwater mussel

Freshwater mussels are some of the most imperiled species in North America and are particularly susceptible to environmental changes due to their sedentary nature. One environmental disturbance that mussels in the Midwest may encounter is an increase in the partial pressure of CO₂ (pCO₂) that is being explored as a management strategy for the movement of Asian carp. The present study examined the impact of acute (6 h) and chronic (up to 32 d) exposure of elevated pCO₂ levels on the mRNA abundance of genes associated with shell growth (chitin synthase; CS) and the stress response (heat shock protein 70; HSP70) in *Fusconaia flava*. Although mussels initially exhibited an increase in CS following exposure to elevated pCO₂ levels for 6 h, long-term exposure resulted in a decrease in CS mRNA abundance, suggesting that mussels may invest less in shell growth during chronic exposure to elevated pCO₂ levels. In response to an acute elevation in pCO₂ levels, mussels increased the mRNA abundance of HSP70 in mantle and adductor muscle. A similar increase in HSP70 transcript levels was observed in the gill and adductor muscle of mussels exposed to chronically elevated levels of pCO₂. This overall increase in HSP70 mRNA levels in *F. flava* suggests that both acute and chronic exposure to elevated pCO₂ levels initiates activation of the stress response. Together, these results suggest that freshwater mussels respond to elevated pCO₂ levels by increasing the machinery necessary to deal with the stressor and over the long-term, mussels may reduce their investment in processes such as shell growth. Further experiments are underway to assess the capacity of freshwater mussels to recover from exposure to elevated pCO₂ once the stressor has been removed.

66-3 JAYARAM, K*; FULL, R.J.; Univ. of California, Berkeley;
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Cockroaches squeezing through crevices

Cockroaches possess an almost unparalleled tenacity to squeeze through the smallest cracks. To quantify cockroaches' capacity to traverse crevices, we ran, *Periplaneta americana*, through a rectangular acrylic tube with a vertically adjustable gate at 3.2, 4.4 and 6.1 mm crevice heights. We discovered that cockroaches traversed crevices as small as 3 mm, the height of two stacked US pennies, by compressing their body segments 40-60%. Crevice traversal was rapid (288-821 ms) and appeared continuous in real time. However, high-speed videography revealed a complex behavior involving several stages - exploration and crevice detection, head traversal with entry and body reorientation, followed by pronotum, thorax and abdomen traversal. The time taken from head entry until abdomen tip exit increased with a decrease in crevice height from 6.1 to 3.2 mm. Traversal time was similar for 6.1 and 4.4 mm crevices (0% and 27% abdomen compression, respectively), but significantly longer at 3.2 mm (47% abdomen compression), approaching the limit of performance. The probability of successful crevice traversal decreased significantly with a decrease in crevice height from 72% at 6.1 mm to 17% at 3.2 mm. Turning back during a trial was the dominant failure mode suggesting that animals seek alternate routes if crevices are too small. Animals were never trapped in the largest crevices, but occasionally became stuck at the smallest crevice heights (9%) during thorax traversal, a potentially fatal event in nature if exposed to predators. The compressibility of the abdomen reduced the normal load on the body enabling animals to generate thrust sufficient to successfully negotiate the crevice. Cockroaches traversing crevices provides inspiration for soft search-and-rescue robots that can penetrate rubble.

128-1 JENNINGS, EC*; HENDERSHOT, JM; SHEMAS, S; RIBEIRO, JMC; BENOIT, JB; University of Cincinnati, National Institute of Allergy and Infectious Diseases; jenninec@mail.uc.edu
Gene expression changes underlying matrotrophic viviparity in the cockroach, *Diploptera punctata*

Viviparous reproduction is characterized by maternal retention of developing offspring within her reproductive tract during gestation, culminating in live birth. In some cases a mother will provide nutrition beyond that present in the yolk; this is known as matrotrophic viviparity. While this phenomenon is best associated with mammals, it is observed in insects such as the viviparous cockroach, *Diploptera punctata*. Female *D. punctata* carry developing embryos in the brood sac, a reproductive organ that acts as both a uterus and placenta by providing a nutritive milk-like secretion to the intrauterine developing progeny. While the basic physiology of milk secretion has been characterized, little is known about the underlying molecular mechanisms of *D. punctata* pregnancy. This study utilizes RNA-seq analysis to characterize transcriptional changes associated with *D. punctata* pregnancy and provides the first transcriptome for this species. Following *de novo* contig assembly, a comparison of four stages of the female reproductive cycle (mated but not pregnant, pre lactation pregnancy, early lactation pregnancy, and late lactation pregnancy) along with a male-female comparison revealed unique transcriptional profiles corresponding to each stage. Differentially regulated transcripts of interest include the previously identified family of milk proteins, transcripts associated with juvenile hormone metabolism, and other reproduction-associated transcripts. Further examination of differentially expressed transcripts will likely reveal novel molecular mechanisms underlying *D. punctata* reproduction.

28-1 JIMENEZ, A.G.; Colgate University; ajimenez@colgate.edu
Physiological underpinnings in life-history trade-offs in man's most popular selection experiment: the dog.

Animal life-history traits fall within limited ecological space, a continuum referred to as a "slow-fast" life-history axis. Differences in life-history traits are thought to result from trade-offs between investment in reproduction or self-maintenance as mediated by the biotic and abiotic environment. Dogs seem to be an anomaly to the typical correlations within these life-history trade-offs, with smaller dogs having higher mass-specific metabolic rates and longer lifespans compared with larger dogs. Thus, dogs provide a unique system to examine physiological consequences of life-history trade-offs. I have collected data from the literature to explore implications of these trade-offs at several levels of physiological organization including whole-animal, organ systems, and cells. Small dogs tend to have longer lifespans, fewer pups per litter, faster and shorter growth trajectories, higher mass-specific metabolic rates and, in general, larger metabolically active organs compared with large dogs. From work on isolated primary fibroblast cells and telomeres of dogs, I will show that selection for body size may influence attributes of cells that shape proliferative cellular rates and rates of telomere shortening. The potential links between body size, and cellular oxidative stress in dogs as they age will be discussed. Furthermore, small size in dogs has been linked to reduced insulin growth factor-1 (IGF-1) levels in plasma, a possible metabolic advantage that may provide higher resistance to oxidative stress, a parameter essential to increases in lifespan.

85-4 JOHNSEN, S.*; GAGNON, Y.L.; MARSHALL, N.J.; CRONIN, T.W.; Duke Univ., Univ. of Queensland, Univ. of Maryland, Baltimore; sjohnsen@duke.edu

Another beautiful hypothesis slain by an ugly fact: Polarization vision does not increase the sighting distance of silvery fish

Although the function of polarization vision in terrestrial and benthic species is generally well-established, its purpose in pelagic species (squid and certain fish and crustaceans) is poorly understood. A long-held hypothesis is that polarization vision in the water column is used to break the mirror camouflage of silvery fish, since biological mirrors can change the polarization of reflected light. While the addition of polarization information likely increases the conspicuousness of silvery fish at close range, direct *in situ* evidence that silvery fish, or indeed any pelagic animals, are visible at longer distances using polarization vision than they are when using radiance vision is lacking. Here we combine *in situ* polarization imagery with novel models of visual detection that allow us to directly compare the sighting distances of underwater animals when viewed by polarization-sensitive and polarization-insensitive visual systems. We find that, in general, the sighting distances of the lateral surfaces of these animals is shorter for polarization vision than for radiance vision. The primary factors limiting the polarization sighting distances are the relatively low degrees of polarization of underwater light and the low polarization sensitivity of the photoreceptors themselves. The lateral surfaces of silvery fish may be particularly hard to detect via polarization vision in horizontal viewing because the incident light that is reflected is generally similar to the background in both radiance and polarization.

132-5 JOHANSEN, JL*; AKANYETI, O; TAGUCHI, M; LIAO, JC; Whitney Laboratory for Marine Bioscience, University of Florida, FL 32080, USA, Dept. of Agricultural and Biological Engineering, University of Florida, FL 32611, USA; jacob.johansen@my.jcu.edu.au

Oxygen consumption in drift feeding trout: energetic implications for habitat selection and prey choice

Many drift-feeding fishes occupy high flow habitats that provide increased prey abundance but also incur a high cost of swimming. These fishes are thought to exploit hydrodynamic refuges to reduce energetic swimming costs. We show that the energetic cost and success rate of prey attacks are critical in determining whether refuging is energetically favorable for drift-feeding fishes. Using a flow tank respirometer, we systematically measured the oxygen consumption of rainbow trout (*Oncorhynchus mykiss*, 33.0±0.6 cm total length, 423±19 g) refuging behind a 5 cm D-cylinder or free swimming at variable flow speeds up to 100 cms⁻¹. During feeding experiments, we used artificial prey to examine the energetics of repeated foraging attempts without the interference associated with the cost of digestion (i.e. specific dynamic action). We show that contrary to current belief, refuging is not an energetically beneficial strategy when foraging in high flow habitats due to the lower capture success rate and higher cost of prey attack. At flow velocities >50 cms⁻¹, refuging causes a net energetic loss due to a 67% increase in the cost of attacking prey and a 40% reduction in attack success rate. This is most likely due to the cost of traversing a velocity gradient and tracking prey with unpredictable motions. Our results suggest that it is energetically most favorable to feed in the free stream during high flows and refuge when not feeding. Our data reveal that there is an energetic tradeoff between foraging and refuging behavior, which is influenced by prey size, prey abundance and flow velocity.

S4-12 JOHNSEN, S.; Duke Univ.; sjohnsen@duke.edu
What Next? Unanswered questions about extraocular photoreception and how we might answer them

Recent advances in genomics have led to the discovery of diverse arrays of opsins in a myriad of tissues, which, together with behavioral and histological approaches, has greatly advanced the field of extraocular photoreception. It now appears that extraocular photoreception, particular in marine phyla such as the Mollusca, is the rule rather than the exception. However, many questions remain unanswered. First, we still do not understand the function of extraocular photoreception in most species. Suggested functions include entrainment of circadian rhythms, mediation of camouflage and bioluminescent responses, and shadow detection and crude image formation in eyeless animals. However, these hypotheses primarily remain speculative. Second, it is unknown why animals that have evolved eyes often retain extraocular light sensing. Is this form of photoreception better suited than eyes for certain tasks, or are we merely looking at a historical remnant? For that matter, in most cases we do not know whether extraocular photoreception preceded or followed vision. The fact that the classes and spectral sensitivities of the photoreceptors involved in the two senses generally differ makes this an especially intriguing set of questions. Finally how is the information gathered by extraocular photoreceptors encoded by the nervous system and interpreted by the brain? These concluding remarks address these unsolved issues and suggest methods by which we might further our understanding of this poorly known sense.

S11-1 JOHNSON, Jillian G.*; BURNETT, Louis E.; BURNETT, Karen G.; College of Charleston; jill.johnson821@gmail.com
Alternative approaches to building transcriptomes can impact differential gene expression analyses in crustaceans exposed to high CO₂ and low O₂

Aquatic crustaceans can experience hypoxia (low O₂) and hypercapnic hypoxia (high CO₂/low O₂) both in the natural estuaries and in aquaculture ponds. RNA-Seq data were collected from the hepatopancreas of aquacultured Pacific whiteleg shrimp *Litopenaeus vannamei* (n=6/treatment x time) exposed to short term (4 h) or prolonged (24 h) hypoxia, hypercapnic hypoxia, or air-saturated water (normoxia) to explore the global transcriptomic response and specific involvement of the suite of hemocyanin (Hc) subunits that make up the higher order O₂-transport protein. Assembly using the robust *de novo* assembler, Trinity, produced a high-quality stranded transcriptome (assembly size, 52,190 contigs; mean length, 870 bp; N50 1680 bp; RMBT%, 96.03%); however, the highly expressed Hc gene family (hemocyanins, prophenoloxidases, cryptocyanins) experienced high rates of assembly misalignments, hybrids, and partial fragments. Manual curation of the Hc subunits revealed 1) the large Hc subunit has more sequence diversity than previously identified (HcL1-3 isoforms) and 2) penaeid shrimp express a -type Hc subunit (HcB). Transcriptome assemblies of wild caught *L. vannamei* and Atlantic brown shrimp *Farfantepenaeus aztecus* demonstrated the same Hc transcript assembly misalignments and hybrid transcripts, but highly expressed transcripts from single copy gene loci assembled into full-length contigs. High occurrence of single nucleotide polymorphisms (SNPs) coupled with high sequencing error rates for overrepresented sequences, like the hemocyanins, have a profound affect on assembly accuracy and thus downstream differential expression analyses. (NSF IOS-1147008)

9-5 JONES, M.E.H.; HUTCHINSON, M.N.; LAPPIN, A.K.*; The University of Adelaide, South Australian Museum and The University of Adelaide, California State Polytechnic University, Pomona; aklappin@cpp.edu

Sexual dimorphism of bite-force performance in the central bearded dragon (*Pogona vitticeps*)

The Agamidae include over 350 species of lizards that exhibit considerable morphological diversity. This provides an excellent opportunity to examine relationships among life history characteristics, body size, head size and shape, sexual dimorphism, and bite-force performance. We examined bite force in the central bearded dragon (*Pogona vitticeps*), one of the most familiar Australian agamids, which occupies a wide range in Australian semiarid regions. Bite force was obtained in the field from 40 wild specimens using a force transducer with a biting surface covered with leather, to provide a naturalistic biting surface and to protect the animals' teeth and jaws. Five trials were conducted with each specimen, and the trials were video recorded. The video recordings were used to standardize for variation among individuals and trials in the anteroposterior position of the jaws engaging the transducer, as previous work has shown that this is necessary to provide comparable measurements. Our results indicate that adult males bite harder than adult females of similar body size (snout-vent length) and head length. The mean bite force at the posterior-most teeth was ~175 N for males versus ~100 N for females. A significant positive relationship between bite force and size (snout-vent length and head length) is evident in females, but lacking in males. This pattern may reflect relatively greater variation in adult male condition, compared to females, which may be associated with the costs of male competition for territorial space and/or access to females.

19-3 JOHNSON, M.A.*; OBERNDORF, M.E.; DECKARD, F.M.; ROBINSON, C.D.; Trinity University, Trinity University; University of Central Arkansas; mjohnso9@trinity.edu
Endurance vs. speed: the evolution of muscle physiology and behavior in lizards

Muscles used in short, rapid movements experience a different set of physiological challenges than muscles used for slow movements that require endurance, and muscle physiological traits may evolve to support such specialized movements. In this study, we measured the fiber size and type composition of forelimb muscles in a diverse group of lizard species to determine whether these traits were associated with the frequency and type of locomotor and social behaviors (i.e., push-up displays). Using data from field behavioral observations, we classified three species (green anole, *Anolis carolinensis*; spiny lizard, *Sceloporus olivaceus*; and curly tail, *Leiocephalus carinatus*) as "short burst" species, as they are primarily sit-and-wait predators that run and jump to capture prey, and they perform frequent push-up displays during social interactions. We classified three other species (skink, *Scincella lateralis*; whiptail, *Aspidoscelis gularis*; and gecko, *Hemidactylus turcicus*) as "endurance" species, as they are active foragers that perform frequent, slow crawls, and they do not regularly use push-up displays. Using enzyme stains for myosin ATPase and succinate dehydrogenase in sectioned forelimb muscle tissues, we found that short burst species had a higher proportion of tonic muscle fibers (those most involved in maintaining posture and balance) and larger forelimb muscle fibers than the endurance species. While there was a positive correlation between fiber size and the frequency of rapid locomotor movements among species, there was no relationship between push-up displays and muscle fiber size. These results suggest that the behavioral use of forelimb muscles has influenced the evolution of their physiological traits.

47-1 JUNG, S.*; GART, S.; SOCHA, J.; VLACHOS, P.; Virginia Tech, Purdue University; sunnyjsh@vt.edu

A real lapping matter: the difference between dogs and cats when drinking

Animals that drink must transport water into the mouth using either a pressure-driven or inertia-driven mechanism. Previous work on cats shows that these mammals lap using a fast motion of the tongue with relatively small acceleration (~1g), in which gravity is balanced with steady inertia in the liquid. Do dogs employ the same physical mechanism to lap? To answer this question, we recorded 19 dogs while lapping and conducted physical modeling of the tongue's ejection mechanism. In contrast to cats, dogs accelerate the tongue upward quickly (~1-4g) to pinch off the liquid column, and thus operate within a high-inertia regime. The amount of liquid extracted from the column depends on whether the dog closes the jaw before or after the pinch-off. Our recordings show that dogs close the jaw at the moment of pinch-off time, enabling them to maximize volume per lap. In addition, dogs significantly curl the tongue ventrally to increase area in contact with water, which scales with body weight to the 1/3 power. By combining a theoretical pinch-off timescale and observational tongue-weight relation, we found that the scaling of lapping frequency with body weight (frequency ~ weight to the -1/6 power) is the same in dogs and cats.

99-3 JURCAK, AM*; MOORE, PA; Bowling Green State University, Bowling Green State University ; ajurcak@bgsu.edu
Beyond the landscape of fear: Defining the impact space of the sensory signals involved in predator-prey interactions.

Non-consumptive effects (NCEs) of predators can impact prey as much or more as consumptive effects (CEs) and to explain these effects the concept of the landscape of fear has been created. Within the landscape of fear, any alteration in predatory actions (such as hunting mode) impacts prey behavior and ecological functions. NCEs are mediated through the prey's knowledge of a predator's presence via sensory signals. The purpose of this study was to understand how the physics of the environment interacts with different hunting modes to create spatially and temporally dynamic impact spaces where prey are influenced by the sum total of sensory signals produced by the presence of predators. To understand the creation of an impact space, we placed prey in two different aquatic habitats (flow and non-flow) and in the presence of one of two different types of predators (an active predator and sit and pursue predator). The behavior of prey (crayfish) were quantified over a 21 hour period while being exposed to only sensory signals from the predators (bass or catfish) as the predators moved throughout mesocosm habitats. Changes in the prey behavior were correlated to the movement and hunting patterns of predators and in addition, alterations in prey behavior were influenced by the physics of the habitat. Thus, it appears as if the sensory signals from predators create a spatially and temporally dynamic impact space where NCEs are influential.

22-7 KAHN, A.S.*; LEYS, S.P.; University of Alberta, Edmonton, Canada; kahn@ualberta.ca

Immigrant choanocytes reveal multiple origins of choanocytes in sponges

Choanocytes are the iconic feeding cells in sponges and are one of their most well studied cell types, yet surprisingly little is known about how they form. Our studies of glass sponges, which lack conventional choanocytes, prompted us to re-assess choanocyte chamber formation and function. In freshwater demosponges, a more readily studied model, choanocyte flagella beat to draw water through canals for food, respiration and evacuation of wastes. Highly proliferative cells maintain choanocyte chambers, yet choanocytes are seldom caught in the act of mitosis. We studied choanocyte formation in small freshwater sponges using time-lapse photography. In *Spongilla lacustris* a founding cell divides 4-5 times, producing 30-50 choanocytes. Chambers start by division of a founder cell, but thereafter, surprisingly, small mobile cells wandering through the mesohyl stop, change direction, and enter an existing choanocyte chamber then differentiating into choanocytes, becoming part of the choanocyte chamber as 'immigrant choanocytes.' We propose that feeding chambers form through similar processes across sponge groups, but that choanocyte chambers add new choanocytes through a variety of different processes. This discovery has implications regarding our understanding of the choanocyte lineage and the potential for cell differentiation in early metazoans.

48-4 KAHRL, A.F.*; COX, R.M.; University of Virginia; afk7df@virginia.edu

Variation in sperm morphology between native and introduced populations of three Anolis lizard species

Sperm morphology is highly variable among species, but less is known about its variation among individuals and populations. *Anolis* lizards are native throughout the Caribbean and Central America, but several species have recently been introduced in southern Florida, providing an opportunity to compare native and introduced populations of multiple species. We collected sperm samples from three populations each of *Anolis sagrei* and *A. distichus*, and two populations of *A. cristatellus*, comprising of both native and introduced populations. We found that multiple aspects of sperm morphology differed consistently in mean and variance between native and introduced populations, despite introductions occurring within the last 100 years for each species. In all three species, lizards from introduced populations had sperm with shorter tails and larger midpieces than those of lizards from native populations. These data suggest that sperm morphology is highly plastic and/or capable of rapid evolution in response to environmental changes. Though these changes may be predictable, their underlying causes require further study.

65-3 KAMRAN, M*; MOORE, M.E.; MOORE, P.A.; Bowling Green State University, Baldwin Wallace University, Bowling Green State University ; mkamran@bgsu.edu

Homeward bound: a comparative study of homing behaviors between primary and tertiary burrowing species.

The ability to navigate successfully to and from sites rich in resources is essential for survival for many organisms. In particular, the ability to repeatedly locate a shelter is critical for avoiding predation. Within crayfish, species can be primary burrowers (those that create and use burrows with increased frequency) or tertiary burrowers (those that utilize burrows constructed by other species). This difference in energy expenditures on shelter construction might lead to differences in the ability to home to burrows. We tested this hypothesis by challenging a primary burrower (*Fallicambarus fodiens*) and a tertiary burrower (*Orconectes rusticus*) to relocate a burrow that had been displaced in space. Rotational displacements of burrows allow us to further examine the mechanisms (and cues) utilized by crayfish during short-range homing. Homing abilities are correlated with the label of primary or tertiary burrowers and results indicate that the underlying mechanisms of homing appear to be different between the two species.

44-4 KANE, EG*; REITZEL, AM; KANE, Eric; U. North Carolina Charlotte; ekane1@uncc.edu

Evolution of bZIP Transcription Factor Dimerization: Surprising Interaction Complexity in Cnidaria

The genomic era has revealed that metazoan body plan diversification may rely on the selected expansion and diversification of transcription factor families as well as the developmental gene regulatory circuits these proteins regulate. Shifting dimerization activity within transcription factor superfamilies is one potent strategy for changing regulatory network attributes. Understanding changes in the protein-protein interactions of developmental transcription factors is crucial for uncovering the mechanisms of animal development, disease progression and other transcription factor-mediated processes. To probe the evolution of transcription factor protein-protein interactions in the metazoan lineage, we focused on the bZIP superfamily of transcription factors. bZIP proteins are highly conserved, dimer-forming eukaryotic transcription factors that regulate a variety of central cellular and tissue-grade functions. bZIPs act both as environmental biosensors and as intrinsic regulators of body plan. The central role of bZIPs in development led us to ask whether the complexity of bZIP interactions encoded by a genome increases as organisms become more complex. In this study, we used data-driven predictive algorithms to predict the entire bZIP "interactome" of 18 species that span the metazoan lineage and closely related unicellular outgroups. Our results show that a general increase in bZIP dimerization complexity accompanies the transition from unicellular outgroups to the multicellular animals. We also show that bZIP promiscuity is surprisingly high in the cnidarian lineage, surpassing dimerization complexity contained in all representatives of Bilateria excluding vertebrates. This study indicates, with high representative species resolution, that increases in bZIP dimerization activity are decoupled from an increase in morphological complexity.

112-5 KATZ, HR*; LIU, YC; HALE, ME; Univ. of Chicago, Vollum Institute, Oregon Health and Science Univ.; katz20h@uchicago.edu
What can tails tell fish? How caudal touch mediates startle behavior

The S-start startle behavior is produced in response to caudal stimuli in zebrafish and other taxa. By examining the mechanistic basis of the S-start behavior, we aim to gain insight into how the organization of the spinal sensory network influences behavioral choice. First, we performed behavioral kinematic studies in larval zebrafish to describe the initial "S" shaped double bend of the startle and to determine its relationship to stimulus position. We found that the bend pattern is conserved despite variation in the rostrocaudal location of the tail stimulation, indicating that there is a morphological demarcation between the anterior and posterior bends. Second, we investigated the neural basis of the double bend movement pattern. There is no evidence of regional organization of motor neurons or premotor interneurons that could explain this pattern of bending. We identified Rohon Beard (RB) cells, a type of somatosensory cell, as a key sensory input that produces local caudal bending. Paired recordings have shown that caudal RBs indirectly inhibit contralateral caudal motor neurons and predispose the axis to generating an S bend. This finding led us to investigate sensory input as a potential mechanism for regionalized motor activity. Because we only observe RB-elicited inhibition in the caudal region, it suggests that there is regionalization in RB subtype distribution or connectivity. Using *in vivo* light sheet imaging of GFP-labeled somatosensory neurons, we explore rostrocaudal differences in RB arborization and dendritic projections in zebrafish larvae to better understand how these subtypes may be distributed. This work sheds light on the roles of tail sensation and local spinal circuits in behavioral decision-making and regionalization of the body axis.

35-2 KATIJA, K*; SHERMAN, A; GRAVES, D; SHERLOCK, R; ROBISON, B; Monterey Bay Aquarium Research Institute, Moss Landing; kakani@mbari.org
Revealing the structure and function of deep-sea, giant larvacean mucus houses

The midwater region of the ocean (below the euphotic zone and above the benthos) is one of the largest ecosystems on our planet, yet remains one of the least explored. Little-known marine organisms that inhabit midwater have developed life strategies that contribute to their evolutionary success. Larvaceans (Class Appendicularia) are found throughout the world's oceans and affect food webs across trophic levels via elaborate mucus feeding structures they create. Larvaceans swim tethered to their mucus house, forcing fluid and particles through filters that eventually lead to their mouth. Once filters become clogged, the house structure is abandoned, sinks, and eventually the particle-rich structure reaches the seafloor. It is estimated that larvaceans are responsible for the deposition of a third of the particulate that reaches the seafloor in Monterey Bay. Despite having such an important ecological role, little is known about the structure and function of giant larvacean (*Bathochordaeus stygius*) houses. To address this need, we developed DeepPIV, an instrumentation package that incorporates a high-powered, continuous laser and optics, which is deployed on board remotely operated vehicles (ROVs). This instrumentation enables investigation of various biological and physical phenomena from the surface down to 4000 m. Using DeepPIV and image processing algorithms, we are able to reveal the structure of mucus houses as well as filtration rates and flow directions within houses. These quantitative measurements are used to elucidate how these mucus structures function and contribute to carbon flux in midwater regions of the ocean.

28-5 KAUR, M.*; LINVILLE, M.C.; RASNIC, C.; REDMOND, S.B.; DAVIS, J.E.; Radford University; mlinville3@radford.edu
Super-fly! The effects of Vespa Amino Acid Mixture on endurance, mortality, metabolic and mitochondrial function in *Musca domestica*

Vespa amino acid mixture (VAAM) is health product ostensibly based on a tropholactic product of giant Japanese hornet larval saliva, consisting of 17 amino acids in specific ratios. Previous studies suggest that this mixture may improve physical endurance by means of lipolysis or other mechanisms unknown. During the course of this study, both VAAM from the producer of VAAM-Power and lab prepared synthetic VAAM (sVAAM) were tested on the housefly (*Musca domestica*) using a swim test to measure physical endurance. While endurance increased by more than 275% in experimental flies, mortality increased significantly in these flies as a result of exposure. Upon testing, sVAAM yielded near identical results when compared to VAAM. Components of sVAAM were individually tested to determine specific agency effects. Further testing was also done to determine the impact of VAAM may be doing on the cellular and subcellular level. To do this, reconstituted mixtures of VAAM at various strengths were tested on a variety of animal and plant cells. The cells were tested at various concentration levels to determine whether or not VAAM influenced cellular apoptosis and viability. Over a one hour period, cell viability and apoptosis were noted when exposed to the reconstituted VAAM. Overall, an inverse relationship between viability and apoptosis was shown as levels of VAAM increased, indicating that VAAM may directly contribute to cellular death. This relationship was seen in the chicken blood cells, yeast cells, army flatworm cells, and cauliflower mitochondria. No such relationship was seen in the spinach chloroplasts. These results indicate that VAAM may overpower the mitochondria in such cells, leading to a burst of energy before burnout, in which case cell death ensues.

97-2 KAWANO, S.M.; NIMBioS; *skawano@nimbios.org*
A synthesis of quantitative methods to estimate patterns of phenotypic selection

Quantifying the patterns and strength of phenotypic selection in the wild is fundamental to explaining causes of adaptive evolution. The advent of a theoretical framework to distinguish the direct and indirect components of multivariate selection on correlated phenotypic traits catapulted the study of selection, with thousands of estimates now published. Syntheses have yielded powerful insights into phenotypic selection, including that selection tends to be weak and that stabilizing selection was as common as disruptive selection. Although these patterns could be due to biological and environmental determinants, there is growing recognition that variation in computational methods is also important factors. A synthesis of regression-based methods for quantifying phenotypic selection was conducted via data aggregation, in which the raw data were re-interpreted using a systematic workflow to directly compare the effects of specific procedures on patterns of selection. Analyses were conducted on several empirical and simulated longitudinal datasets on morphology, and a sensitivity analysis was conducted on each dataset to evaluate how different model parameters, standardizations, regression types, inclusions of nonlinear selection, etc. impact selection coefficients. Preliminary results suggest that variation in the workflow generally did not alter which traits were under direct selection, but did change the strength of selection. An R package is in development to provide open-source datasets and computer code for reproducible evaluations of phenotypic selection to facilitate future syntheses. Evolutionary biologists are now equipped with an arsenal of tools to quantify and visualize the multivariate nature of selection, and a synthesis on these theoretical tools provide new perspectives on the patterns and strength of selection.

88-5 KELLEY, J.B.*; FREEMAN, D.A.; CARTER, S.N.; Univ. of Memphis; *jbkley3@memphis.edu*
Mate choice in the eusocial Damaraland mole-rat: Love at first sight

Eusocial Damaraland mole-rats (DMR) live in colonies made up of a single breeding pair and their offspring. The offspring are non-breeders and do not express sexual behavior within their natal colony and only in the presence of unfamiliar, opposite-sex conspecifics do sexual behaviors manifest. Thus, familiarity with colony mates appears to preclude mating, resulting in inbreeding avoidance within colonies. Previous results indicate that siblings separated from each other for 5 weeks treat each other as unfamiliar and readily mate with one another. Thus, genetic relatedness does not appear to explain the inbreeding avoidance in DMR colonies. Familiarity alone does not sufficiently explain the regulation of sexual behaviors either, since breeding pairs continue to mate after becoming "familiar." The presence or absence of sexual behaviors defines two types of relationships: sibling and breeder. Our hypothesis regarding the development of these relationships is that the presence or absence of sexual behavior during the initial interaction determines the long-term relationship between individuals. We tested this hypothesis by either restricting or allowing physical contact upon first interaction between opposite-sex unrelated non-breeders, then allowing them olfactory access to one another each day for two weeks (familiarization period). Pairs that were not allowed to mate upon first interaction developed a sibling-like relationship when paired without restraint, while pairs that were allowed to mate developed a breeding relationship and expressed significantly more sexual behaviors when paired. Inbreeding avoidance may depend upon the absence of sexual behaviors when siblings are first familiarizing within the colony. Likewise, breeding pairs may develop due to the expression of sexual behaviors upon first meeting.

30-6 KEISER, C.N.*; AUGUSTINE, D.A.; ZIEMBA JR., M.J.; LAWRENCE, J.G.; PINTER-WOLLMAN, N.; PRUITT, J.N.; Univ. of Pittsburgh, Univ. of California, San Diego; *cnk21@pitt.edu*
Variation in host behavioral type and body condition produce heterogeneity in the transmission of cuticular bacteria among group-mates

Decades of research have been dedicated to understanding how host traits predict the transmission dynamics of infectious agents. Despite empirical, anecdotal, and axiomatic evidence that individuals vary in phenotypes that could influence microbial transmission, individuals are often considered identical in predictive models or experimental designs. Here, we test to what degree variation in host phenotypes can alter the direct and indirect transmission of bacteria to a susceptible, unexposed colony-mate. We inoculated individual social spiders, *Stegodyphus dumicola*, with GFP-transformed *Pantoea* sp., a resident cuticular bacterium, and allowed them to directly interact with a colony-mate for 24h. Using selective growth media and surveying for GFP fluorescence from bacteria cultured from unexposed individuals' cuticles, we found evidence for transmission in 58% of cases, the likelihood of which was influenced by the phenotypes of both the exposed and susceptible individuals. Transmission was more likely when exposed spiders exhibited higher "boldness", a key behavioral trait for this species, and when unexposed individuals were in better body condition (i.e., weighed more than predicted based on their body size). When unexposed spiders were housed for comparable periods of time solely with silk with which exposed spiders had previously interacted, indirect transmission took place in only 11% of cases. Thus, bodily contact or other affiliative/social behaviors appear to play an important role in higher incidence of bacterial transmission among co-resident spiders. These data represent a fundamental step towards understanding how individual traits can influence larger scale epidemiological processes.

15-3 KELLY, T. R.*; LYMBURNER, A. H.; MACDOUGALL-SHACKLETON, E. A.; MACDOUGALL-SHACKLETON, S. A.; The University of Western Ontario; *tkelly43@uwo.ca*

Testosterone as a potential mediator of migration distance and migratory timing in song sparrows *Melospiza melodia*

In seasonally migratory animals, migration distance often varies substantially within populations, such that individuals breeding at the same site may overwinter different distances from the breeding grounds. Shorter migration may allow earlier return to the breeding grounds, which may be particularly advantageous to males competing to acquire a breeding territory. However, little is known about potential mechanisms that may mediate migration distance. We investigated naturally-occurring variation in androgen levels and its relationship to migration distance in male and female song sparrows (*Melospiza melodia*). We used stable isotope analysis of hydrogen in winter-grown claw tissue to infer relative overwintering latitude (migration distance), combined with 14 years of capture records from a long-term study population to infer the arrival timing of males versus females. Relative to females, males had higher circulating androgen levels, migrated shorter distances, and were more likely to be caught early in the season. Males that migrate short distances may benefit from early arrival at the breeding grounds, allowing them to establish a breeding territory. Even after controlling for sex and date, androgen levels were highest in individuals that migrated shorter distances. Our findings suggest that androgens such as testosterone may mediate variation in migration distance within and between sexes. If so, selection on androgen levels may therefore have correlated effects on optimal migration strategies.

31-1 KELLY, TR; MACGILLIVRAY, HL; WATSON, M; SARQUIS-ADAMSON, Y; HOBSON, KA; MACDOUGALL-SHACKLETON, SA; MACDOUGALL-SHACKLETON, EA*; University of Western Ontario, Environment Canada; emacdoug@uwo.ca

Seasonal migration distance varies with natal dispersal and predicts parasitic infection in song sparrows (*Melospiza melodia*)

Seasonal migration and natal dispersal represent the major large-scale movements in the lives of many animals. Individuals that are more prone to movement might both disperse and migrate farther distances. Such behavior may increase encounter rates with parasites and diversity of parasites encountered. Alternatively, parasitism may prevent individuals from migrating long distances, potentially resulting in a negative relationship between infection and movement. We examined whether natal dispersal tendency predicts seasonal migration distance in song sparrows (*Melospiza melodia*), and whether migration distance predicts haematozoan parasitism. Migration distance, inferred from stable-hydrogen isotope analysis ($\delta^2\text{H}$) of tissue grown on the wintering grounds, varied consistently among individuals over years, and was greater in females than males. Migration distance varied with natal dispersal, as inferred from genetic assignment tests: birds that had immigrated from farther outside the study area also overwintered farther south from the breeding grounds. Among after-second-year birds, but not in yearlings, longer-distance migrants were more likely to be infected with haematzoa. Individuals that travel long distances in the context of natal dispersal also appear to travel long distances in the context of seasonal migration, supporting the possibility of a behavioral syndrome with respect to movement in this species. The degree to which individuals move across the landscape may influence their exposure to infectious disease, particularly in adulthood once immune repertoires are relatively crystallized.

S5-1 KELLY, Diane A.; Univ. of Massachusetts, Amherst; dianek@psych.umass.edu

Intermittent Organ Morphology and Biomechanics: Exploring the Morphospace of Intromission

Intermittent organs (IOs) have evolved many times within the animal kingdom and are remarkable for their extravagant morphological diversity. In some species, an IO is built of tissues with reproductive system antecedents, but others have modified fins, tentacles, or legs for intromission; anatomically, IOs can include combinations of stiff tissues, extensible tissues, and muscle. IO behavior during copulation is also diverse: males in some taxa reorient or protrude their genital structures, others inflate them and change their shape or use a combination of these behaviors. But despite morphological and behavioral variation, all IOs share a function: intromission during copulation. Typically, IOs are stored in a non-reproductive state and shifted into a distinct reproductive morphology immediately before or during copulation. I propose that the timing of this shift constrains the subsequent mechanical behavior of the IO. If the IO shifts to its reproductively relevant morphology before copulation, its morphology will be optimized for high flexural stiffness to allow it to effectively enter female reproductive structures. IOs that shift into a reproductively relevant morphology during copulation will be more likely to have tissues with material properties that permit them to fill female reproductive spaces, but produce structures with lower overall flexural stiffness.

114-4 KELLY, MW*; PANKEY, S; DEBIASSE, MB; PLACHETZKI, D; Louisiana State University, University of New Hampshire, University of New Hampshire; morgankelly@lsu.edu
Adaptation to heat stress reduces phenotypic and gene expression plasticity in a marine copepod

Organisms may respond to changing environments through phenotypic plasticity or adaptive evolution. In most cases, the two processes will interact to influence phenotypic trajectories, but whether adaptation will lead increased or decreased plasticity will depend on the genetic correlation between trait values and the slopes of their norms of reaction (plasticity), a relationship that is unknown for most traits. To examine the effect of adaptation to heat stress on the plasticity of heat tolerance, we hybridized populations of the crustacean *Tigriopus californicus* that show divergent phenotypes for heat tolerance, selected for increased tolerance in hybrids, then measured heat tolerance, and the phenotypic plasticity of heat tolerance in selected lines and unselected controls. To test whether changes in phenotypic plasticity are associated with changes in the plasticity of gene expression, we also sequenced the transcriptomes of selected and unselected lines, both under heat shock and at ambient temperatures. We observed increased heat tolerance in selected lines, but also lower phenotypic and gene expression plasticity in response to heat stress. The plastic response to heat stress was highly enriched for hydrolytic and catalytic activities, suggesting a prominent role for degradation of mis-folded proteins in heat tolerance. Our findings have important implications for biological responses to climate change: if adaptation to heat stress reduces plasticity, then plasticity and adaptive evolution will make overlapping, rather than additive contributions to buffering populations from environmental change.

20-1 KENALEY, C. P.*; MARECKI, M.C.; LAUDER, G. V.; Boston College, University of Florida, Harvard University; cpkenaley@gmail.com

The Role of An Overlooked Adductor Muscle in the Feeding Mechanism of Ray-finned Fishes: Predictions from Biorobotic Modeling of a Deep-sea Viperfish

In a majority of ray-finned fishes (Actinopterygii), affective acquisition of food resources is predicated on rapid jaw adduction after prey enters the oral cavity. Although it is understood that the dorsal adductor divisions that arise from the head and insert on the posterior of the lower jaw are major contributors to closing dynamics, the contribution of the ventral components of the adductor system has been completely overlooked. In many ray-finned fishes, the ventral component is comprised of a single division, the A_1 , that originates on an intersegmental aponeurosis of the facialis divisions and inserts on the medial face of the dentary, anterior to the insertion of the dorsal divisions. Thus, this configuration resembles a two-anchor sling applied to a third-order lever with offset anchor points. The goal of this study was to elucidate the contributions of the A_1 to jaw adduction by modeling jaw closing in the deep-sea viperfish *Chauliodus sloani*. To do this, we simulated adduction with a completely novel biorobotic system that incorporates the geometry of the A_1 . By comparing results between simulations that included and excluded A_1 input, we show that the A_1 adds substantially to lower-jaw adduction dynamics in *C. sloani* by displacing the line of action of the dorsal facialis adductor muscles and increasing the mechanical advantage and input moment arms of the jaw lever system. Modifications of mechanics and posture result in significant increases in closing performance, including bite force, angular velocity, and adduction time. In the context of our results, the prevalence of a similar A_1 sling design across the fish tree of life indicates the importance of this division in feeding and identifies a productive topic for future comparative work.

65-1 KENDALL-BAR, J.M.*; WELLER, D.; FEARNBACH, H.; SHANE, S.; SCHORR, G.; FALCONE, E.; CALAMBOKIDIS, J.; SCHULMAN-JANIGER, A.; BARLOW, J.P.; Univ. of California, Berkeley, Southwest Fisheries Science Center, NMFS, Center for Whale Research, West Coast Whale Research Foundation, Cascadia Research Collective, Pacific Nature Tours; jmkendallbar@berkeley.edu

Using photo-identification data to investigate movement and occurrence patterns of short-finned pilot whales (*Globicephala macrorhynchus*) in the eastern North Pacific

Photo identification is a widely employed method to estimate population size and identify individual marine mammals. Here, a photo-identification catalog was created for short-finned pilot whales (*Globicephala macrorhynchus*) sighted along the U.S. west coast between 1980 and 2015. This species was effectively gone from the California coast for about a decade after the 1982-1983 El Niño but has recently started to reappear. This study compared individuals recently photo-identified with those identified previously, including some from prior to the 1982-83 El Niño. To create the catalog, high quality images of pilot whales from 20 sightings (1996-2015) and six years of study at Santa Catalina Island (1983-1989) were compiled and used for comparison across sightings. This resulted in the identification of 207 individuals, including 22 short-term and long-term matches between groups sighted off Southern California and groups sighted off Baja California. No matches were found, however, between individuals recently sighted and those identified prior to the El Niño. Large sightings (occasionally as great as 200 whales) suggest that a sizeable portion of this population (estimated at 350 pilot whales (CV=0.48) in 2007) can sometimes be temporarily associated. Continued monitoring will help fill key data gaps on the distribution, occurrence, potential threats and demographic trends of pilot whales in this region.

60-3 KEREN, T; HOLZMAN, R*; MANN, O; KIFLAWI, M; CHINA, V; MARTIN, C; Tel Aviv Univ, Ben Gurion Univ, Ben Gurion Univ, UNC Chapel Hill; holzman@post.tau.ac.il
Morphological Evolution on a Performance Landscape: example from the Suction-Feeding Mechanism of Reef Fish

Understanding the relationship between form and function is a major goal in evolutionary biology. In complex mechanisms, function is the product of several phenotypic components, and evolution of the functional system is affected by the interactions between those components. Therefore, the key to understanding the evolution of complex functional systems lies in the ability to predict how the multiple phenotypic characters interact in determining performance. Performance landscapes enable the mapping of several phenotypic characters to their performance value. In this work, we constructed a performance landscape to describe the relationship between phenotypic characters and performance in the suction feeding mechanism of fish. Morphology and kinematics were collected in the field for 5 populations of *Chromis viridis* feeding in their natural coral reef habitat, using high-speed three-dimensional video footage. Using random phenotypic combinations, sampled as permutations from the observed phenotypic distribution, we constructed a continuous, multi-dimensional performance landscape, statistically modeling the relationship between multiple feeding-related phenotypic traits and feeding performance. We then used randomization tests to determine the effect of natural selection, portrayed by the performance landscape, on the intra-specific phenotypic distribution of this functional system. Our results indicate that the suction-feeding mechanism evolves under a complex selective regime, driven by the adaptive value of specific phenotypic combinations, and constrained by several correlations between phenotypic characters. Our study demonstrates that functional systems can evolve on a performance landscape, and it is now possible to apply our framework for other systems.

31-2 KEOGH, CL*; NISHIMURA, T; MIURA, O; BYERS, JE; University of Georgia, Athens, Kochi University, Shikoku, Japan; clkeogh@gmail.com

Costs and benefits of parasite escape: immune defense trade-offs in the invasive shore crab *Hemigrapsus sanguineus*

When invasive populations become established in novel environments, they often leave behind enemies such as predators and parasites that may regulate populations in the native range. Parasite escape can confer fitness benefits to invaders when they no longer experience infection pathology, and also because relaxed selection on immune defenses may promote resource reallocation towards growth or reproduction. However, this relaxed selection may ultimately lead to increased susceptibility upon exposure to parasites. We conducted laboratory studies comparing shore crabs (*Hemigrapsus sanguineus*) from their invasive (USA) range where parasite escape is well-documented to crabs from the native (Japan) range to test for differences in susceptibility to infection by a native rhizocephalan parasite, and to explore potential differences in immune characteristics and energy allocation. While invasive-range individuals mounted a stronger non-specific encapsulation response against a parasite mimic, we found that invasive-range crabs were ultimately more susceptible to rhizocephalan infection than their native-range counterparts. Individuals from the invasive populations also showed lower resting oxygen consumption and higher juvenile growth compared to natives. Our results suggest that invaders' ability to defend against parasites may be reduced in favor of increased fitness in the absence of the threat of infection, but that further work is needed to identify the immunological underpinnings of the observed increase in susceptibility.

99-2 KESSLER, B.J.*; KESSLER, D.J.; CALSBEEK, R.G.; Univ. of California, Berkeley, Dartmouth College; benjik2013@gmail.com
***Eciton burchellii* army ants avoid *Nasutitermes* termites**

Eciton burchellii army ants prey on a wide variety of arthropod taxa, but display avoidance behavior in response to *Nasutitermes* termites. This study investigates the roles of olfactory signals, termite caste, and active employment of termite defenses in provoking this avoidance behavior. Ants were found to be less likely to bite cotton swabs rubbed into termites than swabs that had been rubbed into a prey species or left clean, indicating that the presence of termite chemicals decrease attack behavior in the ants. This result did not depend on termite caste. Field experiments with the introduction of termites to trails of foraging ants explored the role of termite defensive behavior in repelling ants. Ants were less likely to make physical contact with live soldier termites placed in their trail than they were with a piece of rice, but this decreased likelihood of contact was not seen when the introduced termites had been first killed by freezing. Introduction of live or dead termites both increased the likelihood that ants would divert their direction of motion, but direction-changes of greater magnitude were observed for the live termite treatments. These results suggest that chemicals present on the termites act as olfactory cues to trigger avoidance behavior in the ants, and that defensive behavior by the termites also contributes to repelling the ants.

111-2 KHAN, N.Y.*; ROBERT, K.A; University of Georgia, La Trobe University; nykhan@uga.edu

Chronic Stress Affects Parental Nest Visitation Trends during Incubation and Chick Rearing

Reproduction is essential for species survival, and the ever-increasing stressors that birds are exposed to raises concerns for population-level health and reproduction. However, studies of chronic stress and individual parental effort have been limited to short periods of surveillance due to difficulty and the high cost in observer hours. This project addressed a key gap in our understanding of stress and reproduction by determining how elevated stress affects nest visitation of parents throughout incubation and chick rearing in zebra finches *Taeniopygia gutatta*. We used PIT tags in combination with microchip readers, directional sensors and infra-red cameras to track individual visits when one or both parents had experimentally elevated stress levels. We identified sex differences in visitation length and timing, where males and females traded off halfway through incubation. Time of day, and age of chicks also affected visitation trends during chick rearing, and we found clear differences in the behaviour of chronically stressed vs unstressed birds during both incubation and chick rearing. This is the first study, to our knowledge, to identify individual behaviour of parents under chronic stress throughout their primary reproductive investment. These results highlight that chronic stress, even when birds are provided with *ad libitum* resources, dramatically affects parental behavior and reproductive success, thus raising potential issues with reproduction in disruptive environments, and the captive breeding of birds. Moreover, our study offers insight into potential endocrine factors responsible for variation in parental care tactics, and life-history trade-offs.

46-1 KHUDYAKOV, JI*; CHAMPAGNE, CD; PREEYANON, L; CROCKER, DE; Sonoma State University, Old Dominion University, Mahidol University; khudyako@sonoma.edu

Molecular Indicators of Stress in Free-Ranging Marine Mammals

Downstream molecular consequences of stress responses are not well known in free-ranging marine mammals, hindering understanding of stress-related pathologies and regulation of metabolic activity by stress hormones. We examined cellular responses to a stress challenge in juvenile northern elephant seals by stimulating the hypothalamic-pituitary-adrenal (HPA) axis with exogenous adrenocorticotrophic hormone (ACTH) and profiling resultant changes in tissue gene expression using transcriptomics (RNA sequencing). Global gene expression changes were analyzed in the inner layer of blubber, a metabolically active tissue that responds rapidly to fluctuations in stress hormone levels. We sequenced and assembled the first blubber transcriptome, producing over 350,000 assembled transcripts, including a number of seal-specific adipose genes with no homology to terrestrial mammal proteins. The acute response to ACTH was measured two hours after administration and involved significant elevation in circulating cortisol and aldosterone and alteration in expression levels of over 200 transcripts. Differentially expressed genes included key mediators of lipid metabolism, inflammation, and cell proliferation, global transcriptional regulators, and smooth muscle and endothelial markers of smooth muscle due to the extensive vascularization of marine mammal blubber tissue. This study provides a number of marine mammal-specific blubber and stress markers and complements previous work on the elephant seal muscle transcriptome response to ACTH, furthering understanding of how stress responses are integrated across multiple tissues in marine mammals.

93-3 KHANDELWAL, P.C*; EVANGELISTA, D; HEDRICK, T L; Univ. of North Carolina, Chapel Hill; pranavk@live.unc.edu
The glide of the dragon - glide characterization and performance of *Draco dussumieri*

Recent studies of various gliding organisms including frogs, ants, squirrels, colugos, snakes and partially fledged birds uncovered a wide range of non-equilibrium behaviors. These indicated that all gliding animals in air must be able to stabilize, steer or maneuver to avoid injury and land at intended locations with a manageable kinetic energy. The ability of gliding animals to meet the above requirements may be more biologically relevant than factors directly relevant to equilibrium gliding such as lift to drag ratio, but the breadth of capabilities among species remains largely unknown. Unlike other limbed gliding vertebrates, the gliding lizard (*Draco*) uses a wing not derived from appendages but still must meet all the above requirements for successful gliding. This begs the question of how is this behavior achieved and how it compares on various performance scales to other gliding taxa. We recorded 3D tracks of natural glides from a wild population of *Draco dussumieri* in the field using a non-invasive multi-camera videography scheme. Initial analysis and observations reveal no equilibrium glides. Instead, we found a wide range of glide angles (-64 to 20°), glide ratios of ~0.9-1.6 and dramatic body orientation changes during glides, from sharply pitched down to pitched upward. These produced continuously changing kinematic profiles for velocity (peak ~6.3 ms⁻¹), acceleration (peak a_v ~13 ms⁻², peak a_h ~8.3 ms⁻²), energy, and aerodynamic parameters (lift, drag, angle of attack). Lateral and vertical maneuvers were also quantified during glides. These results provide the first look at time-resolved freely maneuvering glide trajectories in the field, revealing maneuvering and non-equilibrium control capabilities in *Draco* in realistic settings.

129-4 KILMER, J.T.; University of Wisconsin-Milwaukee; jtkilmer@uwm.edu

Brain size and memory of captured prey in the cellar spider *Pholcus phalangioides* (Araneae: Pholcidae)

The evolutionary reduction of body size can present animals with some major challenges. Animals with smaller bodies tend to have absolutely smaller brains. As a result, tiny animals are expected to face cognitive limitations. I address the hypothesis that brain size limits the amount of time a memory remains functionally active (i.e., the retention interval). I tested predictions of this hypothesis with a behavioral assay in long-bodied cellar spiders, *Pholcus phalangioides* (Araneae: Pholcidae), which search for captured prey that goes missing. I altered the amount of time between memory formation (prey capture) and memory use (prey searching) to determine the length of time over which memory influences behavior in large and small spiders (spanning a two-fold difference in brain mass). I found that as I increased the delay between memory formation and the opportunity for memory use, search time in small spiders sharply dropped off, and with long enough delays, they did not search at all. Spiders simply rested during delays, so these results cannot be attributed to exhaustion. The same delays decreased search time in large spiders as well, but had a much weaker effect, and even after delays of 16 minutes, large spiders consistently searched for lost prey. Thus, smaller spiders tended to have shorter retention intervals. These results suggest that at small scales, brain size may be important for the persistence of memories and animal's ability to respond to past events. This may impose important selective pressures on species evolving miniaturization.

105-4 KILVITIS, HJ*; MARTIN, LB; SCHREY, AW; Univ. South Florida, Armstrong Atlantic State; hkilviti@mail.usf.edu
Epigenetic regulation of Toll-like Receptor 4 expression as a facilitator of invasiveness in Kenyan house sparrows (*Passer domesticus*)

Regulation of the innate immune system (e.g. inflammation) has been implicated as mediator of vertebrate range expansions. Previous research from our lab has shown that leukocyte expression of Toll-like receptor 4 (TLR-4), the major surveillance molecule for Gram-negative bacteria, varied among Kenyan house sparrow (*Passer domesticus*) populations of different ages: individuals at the range-edge expressed more *TLR-4* than individuals at the site of introduction. Given that genetic diversity is relatively low in this introduced range, epigenetic variation, namely DNA methylation, may unmask phenotypic variation in response to novel environments. Further, we know that at the population-level, neutral genetic variation is inversely correlated to genome-wide DNA methylation. Here, we investigated DNA methylation within the *TLR-4* promoter in the liver – an immunologically important tissue – asking whether i) methylation was correlated to hepatic *TLR-4* expression within individuals and ii) whether the extent of methylation and/or its effects on expression differed among populations of different age. We predicted the least DNA methylation (and the most hepatic *TLR-4* expression) in range edge birds, while we expected similar relationships between expression and methylation among populations. Our initial findings provide evidence of high CpG diversity (i.e. CpG-SNPS) within the avian *TLR-4* promoter, in just a few individuals sampled so far. Further analysis will indicate whether diversity at the population-level influences the potential for epigenetic regulation of *TLR-4* in invasive Kenyan sparrows. Such studies will provide insight into the importance of molecular-level mechanisms for influencing physiological and/or organismal-level responses to rapid environmental change.

S12-6 KINGSBURY, M.A.; Indiana University; mk24@indiana.edu
Social variation across sexes, individuals, species and seasons: The role of vasoactive intestinal polypeptide in avian affiliative behavior
 Although the social functions of most major neurochemical systems have been explored, there are still some major standouts, including the study of vasoactive intestinal polypeptide (VIP). VIP is perhaps best known as a major regulator of prolactin secretion from the pituitary in vertebrates and as a modulator of circadian, reproductive and seasonal rhythms. However, VIP and its cognate VPAC receptors are found in virtually every brain area that is important for social behavior, including all nodes of the core "social behavior network," suggesting that VIP may have widespread effects on behavior that have been heretofore unknown. We have studied this peptide extensively over the last few years, both in socially diverse species of estrildid finches that breed opportunistically and in socially diverse species of emberizid sparrows that are strongly seasonal in terms of their behavior and physiology. Through a combination of comparative and mechanistic approaches to behavior, we have found that 1) VIP fiber densities and VIP receptor binding correlate with both species and seasonal differences in flocking behavior in a brain-site specific manner; 2) VIP cells show network-wide increased transcriptional activity in response to nest building, including within brain areas identified as important for other affiliative behaviors; and 3) signaling through VPAC receptors modulates social contact, gregariousness, pair-bonding and nesting behavior. Thus, based on our findings from central VPAC receptor antagonism, immediate early gene expression studies, and comparisons of VIP circuitry in territorial and flocking species of finches and sparrows, we propose that VIP is a widespread modulator of affiliation in birds.

92-5 KIMMITT, A.A.*; KETTERSON, E.D.; Indiana Univ., Bloomington; akimmitt@indiana.edu
Do female differences in reproductive timing alter gene flow in heteropatric populations?

Population differences in migratory behavior and reproductive timing can lead to reduced gene flow and population divergence. Some migratory and sedentary (resident) populations that are sympatric in winter become allopatric after migration in a pattern of distribution known as heteropatry. If residents begin to breed prior to the departure of migrants, a window exists in which interbreeding may occur. In a previous study, male dark-eyed juncos from heteropatric populations were held in spring in a captive common garden, and migrants were shown to lag behind residents in testis size and testosterone. Far less is known about the impact of migration on the reproductive development of females, despite the obvious importance of female timing to gene flow. Although females rarely come into full reproductive condition in captivity, female European Starlings held on long-day photoperiod and exposed to multiple estradiol injections, exhibited elevated yolk proteins, an indicator of reproductive readiness. We predicted that migrant female juncos would be less responsive than residents to estradiol injections. We injected 38 females with estradiol for 5 days and then collected a blood sample. We sampled at two time points while females were held at a natural photoperiod of the wintering grounds: mid-March, prior to migration, and early May, during migration for migrants and early breeding season for residents. We sampled again in mid-June after all females had been advanced to a 16L: 8D photoperiod. Blood samples will be analyzed for triglycerides as indicators of VLDL, a female yolk protein. The data will bear on whether female reproductive readiness plays a role in the frequency of interbreeding between heteropatric populations, enabling us to better understand the role of migration in population divergence.

130-3 KINGSOLVER, J.G*; WOODS, H.A.; Univ. of North Carolina, Univ. of Montana; jkking@bio.unc.edu
Beyond thermal performance curves: Modeling time-dependent effects of thermal stress on ectotherm growth rates

Thermal performance curves have been widely used to model the ecological responses of ectotherms to variable thermal environments and climate change. Such models ignore the effects of time-dependence – the temporal pattern and duration of temperature exposure – on performance. We developed and solved a simple mathematical model for growth rate of ectotherms, combining thermal performance curves for ingestion rate with the temporal dynamics of gene expression and protein production in response to high temperatures to predict temporal patterns of growth rate in constant and diurnally fluctuating temperatures. We used the model to explore the effects of heat shock proteins on larval growth rates of *Manduca sexta*. The model correctly captures two empirical patterns for larval growth rate: First, maximal growth rate and optimal temperature decline with increasing duration of temperature exposure; and second, mean growth rates decline with time in diurnally fluctuating temperatures at higher mean temperatures. These qualitative results apply broadly to cases where proteins or other molecules produced in response to high temperatures reduce growth rates. I may also discuss a new statistical method, developed in collaboration with Frank Shaw, which estimates performance curves using data on mean performance in fluctuating environments. Incorporating time-dependent effects will be essential for making more realistic predictions about the physiological and ecological consequences of temperature fluctuations and climate change.

54-6 KINGSTON, ACN*; CRONIN, TW; Univ. of Maryland, Baltimore County; anahm1@umbc.edu

Extraocular opsins in skin and nervous systems of aquatic animals
Extraocular photoreceptors are common throughout animals, and many of these photoreceptors function using opsin proteins expressed in many tissues and cellular structures. Cephalopods, crustaceans, and fish represent phyla where extraocular opsin expression appears to be common. Cephalopods express their retinal rhodopsin and several other phototransduction proteins in chromatophore organs, parolfactory vesicles, mantle muscles, arm ganglia, sucker peduncle nerves, and a distributed array of hair cells that covers the outer epidermis. This protein expression throughout cephalopod tissues suggests that they have many extraocular photoreceptors, particularly since these tissues express the same proteins found in other photoreceptive tissues such as retinas and parolfactory vesicles. Similarly to cephalopods, crustaceans appear to have many extraocular photoreceptors. Retinal short- and long-wavelength sensitive (SWS and LWS) opsins are expressed in cell body clusters in the cerebral ganglion of the crayfish, *Procambarus clarkii*. From those cell bodies extend two pairs of nerve fibers that express LWS opsin protein. One pair of fibers terminates in the subesophageal ganglion (SEG) while the second pair continues through the SEG, thoracic and abdominal regions of the nerve cord, ultimately terminating in the sixth abdominal ganglion where the caudal photoreceptor exists. Like cephalopods, flounder have opsin transcripts located within the skin. The flounder, *Paralichthys dentatus*, has both visual opsin transcripts (RH1, RH2, SWS1, SWS2, LWS) and melanopsin in many skin regions, suggesting that putative extraocular photoreceptors may function using more than one phototransduction pathway. Opsin expression that likely contributes to extraocular light detection appears to be a common occurrence that is not well understood in these and many other animals.

17-3 KIRSCHMAN, L.J.*; WARNE, R.W.; MCCUE, M.D.; Southern Illinois University, St. Mary's University; l.j.kirschman@siu.edu

The effects of stress and disease on energetics and macronutrient usage in metamorphosing larvae

Susceptibility to stressors and disease varies with ontogeny. The prevalence and virulence of pathogens tends to be highest in larvae, neonates, and juveniles, but decline through adulthood. While immature immune systems often contribute to high susceptibility in developing animals, emerging evidence suggests organ physiology and nutrient allocation may play a central, but still poorly understood, role. We examined the effects of stress and ranavirus infection on larval amphibians, a model system to test these interactions. Metamorphosis requires a substantial amount of energy and concurrent reorganization of the digestive tract exacerbates this strain, as larvae must complete metamorphosis with stored energy. Stress-induced, accelerated metamorphosis may increase this cost. Similarly, ranavirus accelerates metamorphosis and the additional cost of infection has unknown effects on larval energy budgets. We measured oxygen consumption and energetics of wood frog (*Lithobates sylvaticus*) larvae exposed to exogenous stress hormones or ranavirus. To determine if stressed or infected larvae oxidize different macronutrients to fuel metamorphosis, we labeled diets with ¹³C-tracers. Preliminary results show stressed larvae are smaller ($p > 0.01$) and consume less oxygen ($p > 0.01$). Infected larvae consume much less oxygen ($p > 0.01$) and pre-infection oxygen consumption predicts day of death following ranavirus exposure. ($R^2 = 0.53$, $p = 0.02$). These results indicate a metabolic cost for accelerated metamorphosis, as the oxygen consumption of stressed larvae did not decrease congruent to their mass. Furthermore, severe hepatitis and liver failure, caused by ranavirus, may deprive larvae of energy and nutrients, leading to earlier deaths of individuals with higher metabolisms.

109-7 KIRK, NL*; HOWELLS, EJ; ABREGO, D; BURT, J; MEYER, E; Oregon State Univ., New York Univ. at Abu Dhabi; kirknl@science.oregonstate.edu

Transcriptomic analysis of heat and salinity tolerance in corals from the Arabian Gulf

Scleractinian corals are severely threatened by rising ocean temperatures. Several recent studies have shown that some coral populations possess heritable genetic variation in thermal tolerance, providing raw material for adaptation to climate change. High seawater temperatures (36°C) and salinity (44 ppt) in the Arabian Gulf have likely selected for environmental stress tolerance in the local populations, presenting a unique resource for the study of corals' adaptive potential in a warming climate. To investigate thermal tolerance phenotypes in these populations, we focused on aposymbiotic larval stages of *Platygyra daedalea*. Thermal tolerance (survival during heat stress) was measured in 64 controlled crosses generated from 12 parental colonies. We documented extensive genetic variation in thermal tolerance ($h^2=0.33$), and identified families with contrasting tolerance phenotypes. To investigate the functional basis for these differences, larvae were exposed to factorial combinations of elevated temperature and salinity. To compare families' transcriptional responses we sequenced and annotated a de novo transcriptome, which was used as a reference to profile gene expression using RNA-Seq. This snapshot of gene expression revealed higher expression of putative stress response genes in susceptible than tolerant families. To investigate the dynamics of gene expression more directly, we conducted additional crosses in a subsequent season and profiled changes in gene expression over time in tolerant and susceptible families. This study provides insights into the mechanisms through which stress tolerant corals persist in the Gulf, and ultimately into possible mechanisms through which corals may adapt to climate change.

69-7 KITCHEN, SA*; POOLE, AZ; WEIS, VM; Oregon State University; kitchens@science.oregonstate.edu

Modulation of cnidarian sphingosine rheostat during symbiosis onset and breakdown

Lipids play a central in symbiosis, providing both cellular structure and energy storage, but little is known about how signaling lipids participate in onset and breakdown of symbiosis between cnidarians and dinoflagellates of the genus *Symbiodinium*. Signaling lipids, sphingosine (Sph) and sphingosine-1-phosphate (S1P), play a pivotal role in determining cell fate, where increased Sph drives apoptotic activity within the cell while S1P promotes cell survival. The balance of these lipids creates the 'sphingosine rheostat' controlled by enzymatic reactions of sphingosine kinase (SPHK) and sphingosine-1-phosphatase (SPPase). A recent study demonstrated that exogenously applied sphingolipids could alter the cnidarian-dinoflagellate partnership, however endogenous regulation of the rheostat in cnidarians has not been characterized. In this study, we investigated the role of rheostat during symbiont colonization and thermal stress in the sea anemone *Aiptasia*. During colonization, anemones were inoculated with *Symbiodinium* and monitored over three days. For thermal stress, anemones were exposed to a range of elevated temperature (27 to 33°C) over one week. Symbiont uptake was quantified with qRT-PCR and symbiont loss measured by fluorescent microscopy. In both treatments, the expression of rheostat enzymes was examined using qRT-PCR. During symbiont colonization, the rheostat shifted toward cell survival with up-regulation of SPHK after 24 hours. Conversely, under hyperthermal stress the rheostat shifted to cell death after 1-2 days of exposure. Finally, to link gene expression to enzymatic activity, we quantified sphingolipid concentrations using mass spectrometry analysis of lipid extracts. Collectively these data suggest that sphingolipid signaling plays a regulatory role in cnidarian-dinoflagellate symbiosis.

97-10 KLAASSEN VAN OORSCHOT, B*; TOBALSKE, B.W.; Univ. of Montana; brett.kvo@umontana.edu

Slotted feathers aren't just for efficiency

Soaring birds including hawks and vultures exhibit emarginated primary feathers that collectively create a slotted wing-tip. Research has indicated these wing-tip slots reduce induced drag, resulting in a more efficient wing (i.e. better lift:drag ratio). These feathers routinely deform due to aerodynamic and inertial loading during flapping and gliding flight. Here we provide evidence that spanwise bending and twisting in these feathers results in greater roll stability and stall minimization. We measured primary feathers from 8 species and quantified force production and deformation at varying attack angles through a range of velocities. Markedly-emarginated primary feathers bend and twist more than less-emarginated feathers. Bending reorients forces medially, thereby contributing to roll stability for the animal. Twisting into incurrent flow decreases local attack angles and reorients force vertically. These findings reveal that emarginated primary feather slots are likely of greatest benefit during accelerative behaviors where attack angles are often high and variable, including take-off, landing, maneuvering or flying in turbulent conditions. NSF DGE-0809127, DGE-1313190 and IOS IOS-0923606.

109-2 KOCH, J.C.*; CONTOLINI, G.M.; University of Washington Friday Harbor Laboratories and Oregon State University, Corvallis, University of Washington Friday Harbor Laboratories and University of California, Santa Cruz; kochja@science.oregonstate.edu
Anemones on acid: The effects of increased pCO₂ on carbonic anhydrase activity in the symbiotic sea anemone *Anthopleura elegantissima*

Anthopleura elegantissima participates in a facultative symbiosis with two genera of microalgae, the dinoflagellate *Symbiodinium* spp. and the chlorophyte *Elliptochloris marina*. The symbiosis is centered around nutrient exchange including reduced organic carbon, inorganic nitrogen and carbon dioxide (CO₂). The CO₂ is used in algal photosynthesis and is produced in part by anemone carbonic anhydrase (CA) which catalyzes the reversible reaction of sodium bicarbonate to CO₂. Under ocean acidification conditions, algal symbiont densities in *A. elegantissima* have been shown to increase, thereby increasing the demand for CO₂ by the symbionts. Additionally, ocean acidification causes an increase in the abundance of bicarbonate and CO₂ in seawater. Therefore, we predicted that an increase in algal symbiont density under acidifying conditions would trigger an increase in anemone CA activity to meet the need for increased CO₂. Aposymbiotic, *Symbiodinium*-, and *Elliptochloris*-containing *A. elegantissima* were collected from four locations around San Juan Island, and placed into ambient and high pCO₂ conditions for 10 days. Anemone CA activity was only measured after the experiment and algal densities were measured before and after the experiment. There was no significant effect of pCO₂ or symbiotic state on the CA or density of algal symbionts after ten days of treatment. Our findings suggest that *A. elegantissima* may have internal homeostatic mechanisms to respond to increased pCO₂ levels and concomitant increased algal densities.

62-4 KNOTT, K. E.*; HEISKANEN, S.; THONIG, A.; BANTA, G. T.; University of Jyväskylä, Finland, Roskilde University, Denmark, Roskilde University, Denmark; emily.knott@jyu.fi

Exploring temporal variation in genetic diversity of *Pygospio elegans* (Spionidae) and its relationship to community diversity.

Because some ecological and evolutionary processes can have similar effects on genetic diversity within species and on species diversity within communities, positive correlations between the different levels of biodiversity are expected. Such correlations are useful indicators of habitat characteristics that can support high diversity at multiple levels. However, selection can disrupt potential species- genetic diversity correlations; for example, in cases of species with specific adaptations or environmental tolerances. Moreover, recent meta-analyses indicate that species- genetic diversity correlations are more commonly found in studies of discrete habitat units. We determined the genetic diversity of the spionid polychaete *Pygospio elegans* at four sites in the Isefjord-Roskilde Fjord estuary in Denmark over four time points in 2014 (March, May, August and November) using eight microsatellite markers. Temporal variation in species diversity of Annelids and other benthic macroinvertebrates was also evaluated. Despite short geographic distances and ecological similarities between the sites, there were significant seasonal changes in genetic diversity of *P. elegans* that were positively correlated with species diversity. Although *P. elegans* was most abundant in May, genetic diversity of this species was highest in August. Genetic differentiation was also evident, particularly between the site from the inner estuary and those in the outer estuary. Species- genetic diversity correlations in the marine environment have not been studied frequently, and our results provide evidence for such correlations even though it is difficult to discern discrete habitat units.

47-7 KOEHL, M*; WONG, K; CUMMINGS, B; COOPER, T; Univ. of California, Berkeley; cnidaria@berkeley.edu

Hydrodynamics of unicellular vs. colonial choanoflagellates: Swimming, feeding, and hiding

The origin of multicellular animals from a unicellular protozoan represents a pivotal transition in life's history. We are using choanoflagellate protozoans (close relatives of animals) that can be unicellular and can form multicellular colonies as a model system to study functional consequences of being colonial vs. unicellular so that we can gain insights about selective factors that might have affected the evolution of multicellularity. Each choanoflagellate cell propels water by beating a single flagellum and captures bacterial prey on a collar of microvilli around the flagellum. We used high-speed microvideography to study the water flow produced by solitary cells and by colonies, and how that affects their ability to swim, to capture bacterial prey, and to be hydrodynamically-cryptic. We found that unicellular choanoflagellates swim more rapidly than colonies, which often rotate in place. The flux of water past cells tethered to each other in a colony is greater than for single cells, and cells in colonies capture more prey per time than do single cells. The larger the colony, the higher the prey capture rate per cell and the greater the differences between capture rates of the cells in a colony. However, there may be a trade-off between feeding performance and predator avoidance: the region of water disturbed by colonies is much bigger than the region disturbed by unicellular choanoflagellates, thus colonies put out larger hydrodynamic signals. Protozoans, both unicellular and colonial, play an important role in aquatic food webs. Using choanoflagellates as model organisms enables us to compare the trophic performance of uni- and multicellular forms within the same species, while also providing insights about ecological interactions that might have affected the evolution of multicellularity in the ancestors of animals.

115-7 KOENIG, KM*; GROSS, JM; University of Texas at Austin; kmkoenig@utexas.edu

Making an Eye: Optic Vesicle Morphogenesis in the Cephalopod *Doryteuthis pealeii*

Photoreception is a dominant sensory tool found in the majority of taxa across the Metazoa. Photoreceptive organs range in complexity from a single photoreceptor cell, pigmented eyespots and cups, to complicated organs that focus, reflect and absorb light in order to resolve images. Very little is known about how these structures develop and how a simple photoreceptive organ can evolve and elaborate into a more complicated form. Our interest is to better understand the morphogenesis of these complex sensory systems. The single-chambered eye of the squid *Doryteuthis pealeii* is an ideal system to study morphogenesis because eye formation occurs on the exterior of the embryo and is easily visualized. The cephalopod eye is assembled through the internalization of two bilateral retina placodes by the future lens and iris tissue. This internalization event generates the optic vesicles, which will continue to proliferate and develop, ultimately differentiating into all the cell types that compose the eye. We have established *in vivo* imaging protocols using long-term light-sheet microscopy that allow us to better understand how cell division, cell migration and cell shape change may contribute to this morphogenetic process.

53-3 KOETKE, L.J.*; DEVANEY, J.; PARKER, J.D.; Smithsonian Environmental Research Center; koetke@stolaf.edu
Coevolved versus novel plant-herbivore interactions in a non-native world

Invasion of ecosystems by exotic plants is considered to be one of the main threats to biodiversity globally. According to the enemy release hypothesis, plants which are introduced to a non-native environment often escape their coevolved predators and become very abundant. In Maryland, many invasive plant species are native to the Japanese archipelago. However, two Japanese herbivores (sika deer *Cervus nippon* and Japanese beetles *Popillia japonica*) have also been introduced to Maryland and are now classified as invasive. In this case, the invasive plants may not have escaped their coevolved predators. Sika deer and Japanese beetles have the choice between coevolved plants which are also native to the Japanese archipelago or novel plant species which are native to Maryland. We conducted cafeteria-style preference tests to determine the dietary preference of these herbivores. Sika deer showed significant preference for novel plant species in the field. Japanese beetles tended to colonize coevolved plant species in the field, but showed no significant dietary preference in lab assays. Differences in dietary preferences of the herbivore species are possibly due to the different scales of these grazers and their scope for adaptation. Sika deer have greater mobility than beetles, permitting them to be more selective in their dietary choices. Beetles, on the other hand, have much shorter generation times and can potentially adapt faster to new chemical defenses, allowing them to graze on both coevolved and novel plant species. Further chemical and morphological trait analyses of plant species used in our study are required to reveal other factors driving herbivore dietary preference in a non-native world.

51-2 KOHL, K.D.*; BRUN, A.; MAGALLANES, M.; LASPIUR, A.; ACOSTA, J.C.; BORDENSTEIN, S.R.; CAVIEDES-VIDAL, E.; Vanderbilt Univ., Univ. Nac. San Luis, Argentina, Univ. Nac. San Juan, Argentina; kkohl78@gmail.com

It's not easy eating green: physiological and microbial adjustments allow herbivory in an omnivorous lizard

While herbivory is a common feeding strategy in a number of vertebrate classes, less than 4% of squamate reptiles feed primarily on plant material. It has been theorized that physiological or microbial limitations may constrain the evolution of herbivory in lizards. Herbivorous lizards exhibit adaptations in digestive morphology and function that allow them to better assimilate plant material. However, it is unknown whether these traits are fixed or perhaps phenotypically flexible as a result of diet. Here, we maintained a naturally omnivorous lizard, *Liolaemus ruibali*, on a mixed diet of 50% insects and 50% plant material, or a plant-rich diet of 90% plant material. We compared parameters of digestive performance, gut morphology and function, and gut microbial community structure between the two groups. We found that lizards fed the plant-rich diet maintained nitrogen balance. Additionally, lizards fed the plant-rich diet exhibited significantly longer small intestines and larger hindguts compared to those fed the mixed diet, demonstrating that gut morphology is phenotypically flexible. Lizards fed the plant-rich diet harbored small intestinal communities that were more diverse and enriched in Melainabacteria and *Oscillospira* compared to mixed-fed lizards, taxa that are associated with fermentation. Additionally, the relative abundance of sulfate-reducing bacteria in the small intestine significantly correlated with whole-animal fiber digestibility. Thus, we hypothesize that physiological and microbial limitations do not constrain the evolution of herbivory in lizards.

42-2 KOHN, A.B.*; BASANTA-SANCHEZ, M.; MOROZ, L.L.; University of Florida, Whitney lab, University of Albany, The RNA Institute, University of Florida, Whitney lab, Department of Neuroscience and McKnight Brain Institute; abkohn@msn.com
Epitranscriptomic landscape of *Aplysia californica*: Single-cell approach

Post-transcriptional changes in RNA have the potential to influence the epigenetic landscape. As of today there are over a hundred RNA modifications. These chemical changes to nucleotides do not alter the sequence of RNA but can alter gene expression and has recently been described as part of a so-called epitranscriptome. Similar to DNA methylation, there are RNA methylation and demethylation enzymes. Methylation of adenosine to N6-methyladenine (m6A) is the most prevalent internal modification on mRNA and long non-coding RNA with up to 20% of the human mRNA routinely methylated. However, little is known about biological roles of RNA modifications. Here, we used the sea slug *Aplysia*, a prominent model organisms to study learning and memory, and chemically characterized the scope of the epitranscriptome focusing on the central nervous system and plasticity mechanisms. Using an ELISA, we determine that 4% of the total RNA was methylated in *Aplysia*. RNA-seq and computation analysis of the *Aplysia* genome shows that all the enzyme families involved in RNA methylation/demethylation are present in varying amounts from developmental states to single neurons. For the first time RNA modifications were identified and quantified in single neurons using ultrasensitive mass spectrometry (MS) in combination ultra-high performance liquid chromatography. Two different cholinergic neurons in *Aplysia* showed different and distinct RNA modifications. In addition to the RNA modification, we also discover cell- and tissue specific RNA editing in *Aplysia*. RNA editing is a process of targeted alterations of nucleotides in all types of RNA molecules. As a result, the transcriptional output differs from its genomic DNA template.

20-4 KOLMANN, MA*; SUMMERS, AP; LOVEJOY, NR;
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Prey material properties and the evolution of the feeding apparatus in stingrays

Stingrays have diversified to fill an array of trophic niches across freshwater, estuarine, and marine systems despite lacking the prey-processing pharyngeal jaws of bony fishes. Several species have evolved to be "durophagous," feeding on prey like mollusks; while some freshwater rays are the only insectivorous elasmobranchs. We present data on prey processing in insectivorous and durophagous rays in two families, the freshwater potamotrygonids and the marine, pelagic myliobatids. Muscular hypertrophy and a reinforced jaw skeleton enable myliobatids to generate high bite forces over their ontogeny and resist stresses incurred during feeding on stiff prey. Asymmetrical jaw protrusion and substantial lateral movement of the jaws are typical of feeding on tougher prey items like insects. The shape of myliobatid tooth arrays does not affect crushing performance on bivalve and gastropod prey, even as teeth become stiffer over ontogeny. Insectivorous rays can behaviorally reorient their teeth from flattened occlusion to occluding cusps when feeding on tough prey, as the dental ligament is contracted. Despite simple jaw morphology these fishes accomplish impressive post capture prey manipulation and processing by combining hydrodynamic forces with complex movements of the jaws.

14-2 KONOW, N*; HEDBERG, ML; ROBERTS, TJ; SWARTZ, SM; Brown University; nkonow@brown.edu
Antebrachial muscle contraction counteracts tendon elastic action in hovering bat flight

The long forearm and handwing bones of bats are moved by antibrachial muscles via tendons that often exceed half of the total length of the muscle tendon unit (MTU). One such muscle, extensor carpi radialis longus (ECRL) crosses both the elbow and wrist. It has been proposed that its biarticular architecture, coupled with a strut-like MTU behavior lets the ECRL relay elbow extension by triceps brachii to handwing extension. We probed this idea during hovering flight of *Carollia perspicillata* ($n = 3$). We calculated MTU length (L_{mtu}) and strain from *in vivo* measurements of joint kinematics and *ex vivo* measurements of muscle moment arms. Extension of the elbow and wrist occurred at the same time and at similar rates during downstroke. Measured moment arms were similar at each joint (0.016 ± 0.001 mm degree⁻¹; mean \pm S.D.) and remained constant across the operating ranges of both joints. The MTU underwent a modest lengthening of $4.0 \pm 0.2\%$ during wing extension, consistent with the idea of strut-like MTU behavior. A strut-like MTU could result from length change of both muscle and tendon in a compliant system, or alternatively from isometry of both muscle and tendon in a stiff system. To test between these possibilities, we measured muscle length (L_m) using fluoromicrometry and calculated tendon length ($L_{mtu} - L_m$). During wing extension, the muscle shortened by 0.12 ± 0.04 cm and the tendon lengthened by 0.25 ± 0.04 cm. These results suggest that a strut-like function of the ECRL results not from isometric muscle action, but from the balancing influence of muscle shortening and tendon lengthening.

100-2 KOLOMENSKIY, D.*; RAVI, S.; ENGELS, T.; SCHNEIDER, K.; WANG, C.; SESTERHENN, J.; COMBES, S.; LIU, H.; Chiba University, Chiba University and RMIT University, TU Berlin and Aix-Marseille University, Aix-Marseille University, RMIT University, TU Berlin, Harvard University;
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Analysis of Bumblebee Flight in Unsteady Wind Using Wind-Tunnel Experiments and High-Fidelity Numerical Simulations

Bumblebees are relentless foragers capable of flying in a wide range of weather conditions. Flight in unsteady wind is of particular interest as it presents a complex dynamical interaction between the fluid and the insect. To interpret the observed behavior and identify the control strategies employed, it is essential to disentangle the voluntary maneuvering performed by the insect from the passive mechanical response of the flight apparatus in unsteady winds. Here we analyze the lateral flight dynamics of bumblebees through a combination of experimental observations and high fidelity numerical simulations. Detailed flight trajectories of bumblebees flying upwind in unsteady winds towards an artificial flower were measured using high speed videography. Unsteady wind was generated by placing a vertical cylinder at the inlet of the wind tunnel test section, resulting in the formation of a von Kármán vortex street in the wake. We also performed high fidelity numerical simulations of a bumblebee with similar anatomical features, flying in similar unsteady wind, with no flight control to investigate the passive dynamic interactions. By comparing the experiment and the numerical simulation, we reveal that the flight path of the bee is a result of the superposition of two distinct modes: a voluntary low-frequency casting motion and a passive high-frequency buffeting. Our findings suggest that bumblebees use a combination of active and passive strategies to mitigate the challenges imposed by wind unsteadiness.

69-6 KOVACS, J.L.*; VOISIN, D.; Spelman College;
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Temporal variation in honeybee microbial symbionts

Recent losses of honeybee colonies have led to an increased focus on understanding the microbial associations both within honeybee colonies and the honeybees themselves. While advances in sequencing have allowed us to identify the bacterial symbionts living within honeybee guts, still little is known about how differences in foraging behavior affect which fungal and bacterial symbionts are present in a colony and at what relative abundances. For example, seasonal variation in flowering plants may affect the symbionts to which a worker is exposed. Additionally, some colonies may display foraging preferences which could result in a distinctive colony symbiont composition. This study uses non-culture based sequencing methods to identify bacterial and fungal symbionts in multiple honeybee colonies at different times of the year and at different spatial scales. Both honey and honeybee workers were sampled from the same colonies in the fall and the spring, and DNA was extracted from honey and pooled honeybee worker gut dissections. We then used DNA metabarcoding to identify fungi and bacteria found in the honey and honeybee worker gut samples. This study provides us with a clearer understanding of how seasonal variation in honeybee foraging behavior can affect the microbial associations found within a honeybee hive.

91-4 KOVACS, J. L.; WEIGEL, E.G.*; WERREN, J.W.; Spelman College, University of Rochester; *emilyweigel@gmail.com*
Evolutionary novelty: Horizontal gene transfer in the kissing bug, *Rhodnius prolixus*

The inter-organismal movement of genetic material by means other than reproduction, or horizontal gene transfer (HGT), may be more common in eukaryotes than once thought. Using two parallel bioinformatic pipelines, we have identified and characterized horizontally transferred genes of bacterial and fungal origin found and expressed in *Rhodnius prolixus* (the kissing bug). First, proteins yielding significant hits with distantly related blood-feeders, bacteria, and fungi, but returning no hits from non-blood feeding Hemiptera and *Drosophila* were retained as candidate HGTs. These candidates were again queried through a series of protein and nucleotide databases to identify fungal- and bacterial-like regions nested within animal-like scaffolds. These identified functional genes are shared among hematophagous arthropods, but absent in more closely-related organisms which do not share this niche. Thus, HGT likely allowed for the acquisition of phenotypically novel traits in the evolution of hematophagous organisms. Our ultimate goal is to identify those genes shared by multiple hematophagous arthropods of similar and different ecological niches, elucidate their functions, origins, and transfer mechanisms, and determine the inter- and intra-organism effects of HGTs in eukaryotes and their evolution.

96-1 KRAEMER, A.C.*; PARENT, C.E.; Univ. of Idaho; *andrew.c.kraemer@gmail.com*

Color Diversification in the Endemic Land Snails of Galápagos

The Galápagos endemic land snails of the genus *Naesiotus* have undergone a massive, recent radiation into 80 ecologically diverse species over the last five million years. Coupled with this increase in species number is rapid morphological diversification, including remarkable variation in coloration. One hypothesis states that this color variation is adaptive, allowing snails to avoid detection from bird predators. This hypothesis makes several testable predictions. First, birds must actually seek out and consume snails. Second, the coloration of snails will match the backgrounds they are found on. Third, birds will be unable to differentiate the colors of prey and local backgrounds. We document that Galápagos mockingbirds (genus *Mimus*) do in fact seek out and consume *Naesiotus* snails. We then compared 45 species of *Naesiotus* snails to local backgrounds and found that snails closely matched local backgrounds in both color and brightness. Finally, we projected snail and background color data into a bird visual space to characterize the degree of color matching from the perspective of predators. We find strong support for the hypothesis that *Naesiotus* snails match local backgrounds to avoid predation. The next step in this research will be to consider the unique setting of this radiation and evaluate the role coloration and other morphological variables may have played in the colonization and diversification process.

78-1 KOZMA, E.E.*; RAICHLIN, D.A.; WOOD, B.M.; PONTZER, H.; The Graduate Center, CUNY and New York Consortium in Evolutionary Primatology, University of Arizona, Yale University, Hunter College, CUNY and New York Consortium in Evolutionary Primatology ; *kozma.elaine@gmail.com*

Determinants of Energetic Costs of Climbing in Humans

The factors that influence the metabolic cost of locomotion during vertical climbing are not well understood. Previous studies in primates and other animals have demonstrated that mass specific cost of transport for climbing is independent of body size across species, but effects of speed, route difficulty, and within-species variation are largely untested. Here, we assess the effects of speed, route difficulty, and anatomical variation on the energetic cost of climbing. Eighteen experienced, adult human climbers in two populations (U.S., n=12; Tanzania, n=6) climbed a set of laps over a range of levels of difficulty and speeds, with energy expenditure measured via respirometry. As with interspecific studies, we found no effect of body mass on the mass-specific cost of transport. Further, results indicate that route difficulty has no significant effect on energy expenditure. Climbing speed was positively correlated with efficiency (meters climbed/calories expended/kilogram) due to the greater postural cost of clinging onto the substrate at slower speeds. This suggests that both increasing speed (which may be limited by muscle fatigue) and decreasing postural cost are avenues to decrease the energetic cost of climbing.

3-3 KRANS, JL; Western New England Uni; *jkrans@wne.edu*
Reducing expression of giant sarcomere associated proteins: Reducing expression of giant sarcomere associated proteins: Effects on arthropod force hysteresis

We are interested in the contribution of giant sarcomere associated proteins (gSAPs, e.g. titin) to history dependent modulation of force production and have developed an *in vivo* model with which to transiently knock down expression of these proteins. The *Drosophila* gene of fruit fly transcribes several gSAPs that contain repeated PEVK and Ig domains and appear to act similarly to titin in chordate muscle. Several aspects of the larval fruit fly preparation make it especially useful for further exploration of gSAP physiology: muscle length change is relatively large, genetic tools are well established, muscle orientation and geometry are repeated across multiple segments, and motor behavior is simple. Our model utilizes RNAi, under the regulation of a temperature sensitive gene, to reduce transcription of sls. Expression of gSAPs decreases with increased exposure to a restrictive temperature. The molecular and physiologic efficacy of this paradigm will be addressed and early results are given in the context of the hypothesis that gSAPs dampen sarcomere length changes and promote maintenance of force produced after actomyosin activation. Force hysteresis in this preparation is well described and not of synaptic origin; wild type animals maintain force that is greater than predicted when an initial activation precedes the contraction being examined. We tested our hypothesis using isometric conditions, giving an initial burst of actomyosin activation and modulating activation frequency thereafter, and force ergometer / mechanical approaches. Animals with reduced gSAP expression exhibited reduced hysteresis but maintained fundamental parameters of contraction; peak force and time constants were not significantly different from controls. These findings support the hypothesis that gSAPs can act as tethers in arthropod muscle.

S3-4 KRASNOV, B.R.*; KHOKHLOVA, I.S.; Ben-Gurion University of the Negev; *krasnov@bgu.ac.il*

Climate or hosts? Factors determining flea species composition at a local versus a regional scale in the Palearctic

The environment may act as a "filter", allowing a community to contain only species possessing traits necessary for persistence in that environment. Parasites are characterized by a "dual" environment, namely by their hosts and by abiotic (e.g., climatic) factors. We investigated the role of environmental filtering as an underlying mechanism of assembly of compound communities of fleas parasitic on Palearctic small mammals at two spatial scales: a continental scale (across the Palearctic) and a regional scale (within Slovakia). We used an expanded version of three table ordination that links species occurrences with space, environment, species traits and phylogeny. We asked whether environmental filtering acts as an assembly rule of compound communities of fleas and, if yes, (a) whether the effect of environment on species composition of compound communities of fleas differs between spatial scales and (b) what are the relative importance of the abiotic and host environments. We found that compound communities of fleas are, to a great extent, assembled via environmental filters that represent interplay between filtering via abiotic environment and filtering via host composition. The relative importance of these two components of environmental filtering differed between spatial scales. Host composition had a stronger effect on flea assembly than abiotic environment on the continental scale, while the opposite was true for the regional scale. The climate changes, thus, may affect species composition of fleas at local, but not regional scale. The likely reason behind this scale-dependence is that communities on the regional scale are mainly governed by ecological and epidemiological processes, while communities on the continental scale are mainly affected by evolutionary, biogeographic and historical forces.

24-2 KRENTZEL, D*; ANGIELCZYK, K.; Univ. of Chicago, Field Museum; *dkrentzel@uchicago.edu*

Why are mammals such air-heads? Porcupines and function of the frontal sinus in mammals

Fronto-nasal sinuses are common features in the skulls of many mammals, although their function is unclear. We used micro-CT scanning to analyze the 3D internal anatomy of fronto-nasal sinuses in 12 species across the two independent lineages of Old and New World porcupines (Hystricidae and Erethizontidae). Both lineages have convergently evolved large fronto-nasal sinuses that create a prominent dome shape to the skull, with the sinuses sometimes being comparable in volume to the rest of the cranium. The integuments of these domes are covered in anteriorly projecting quills in erethizontids and highly elongated display quills that form a "crest" in hystricids. The sinuses in most erethizontids are small and maintain a flat shape to the dorsal skull roof. Within this family, two independent evolutions of domed sinuses have occurred in the largest taxa. We found that the hystricid *Trichys* completely lacks a frontonasal sinus, but the more derived *Atherurus* contains a small but well defined sinus. Ontogenetic data demonstrates that the sinus in *Hystrix africae australis* invades the maxilla, parietals, and squamosal bones, creating near full coverage of the dorsolateral cranium with sinuses. Both families demonstrate an evolutionary relationship between fronto-nasal sinus volume and body size, as seen in other mammals. The data herein provide some support for the hypothesis that mammals utilize fronto-nasal sinuses to maintain cranial shape when evolving larger body size, and their existence allows for co-option into novel structural roles. In porcupines, this novel function could be to provide a surface for quill attachment, with anatomical data as yet failing to support a novel physiological role.

26-6 KRAUSE, J.S.*; PEREZ, J.H. ; CHMURA, H.E.; MEDDLE, S.L.; HUNT, K.E.; GOUGH, L.; BOELMAN, N.; WINGFIELD, J.C.; UC Davis, Roslin Inst. , N. Eng. Aqua., Towson Univ., Columbia Univ.; *jskrause@ucdavis.edu*

Breeding in an extreme environment: the effects of inter-annual variation in snow cover and snow storms on the timing of arrival and stress physiology in Lapland longspurs

Migrant birds arrive on their breeding grounds as early as possible to initiate breeding, especially in the Arctic where the breeding season is short. However, the timing of this major life history event can be affected by adverse environmental conditions (e.g., temperature, storms, and snow cover) which are highly unpredictable across years. In response to stressful events in the Arctic, birds activate the hypothalamic-pituitary-adrenal (HPA) axis in order to modify physiology and behavior through the actions of corticosterone. The degree to which the HPA axis is activated is thought to be regulated by the interaction of energetic status and environmental conditions. Lapland longspur (*Calcarius lapponicus*) stress physiology and morphology (fat and mass) along with environmental conditions (temperature and percent snow cover) were investigated in the summers of 2011-2014 to understand organism-environment interactions. Over the duration of the four year study, snow melt occurred unseasonably late in 2013 which delayed spring arrival. In response to these harsh conditions in 2013, body condition and mass were reduced relative to other years and HPA axis activity was increased. In addition, in three of the four years snow storms occurred around the period of egg laying which also increased HPA axis activity in every year except for 2013. Interestingly, HPA axis activity in response to snow storms was dependent upon parental status. Pre-parental birds increased activity in HPA axis activity compared to parental birds. In conclusion, HPA axis activity in Lapland longspurs is highly plastic and adapts to environmental conditions and parental status to help individuals cope with unpredictable events.

96-6 KROGMAN, W.L.; Midwestern State University; *wlkrog@gmail.com*

A Shift in Ecological and Physiological Cost/Benefit Provide an Adaptive Advantage for the Ontogenetic Transition from Conspicuous Colored Tails to Cryptic Colored Tails in *Plestiodon fasciatus*

Conspicuously colored autotomous tails of many lizard species can direct predator attacks away from vital body areas thus increasing survival. However, many species transition from this conspicuous tail coloration to a cryptic phenotype. Why should some species ontogenetically abandon an advantageous phenotype in favor of another? Here, I seek to answer this question by empirically evaluating two hypotheses using the five-lined skink, *Plestiodon fasciatus*; (1) the increase in size from juvenile to adult causes a shift in primary predator, thus rendering the adaptive advantage null or even deleterious, and (2) the tail serves as a site for energy storage and it simply is too valuable to lose in adult lizards. Using museum collections, I show that the ontogenetic shift occurs consistently at or around 60mm SVL in *P. fasciatus* and I use clay models to test whether different predators target specific combinations of coloration and size. Increased caloric content of tail tissue in adults indicate that they do indeed incur a greater energetic loss through tail autotomy as they reach adulthood and these calories are manifest in lipid molecules most commonly used for energy storage in vertebrates. These data support both hypotheses and illustrate that, as *P. fasciatus* matures, the ecological benefit of tail autotomy decreases while the physiological cost of losing the tail increases. This provides compelling evidence that the interplay of ecological and physiological elements favor one phenotype in juvenile lizards and another in adults, thus driving the evolution of the ontogenetic shift.

60-1 KRONE, I W*; BLACKBURN, D C; STANLEY, E L;
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Barcoding for braincases: Computed tomography-enabled landmark analysis of pipid frog crania

Despite their unassuming appearance and small size, pipid frogs, including the well-known African Clawed Frog *Xenopus*, are a diverse and evolutionarily informative group of early-diverging Anura. Though their external morphology is not ostensibly varied, pipid braincases are morphologically diverse. Their small size means that they are often recovered with three-dimensional preservation as fossils. Because molecular evidence is almost never available from fossils, placement of these taxa would normally be based entirely on morphological analyses. Our goal was to use 3D imaging and statistical analysis to analyze morphology and affinities of pipids in a less labor-intensive, faster, and more statistically robust way. Using high-energy Computed Tomography (CT) scanning, we modeled and analyzed the braincase morphology of almost two dozen extant and two extinct pipid species: *Oumkoutia anae* and a recently discovered pipid from the Oligocene of Tanzania. A 20-landmark analysis of the braincases proved highly informative. We also achieved significant and revealing results regarding allometry across pipids and *Xenopus*, and regarding the disparity of shape diversity in different areas of the braincase across *Xenopus*. Using Principal Component Analysis (PCA), we were able to investigate the clustering of species in morphospace across the entirety of sampled taxa and use these data to estimate phylogenetic placement of the two fossil species. While the affinities of *Oumkoutia* remain unclear, the fossil pipid from Tanzania can be interpreted with confidence to be a close relative of *X. itombwensis*.

89-3 KRUMMEL, G.*; STEWART, C.; MARUT, K.; PRIYA, S.;
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Studying Siphonophore Colonial Locomotion and Control Using a Biomimetic Robot

Siphonophores are colonial organisms that are capable of rapid movement and changes in direction. This capability is possible due to the distribution of thrust production of the bulk body among multiple jetting propulsion units along the length of the body central stem. In particular, species under the genus *Nanomia* utilize muscular control of the jetting unit outlet to direct the water jet during contraction. By including multiple distributed thrust units with directional control, a larger number of distinct forces can be imparted along the body to finely control the colony kinematics and heading. Understanding the fundamental colonial coordination, control, dynamics, and fluid motion would help in further understanding the growth and behavior of siphonophores in live environments. This study focuses on the characterization of the coordinated movements for velocity and heading control gaits. Preliminary measurements and classifications were developed using shadowgraph and fluorescent dye footage of siphonophores in captivity and open water, respectively. These characterizations were used for the design and preliminary control implementation of a *Nanomia*-mimetic robot. Parameterized modifications of the gait frequency and patterns, as well as the number of propulsion units in the colony, were iterated to determine the effect of gait generation variables on the colony velocity and heading response. These responses were combined to develop an optimized control scheme for rapid colonial locomotion control. Future plans for adaptive control of the colony using neural networks with distributed control, which mimics the minimal control network of *Nanomia*, will be discussed in an effort to automate jetting unit addition and autotomy.

130-8 KROUPA, TF*; MAN, TD; MILLER, LP; DENNY, MW;
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Thermal defense strategy determines limpet response to acute temperature stress on rocky shores

Climate change models predict increases in the frequency and intensity of extreme weather events. The fitness consequences to many organisms will be determined by their capacity to adjust their thermal sensitivities and the associated energetic costs. Our study was designed to determine how thermal defense strategy (constitutive versus induced) and the intensity of an acute high temperature challenge might affect post-stress physiological performance of limpets on rocky shores. The limpets *Lottia scabra* and *L. austrodigitalis* are typically found living together in the high intertidal zone, but may adopt different strategies for dealing with thermal stress. *L. scabra* exhibits high constitutive levels of the stress protein Hsp70 but no additional induced synthesis at high temperatures, whereas *L. austrodigitalis* exhibits low levels of constitutive Hsp70 and high inducibility. We measured respiration rate for field-collected and lab-acclimated individuals of each species under benign conditions in the lab, before and after exposure to one of five peak temperatures (14, 24, 28, 32, or 36 °C) during a 4.5-hour simulated low tide. Unlike *L. scabra*, *L. austrodigitalis* exhibited a significant increase in oxygen consumption following aerial exposure to high temperature, consistent with activation of the heat shock response. We expect ongoing analyses to show a positive correlation between individual respiration rate and Hsp70 expression level in our experimental limpets.

6-6 KUHN, BF; University of the Witwatersrand, Johannesburg,
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Living on the fringe; the carnivore community living in and around Johannesburg, South Africa

In a country renowned for its national parks, game reserves and conservation areas, little is known about the free ranging, non-conserved, carnivores living in and around the major metropolitan areas of Johannesburg and Pretoria, South Africa. The Cradle of Humankind World Heritage Site, an area of approximately 180 square miles, is 40 minutes north of central Johannesburg and 30 minutes west of central Pretoria. Known for its plethora of fossil sites, recent work has shown that a number of carnivore species are making this region their home, and from this region foraging into the fringes of the cities themselves. Some of the species identified via camera traps include black-backed jackal (*Canis mesomelas*), brown hyaena (*Hyaena brunnea*) and leopard (*Panthera pardus*). Additional photographic evidence indicates that the brown hyaena are actively breeding in the Cradle of Humankind, and the capture of a juvenile in the northern suburbs of Johannesburg in 2013 illustrates they are actively foraging within the city limits. While other small carnivores are living within the vast green belts that transect the city of Johannesburg, larger carnivores such as leopard and brown hyaena are sporadic nighttime visitors.

12-2 KULYOMINA, J*; CROSBY, A; FEDERLE, W; MOEN, D; IRSCHICK, D; University of Massachusetts at Amherst, Cambridge University; julia.kulyomina@verizon.net

Evolution of habitat use, body shape and toepad shape in geckos

Many gecko species have evolved to survive in the various environments around the world. Our research is focused on connecting the relationship between the geckos' natural environment to the body and toepad shape of the species. This was done by measuring various body parts of geckos across a 154 of species, determining their natural substrate, and comparing this information with data on toepad shape that is previously published. We conduct all of these analyses in a phylogenetic analysis. Our measurements clearly show that gecko species that adhere to leaves and ground have the smallest average size. While species that live on a combined substrate of rocks and tree trunks are typically several-fold larger. Our data also reveal interesting and previously unknown relationships between body shape, toepad shape and ecology in this important and diverse group. Our work therefore opens new doors on the evolution of adhesion in the context of the natural substrates that geckos use.

S3-6 KURIS, Armand M.; Univ. of California, Santa Barbara; kuris@lifesci.ucsb.edu

The Role of Infectious Processes in Ecosystems as Climate Changes

Infectious agents, when included in food webs, reveal that it is a much more connected and interactive world than when infectious diseases are ignored. More limited research on energetics indicates that at least in some aquatic ecosystems parasites have considerable biomass and high productivity. This implies that the infectious process plays a surprisingly substantial role in ecosystem energetics. Here I ask what are key factors that determine the role of parasites in ecosystems? Where and when is the infectious process important with respect to other ecosystem-level processes such as predation, competition and disturbance? Host density, overall biodiversity, invasive species, pollution and environmental persistence likely have significant impacts on the role of the infectious process in ecosystems. All are of concern with respect to climate change or to anthropogenic impacts. These ecosystem attributes generate hypotheses regarding the role of infectious processes. Changes in the role of infectious processes, as climate change and humans alter environments, are predictable based on those predicated changes. Extending work on estuaries and freshwater aquatic ecosystems, the role of infectious processes will likely be increased when and where host densities increase, environments become less polluted, are less invaded, are more persistent and have higher biodiversity.

53-2 KURNATH, P*; MERZ, NM; DEARING, MD; University of Utah; patrice.kurnath@utah.edu

Temperature-mediated Changes in Plant Toxin Tolerance by Mammalian Herbivores

There is growing evidence for mammalian herbivores that ambient temperature may interact directly with plant toxins in a way that the toxicity of plant defense compounds is amplified at warmer ambient temperatures. This phenomenon is known as temperature-dependent toxicity (TDT). We have been investigating TDT in an ecologically and evolutionarily relevant system of herbivorous woodrats (genus *Neotoma*) and their dietary toxins. Based on our previous work, we predicted that woodrats would have a lower tolerance for, and would thus ingest less, plant toxins at warmer temperatures. We measured tolerance for resin from creosote bush (*Larrea tridentata*) in the desert woodrat (*N. lepida*) at various ambient temperatures. We tested our hypothesis with wild-caught *N. lepida* from the Mojave Desert in lab-based feeding trials. We found that warm temperatures (28-29°C) significantly reduced the maximum dose of creosote resin (g ingested/day) ingested by woodrats compared to that observed at cooler temperatures (21-22°C; ANOVA, $p < 0.01$). We also found that, when dose was held constant, woodrats at warmer temperatures reduced food intake and were unable to maintain body mass at warm temperatures compared to animals at cool temperatures (Kaplan-Meier, $p < 0.01$). Our results demonstrate that tolerance to creosote resin in the desert woodrat decreases at ambient temperatures within the thermal neutral zone of *N. lepida*, temperatures that are well below heat stress for these mammals. The interactions of ambient temperature and plant toxins present a novel dimension to studies on herbivore foraging. Studying this interaction will advance the field of plant-animal interactions and may enable more accurate predictions of the responses of mammalian herbivores to climate change.

36-4 LABARBERA, K.*; HAYES, K.R.; MARSH, K.J.; LACEY, E.A.; Univ. of California, Berkeley; klabarbera@berkeley.edu

Effects of environment on bill morphology in Dark-eyed Juncos across multiple spatial and temporal scales

Phenotypic traits are the product of multiple selective pressures acting across multiple temporal and spatial scales, yet it can be difficult to tease apart these various influences on phenotype. In this study we investigate multiple potential selection pressures acting at different temporal and spatial scales on bill morphology in a widespread passerine bird, the Dark-eyed Junco *Junco hyemalis*. At a fine spatial scale, we explore correlates of bill morphology in contemporary juncos along an elevation gradient in the Sierra Nevada mountains over four years of drought. We then expand the spatial scale, using museum specimens of juncos from across California and historical climate data to examine the relationship of bill morphology to temperature and precipitation in either winter or summer over temporal scales ranging from one month to 19 years. We find that different aspects of the bill are related to different environmental variables at different time scales and at different times of the year. These results underline the value of examining relationships over as complete a set of time scales and spatial scales as possible.

12-5 LABONTE, D; CLEMENTE, C J *; DITTRICH, A; KUO, C; CROSBY, A J ; IRSCHICK, D; FEDERLE, W; University of Cambridge, University of the Sunshine Coast, Anglia Ruskin University, University of Massachusetts Amherst; cclement@usc.edu.au

Extreme positive allometry of animal adhesive pads and the size-limits of adhesion-based climbing

Organismal functions are size-dependent whenever body surfaces supply body volumes. Larger organisms can develop strongly folded internal surfaces, but area enlargement is often constrained by anatomy. Here, we study the allometry of adhesive pad area in 225 climbing animal species, covering more than seven orders of magnitude in weight. Across all taxa, pad area scaled with weight, implying a 200-fold increase of relative pad area from mites to geckos. However, scaling coefficients for pad area decreased with taxonomic level, and were consistent with isometry when evolutionary history was accounted for. Within taxa, we find that the expected size-related loss of adhesion was compensated for by increasing adhesive strength instead. Our results illustrate the size limits of adhesion-based climbing, with profound implications for large scale bio-inspired adhesives.

43-5 LAILVAUX, SP*; HALL, MD; BROOKS, RC; University of New Orleans, Monash University, University of New South Wales; slailvaux@gmail.com

The shape of sexual conflict: dimorphism, morphology and performance in male and female Teleogryllus commodus crickets

Morphological and functional traits are shaped by various parallel and opposing selection pressures. Individuals within a species may experience these pressures differently depending on age or sex, creating the potential for intragenomic conflict. Conflict between males and females over sex-specific expression of morphological traits in particular has received a great deal of attention in various animal taxa, but the functional consequences of these conflicts in terms of integrative traits such as whole-organism performance are less well understood. We conducted a large breeding experiment to quantify the phenotypic and genetic variation in both shape and jumping performance in the Australian black field cricket, *Teleogryllus commodus*. By doing so, we are also able to estimate the functional consequences of intralocus sexual conflict in terms of an ecologically relevant performance trait, and to link morphology and performance to other key fitness-related aspects of the integrative phenotype in this species.

110-4 LABOV, J.B.; National Academies of Sciences, Engineering, and Medicine; jlavov@nas.edu

Integrating Discovery-Based Research into the Undergraduate Curriculum: Overview of an Academy Convocation

The 2012 report, "Engage to Excel," from the President's Council of Advisors on Science and Technology (PCAST) urges the STEM education community and funding agencies to "Advocate and provide support for replacing standard laboratory courses with discovery-based research courses." Emerging evidence suggests that engaging undergraduates in discovery research as early as possible during their undergraduate years is one of the best strategies for supporting and retaining STEM students and improving aspects of scientific literacy. But providing all students with individualized mentored research experiences, one of the traditional routes to a career in science, is not possible given the large numbers of beginning STEM students and limitations in lab space, supply budgets, and available research mentors. Acting on the PCAST recommendation, many undergraduate STEM educators are now experimenting with various strategies for engaging more students in research, and a variety of tested models are emerging. These successes are catalyzing interest in replacing standard "cook-book" laboratories with discovery-based research and related activities in labs associated with lecture courses or in stand-alone laboratory courses, utilizing on-campus, off-campus, and on-the-web resources. This presentation will report on a convocation around these issues that was organized by a committee of the National Academies of Sciences, Engineering, and Medicine. It will summarize successes and challenges that were discussed during the convocation and are presented in the report.

123-6 LAIRD, M.K.*; DARGAN, J.; PATERSON, L.; MCALLAN, B.M.; MURPHY, C.R.; THOMPSON, M.B.; University of Sydney, New South Wales, Australia; mlai9568@uni.sydney.edu.au
Uterine molecular changes during pregnancy in Macropus eugenii (Macropodidae; Marsupialia): implications for the evolution of mammalian pregnancy

Successful mammalian pregnancy requires remodeling of the uterus to become receptive to embryonic attachment. Remarkably similar morphological changes to the inner uterine epithelium occur in both eutherian (placental) mammals and marsupials. Yet molecular differences in marsupial pregnancy, particularly molecular reinforcement of the uterine epithelium just before embryonic invasion in the marsupial *Sminthopsis crassicaudata* (Dasyuridae), suggest that marsupial pregnancy may involve maternal defenses to regulate invasion and tissue destruction by the embryo. To test this theory, we identified patterns of fluorescence of a key basal molecule (talin), which anchors cells of the epithelium to the underlying tissue, during pregnancy in the tammar wallaby (*Macropus eugenii*; Macropodidae). Implantation is non-invasive in *M. eugenii*, yet talin undergoes a clear distributional change during pregnancy, including recruitment to the base of the epithelium just before attachment, that closely resembles that of invasive implantation in *S. crassicaudata*. We conclude that less invasive, and non-invasive, implantation in marsupials may have evolved via accumulation of maternal defenses, as reinforcement of the epithelium before embryonic attachment occurs in marsupial species with different modes of implantation. Hence recruitment of basal molecules to the epithelium, particularly talin, may have played a key role in this evolutionary transition.

26-1 LAMB, J.S.*; O'REILLY, K.M.; JODICE, P.G.R.; Clemson University, University of Portland, U.S. Geological Survey South Carolina Cooperative Fish and Wildlife Research Unit; jslamb@clemson.edu

Long-term physiological responses of nestling seabirds to variation in prey availability and nest conditions

While the number of young produced per nesting pair (i.e., fledging success) is often used as a proxy for recruitment in seabird populations, post-fledging survival is likely to be much lower than this estimate suggests. Mortality is difficult to measure accurately once juveniles disperse from the breeding site; however, accounting for differences in fledging physical condition can expose variation in survival probability not captured by fledging success alone. To assess inter- and intra-colony variation in nestling condition, we collected measures of short-term (relationship of mass to skeletal size) and long-term (corticosterone levels in body feathers) physical condition of 3-6 week-old chicks from pelican colonies across the northern Gulf of Mexico over a three-year period. We found that the overall negative relationship of corticosterone to body condition was strongest in younger chicks and at colonies experiencing nutritional stress. As chicks reached fledging, corticosterone levels remained highest in food-limited colonies but were more likely to reflect colony- and nest-specific variables such as colony size (intraspecific competition), hatch order, and nest site location. Since elevated stress levels during development are known to affect lifetime survival and reproductive fitness, we suggest nestling feather corticosterone as a useful index of developmental conditions and post-fledging survival probability that may capture additional information not reflected in short-term measures of physical condition.

55-4 LANGERHANS, R. Brian*; ANDERSON, Chris M.; HEINEN-KAY, Justa L.; North Carolina State University, East Carolina University; langershans@ncsu.edu

Causes and consequences of genital diversity: ecology and speciation as the missing links

The study of genital diversity has experienced rapidly burgeoning attention over the past few decades. This research has centered on internally fertilizing animals, where male genitalia often show remarkably rapid and elaborate evolution. In recent years, a consensus has emerged that sexual selection and sexual conflict are responsible for most of the observed genital diversity, with natural selection playing a subsidiary role. Despite this major advance in understanding the key forms of selection primarily responsible for genital evolution, we still have a poor understanding of the broader causes and consequences of the striking diversity of genitalia. Here, we plot a course forward for a more complete understanding of genital evolution, highlighting three topics that have so far received comparatively little attention and yet could prove critically important. First, we echo the recent calls for increased research on female genitalia, as non-trivial female genital diversity exists, and 5 major mechanisms can lead to its rapid diversification. Second, we encourage more investigation of ecology's direct and indirect roles in genital diversification, as ecological variation can influence selection on genitalia in many ways, perhaps especially through its frequent alterations of the context of sexual selection. Third, we direly need more research into the effects of genital divergence on speciation, as genital differences could often enhance reproductive isolation through either a lock-and-key process or as an incidental by-product of divergence. For each topic, we review theory and empirical data, and describe specific research approaches for tackling these outstanding questions. We hope we are on the verge of gaining crucial new insights into the causes and consequences of the conspicuous diversity of animal genitalia.

118-3 LANE, S.J.*; SHISHIDO, C.M.; MORAN, A.L.; TOBALSKE, B.W.; WOODS, H.A.; Univ. of Montana, Univ. of Hawai'i; steven.lane@umontana.edu

Epibionts on sea spiders: no control, no problem.

Essentially all surfaces of marine plants and animals host epibionts. Epibionts may harm their hosts in a number of ways, including impeding gas exchange or increasing the costs of locomotion. Epibionts can also be beneficial. For example, epibionts may camouflage their hosts, and photosynthetic epibionts can produce oxygen. In general, the costs of epibionts appear to vastly outweigh their benefits. Many organisms, therefore, shed epibionts by grooming or molting or keep them from attaching initially by using surface waxes and cuticular structures. In this study, we examined how epibionts affect local oxygen supply to temperate and Antarctic species of pycnogonids (sea spiders). We also tested the effectiveness of different methods that pycnogonids use to control epibionts (grooming, cuticle wettability, and cuticular waxes). In two temperate species, epibionts consisted primarily of algae and diatoms, formed layers approximately 0.25 mm thick and colonized at least 75% of available surface area. We used microelectrodes to measure oxygen levels in and under the layers of epibionts. In bright light, the epibionts produced high levels of oxygen. In the dark, the epibionts had no negative effect on local oxygen supply. We tested mechanisms of epibiont control by pycnogonids in three ways: disabling their ovigers to prevent grooming, extracting wax layers from their cuticle, and measuring the wettability of their cuticle; however, none of these mechanisms decreased epibiont coverage. These findings indicate that in temperate environments, pycnogonid epibionts are not costly and, in some circumstances, may be beneficial. We will carry out parallel tests on much larger Antarctic species around McMurdo station in the fall of 2015. NSF PLR-1341485.

67-1 LARSON, P.G.*; DALY, M.; RODRIGUEZ, E.; The Ohio State University, American Museum of Natural History; larsen.309@osu.edu

Evaluating taxonomic characters of *Anthopleura* and other sea anemones in a molecular phylogenetic context

The cosmopolitan sea anemone genus *Anthopleura* is defined by the presence of acrorhagi and verrucae, specialized structures of the oral margin and the column, respectively. Acrorhagi are inducible structures resembling inflatable bulbs that differ from marginal spherules (or 'pseudoacrorhagi') by the presence of holotrichous isorhizae, a type of nematocyst used frequently in intraspecific aggression. Verrucae are hollow outgrowths on the column to which sand and other debris may adhere, providing relief from desiccation and ultraviolet radiation exposure during low tides. Verrucae resemble non-adhesive vesicles which are found in other actiniids, except that verrucae are cup-like while vesicles are rounded. Acrorhagi and verrucae may be complex structures that are homologous among their occurrences across taxa, or merely superficially similar structures that are simply the product of coincidence of their constituent parts. Furthermore, acrorhagi and marginal spherules may be unrelated structures with independent evolutionary origins or alternate states of a single complex character. That these features confer taxonomic distinction in *Anthopleura* and other genera warrants a phylogenetic assessment of their distribution across taxa and an evaluation of their value in defining monophyletic groups. We present a molecular phylogeny which aims to illuminate the evolutionary and taxonomic patterns of these structures under multiple character coding schemes. We find that the genus *Anthopleura* is not monophyletic with respect to other actiniid genera and that the phylogenetic relationships reflect geographic patterns to a greater extent than taxonomic ones. All analyses of character evolution indicate that the presence of acrorhagi and verrucae are plesiomorphic conditions for the ingroup.

61-5 LARSON, DJ*; BARNES, BM; University of Alaska Fairbanks; djlarson@alaska.edu

Cryoprotectant production in freeze-tolerant wood frogs is augmented by multiple freeze-thaw cycles

Ice nucleation of wood frogs (*Lithobates sylvaticus*) induces production of glucose, a cryoprotectant that is necessary for freeze tolerance. Under laboratory conditions, freezing of wood frogs increases glucose concentrations within heart, liver, and leg muscle tissues by 5-fold or more compared to levels in unfrozen frogs. To induce these cryoprotectant concentrations, the standard laboratory practice is to cool wood frogs at rates of $-0.05^{\circ}\text{C h}^{-1}$ or slower; whereas, under natural conditions in Alaska wood frogs cool at rates of -0.35 to $-1.6^{\circ}\text{C h}^{-1}$. Despite rapid cooling rates, glucose concentrations in naturally frozen wood frogs are 12-fold higher in muscle, 10-fold higher in heart, and 3.3-fold higher in liver than corresponding levels in laboratory frozen wood frogs. Under natural conditions, wood frogs undergo multiple freezing-thaw cycles before remaining frozen for the winter. We examined if ecologically relevant repeated freeze-thaw events cause the higher glucose concentrations found in naturally frozen wood frogs. We found that over successive freezing events, glucose concentrations increased stepwise within all measured tissues. Short periods of thawing after freezing did not result in significant decline of tissue glucose concentrations. Wood frogs that experienced three freeze-thaw events had glucose concentrations that approached values of wood frogs frozen in natural conditions. Unlike laboratory wood frogs that only survive frozen for up to 2 months, wood frogs frozen under natural conditions survive frozen for up to 7 months with temperature minima below -18°C . We hypothesize that repeated freeze-thaw cycles allows for greater survival in Alaskan wood frogs through enhanced cryoprotectant production.

53-5 LASCALA-GRUENWALD, DE*; DENNY, MW; Hopkins Marine Station of Stanford University; dianalg11@gmail.com

Suboptimal Limpet Foraging in a Patchy Environment

In the upper intertidal zone, limpets face complex and so far undescribed foraging landscapes. The Lévy walk foraging hypothesis states that when food resources are sparse and randomly distributed, a power law model with an exponent of two describes the most efficient foraging behavior. In this study, we employed a novel field set-up and maximum likelihood statistics to characterize and compare the foraging behavior of two limpet species, *Lottia scabra* and *L. austrodigitalis*, in the intertidal zone adjacent to Hopkins Marine Station in Pacific Grove, California. To do this, we performed multiple deployments of four waterproof, infrared cameras, which photographed limpets once a minute for two weeks across four different field sites. We developed limpet tracking code in MATLAB, and used the tracks to compute a variety of parameters, including step length and turn angle distributions. These data allowed us to characterize limpet foraging behavior during previously unobserved time periods, and to fit statistical models to limpet step length distributions. Results suggest that limpet foraging is suboptimal for an environment with sparse resources, that *L. scabra* and *L. austrodigitalis* have statistically indistinguishable foraging patterns, and that both species exhibit strong individual variation in foraging behavior. Correlations between foraging behavior and environmental factors, including food distributions and rock topography, were investigated to determine whether the observed individual variation might be a signature of behavioral plasticity or animal personality.

81-2 LASALA, J*; HUGHES, C; WYNEKEN, J; Florida Atlantic University; jlalala1@fau.edu

Counting males and mates? Using mating sex ratios of marine turtles in vital rates.

A thorough discussion of the status of a threatened or endangered organism would not be complete without describing key life history behavior. In some cases, animals can be difficult to access, and behavior cannot be directly observed. In some extreme examples, one sex can be easily observed while the other remains cryptic. Sex ratios, population size and relatedness of individuals are important metrics of population status. While primary sex ratios of marine turtles are estimated by an extrapolation incubation conditions, adult sex ratios are primarily determined through census counts of nesting females. Numbers of adult males are enigmatic. Alternative assessment techniques include using molecular markers to identify individuals as well as fundamental relationships among males and females within a population. Successful male breeding numbers can be estimated using exclusion analysis (by comparing maternal genotypes to offspring genotypes). Typically, adult sex ratios differ from those estimated for hatchlings. We are increasing the accuracy of current adult sex ratio estimates in Florida to add to our understanding of effective population size. We compare the successful breeding sex ratios (the number of males and females contributing to a population) for two species of sea turtles nesting in Florida to assess mating behavior and diversity in two growing populations and refine understanding of management units beyond nest counts.

63-7 LATIMER, MN*; FROELICH, JM; SEILIEZ, I; BIGA, PR; University of Alabama at Birmingham, Institut National de la Recherche Agronomique; mmlat@uab.edu

In vitro myotubes derived from zebrafish myogenic precursor cells appear primed for autophagy

Zebrafish have become a popular physiological and biomedical model organism; however, these fish do not represent the normal growth seen in many teleost fish that is characterized by the continual addition of muscle fibers throughout life. Zebrafish somatic growth is characterized as more determinate-like, with a growth plateau reached around sexual maturity. Skeletal muscle growth is governed by a balance between protein synthesis and protein degradation, with a decrease in protein synthesis and increase in protein degradation leading to muscle wasting or atrophy. While zebrafish have been widely used to study; sarcopenia, metabolic disorders, and obesity, pathways associated with starvation, atrophy, and autophagy have not been well characterized in this species. Therefore, primary myogenic cultures were established from the adult zebrafish skeletal muscle to study the mechanisms of skeletal muscle wasting (atrophy) in this species. To induce atrophy, cultures were treated with minimal media and measures of gene expression associated with autophagy/atrophy and proteasomal pathways were measured using qPCR. The differential regulation of transcription factors paired-box 3/7 and myocyte enhancing factor 2 were also measured to assess their regulation during starvation in myotube cultures. Multiple markers of both autophagy and atrophy were upregulated following starvation in the minimal media, which led to questions about chromatin environment. Further investigations revealed the minimal media imparted a repressive nature at multiple loci related to myogenic progression. Overall zebrafish appear more sensitive to small bouts of starvation than indeterminate growing teleosts, and this physiological deviation provides insight into their evolutionary history and may lead to insights into different growth paradigms.

43-7 LATTANZIO, MS; Christopher Newport University; matthew.lattanzio@cnu.edu

Trait divergence among female tree lizards (*Urosaurus ornatus*) in relation to throat color and dorsal pattern

Instances of color or pattern polymorphism in species often coincide with suites of phenotypic differences among discrete morphs. In most species, these trait differences are collectively inferred to represent either alternative mating (e.g., throat color) or ecological (e.g., dorsal pattern) strategies. Both of these phenomena occur in lizards, although typically not in the same species. Moreover, for species expressing a throat color polymorphism, attention is often biased towards males. In ornate tree lizards (*Urosaurus ornatus*), both male and female lizards exhibit multiple throat color morphs. In addition, females also exhibit discrete variation in dorsal pattern that does not coincide with their throat color polymorphism. Aside from differences in mate preferences among female throat color morphs, little is known regarding the ecological or evolutionary implications of these throat color and dorsal pattern differences for female lizards. Here I characterize the throat color and dorsal pattern polymorphisms in female *U. ornatus* and test whether morphs diverge along several phenotypic axes associated with variation in morphology, physiological capacity, behavior, and ecology. Overall, females exhibit discrete throat color and dorsal pattern variation that does not change over time or signal reproductive state. Whereas throat color is associated with variation in male proximity, females differing in dorsal pattern vary in morphology and microhabitat use. Currently, I am analyzing mark-recapture data and data on female performance capacity and behavior to further delineate the role of selection on, and physiological extent of, morph differences. Ultimately, these findings will provide key insights into the degree of phenotypic divergence in female *U. ornatus*, as well as the relative roles of natural and sexual selection in driving their patterns of trait variation.

112-7 LAUDER, G.V.*; ANDERSON, E.J.; GARBORG, C.S.; THORNYCROFT, P.; TURNER, E.; KALIONZES, K.; KENALEY, C.P.; Harvard Univ., Grove City College; glauder@gmail.com
Revisiting the Relationship Between Tail Beat Frequency, Amplitude, and Speed in Swimming Fishes

Richard Bainbridge, in his classic 1958 paper, first provided quantitative data relating the frequency and amplitude of the tail of swimming fishes to the speed of locomotion. Many subsequent studies have built on his work, and suggested that there is a positive linear relationship between frequency and swimming speed, and that at moderate to higher swimming speeds tail beat amplitude changes little with speed. In our previous experiments with passive swimming foils, we observed non-linear effects of trailing edge frequency and amplitude as speed increases. These results stimulated us to revisit the Bainbridge relationships and to determine if freely-swimming fishes exhibit significant local deviations from linear as well as resonant amplitude effects as speed increases. We used automated high-resolution 3D tracking of tail beat amplitude and frequency to investigate how these parameters change with speed in three species (7 individuals total): largemouth bass (3), striped bass (3), and bluefish (1). A custom LabView program was used to automatically track the position of the tail tip and to compute frequency and amplitude at each tested speed. LabView control of speed in the recirculating flume allowed generation of a very high resolution data set for each individual. Statistical analysis confirmed that the frequency-speed plots exhibit significant local deviations from linear, and that there are "sweet spots" where speed increases with little change in frequency, and "sour spots" with a rapid increase in frequency with speed. We conclude that the relationship between frequency and speed in fishes exhibits many of the same phenomena observed for mechanical passive flapping panels.

4-5 LATTIN, CR*; PECHENENKO, AV; CARSON, RE; Yale University; christine.lattin@yale.edu

Computed tomography (CT) imaging demonstrates that captivity causes rapid changes in body composition in wild house sparrows (*Passer domesticus*)

Wild birds are brought into captivity for conservation purposes such as captive breeding and translocation. Additionally, many studies of avian physiology and behavior are conducted on wild birds housed in the lab. In this study, we sought to better understand differences between wild and captive birds by capturing house sparrows (n=20) and examining body mass, several behaviors, and tissue volumes of heart, fat, spleen, pectoralis muscle and testes immediately after capture and after 2 weeks in the lab. We used computed tomography (CT) imaging with a novel gadolinium contrast agent to assess tissue volumes. To reduce circulating corticosterone, half the birds received mitotane injections (180 mg/kg) every other day; the other half received a vehicle control. After two weeks of injections, mitotane-treated birds had ~50% decreased stress-induced corticosterone concentrations compared to controls. Regardless of treatment, all birds lost ~8% body mass in the first week, and this mass loss persisted through the second week. Fat volume increased, and heart and testes volumes decreased, over the two weeks of captivity in all birds independent of treatment. However, beak-wiping behavior, which can indicate aggression, increased over the two weeks of captivity in control birds only. This study demonstrates that rapid changes in body composition occur in wild birds upon transfer to the lab. Specifically, the significant decrease in heart volume after just two weeks suggests that captive birds may have reduced aerobic capacity compared to wild birds, which could potentially affect their ability to survive if released. Also, our data suggest that experimentally reducing circulating corticosterone may mitigate some captivity-induced behavioral changes.

80-4 LAW, CJ*; BALIGA, VB; MEHTA, RS; Univ. of California, Santa Cruz; cjlw@ucsc.edu

Divergence of craniodental morphology in southern sea otters

As a species, southern sea otters (*Enhydra lutris nereis*) are apex predators that consume a wide variety of hard-shelled macroinvertebrates. Recent work, however, suggests that male and females utilize different resources in response to increased population density. Apart from body size, morphological patterns of sexual dimorphism in sea otters are unknown. Females exhibit greater intraspecific dietary specialization than males and this gender difference suggests that sexual dimorphism may influence the functional morphology of feeding in southern sea otters. If intersexual dietary divergence does occur, we would expect to find differences in the feeding apparatus between the sexes. Uni- and multivariate analyses of 22 craniodental traits found that the primary axis of craniodental variation is driven by sexual size dimorphism. In addition, analyses investigating sexual shape dimorphism of the size-independent principal components failed to reject the null hypothesis that no craniodental shape differences occur between the sexes. However, separate ANOVA tests on each size-independent PC suggest subtle shape differences between the sexes. To further examine patterns of intersexual dietary divergence in southern sea otters, we use 2D geometric morphometrics from an ontogenetic series of skulls to investigate differences in cranial growth between female and male otters. Preliminary results suggest that intersexual differences in cranial shape begin to diverge during the transition between the subadult (1.5-2.5 years) and adult (2.5-9 years) age classes.

13-3 LEE, A.H.*; OURFALIAN, R.M.; EZELL, K.D.; Midwestern University; alee712@gmail.com

Development of wing bone laminarity in the pigeon

Wing bones of adult birds may have microscopic adaptations for flight. In birds that use continuous flapping flight, circumferential vascular canals are abundant in the humerus and ulna, where they form laminar bone presumably to resist twisting loads during flight. In contrast, the paucity of laminar bone in the radius presumably reflects reduced twisting loads in that part of the wing. Here, we test this biomechanical hypothesis with ontogenetic data. If wing bone laminarity is an avian adaptation to resist flight-induced torsion, then it should increase with age until maturity. Alternatively, if wing bone laminarity reflects allometry, then laminarity should vary directly with growth rate and decrease with age. We collected 19 pigeons of known age (0 - 9 weeks post-hatching). Transverse sections were cut from the midshaft of the humerus, ulna, and radius. Midshaft bone circumference was measured and used to plot growth curves for each element. From these growth curves, we calculated the mean circumferential growth rate for the elements of each sampled specimen. In elements containing cortical bone, the proportion of circumferential to total canals (laminarity index) was calculated. Linear regression was used to assess the correlation between laminarity and mean circumferential growth rate. Our results reveal that wing bone laminarity is greater in juveniles than in adults. Moreover, as mean circumferential growth rate decreases with age, so does wing bone laminarity. Linear regression analysis suggests that growth rate explains approximately 70% of the variation in wing bone laminarity. We conclude that wing bone laminarity, at least in the pigeon, is not a flight adaptation but instead an expression of ontogenetic allometry. Evolutionary shifts in ontogenetic allometry may explain interspecific variation of wing bone laminarity across birds.

118-4 LEHTONEN, M.P.*; BURNETT, L.E.; Coll. of Charleston; lehtonenmp@g.cofc.edu

Effects of hypoxia and hypercapnic hypoxia on oxygen transport and acid-base status in the Atlantic blue crab, *Callinectes sapidus*, during exercise

Responses of many estuarine invertebrates to hypoxic conditions are well established, however many studies have investigated hypoxia as an isolated condition despite its frequent occurrence with hypercapnia, elevated CO₂. We measured respiratory and acid-base parameters including Po₂, pH, [l-lactate], and total CO₂ in pre- and post-branchial hemolymph sampled from blue crabs before and during light walking exercise under a range of O₂ and CO₂ conditions. Crabs walked at 8 m min⁻¹ on an aquatic treadmill in normoxic (100% air saturation), moderately hypoxic (50%) and severely hypoxic (20%) 30 ppt seawater at 25° C with and without the addition of hypercapnia (2% CO₂). Respiration was completely aerobic in normoxic conditions, with little buildup of lactate and continued maintenance of a substantial venous O₂ reserve. During exercise under moderate hypoxia, the venous reserve was tapped but not depleted, and lactate increased from 0.5 mM to 2.3 mM, indicating the some use of anaerobic respiration. Exercise under severe hypoxia was marked by substantial decreases in both pre- and post-branchial % O₂ saturation, as well as a large increase in lactate from 1.4 to 11.0 mM, indicating a heavy reliance on anaerobic respiration. In all cases, the introduction of hypercapnia caused a significant depression in pH of up to 0.07 units, and a marked increase in total CO₂ and Pco₂, which rose on average 8.2 mM and 7 torr respectively. Although the reduction in pH caused by CO₂ causes a maladaptive decrease in hemocyanin O₂ affinity, molecular CO₂ is known to increase the oxygen affinity of blue crab hemocyanin. This effect may be strong enough to counteract the effects of pH and maintain oxygen transport even in severely hypoxic conditions (NSF OS-1147008).

122-4 LEHN, A.M.*; COLIN, S.P.; COSTELLO, J.H.; TYTELL, E.D.; MIT, Roger Williams University, Providence College, Tufts University; lehn@mit.edu

Three-dimensional flow patterns around swimming lamprey *Petromyzon marinus*

Unlike many bird and insect wings, the fins of fishes have a very low aspect ratio: their span is small compared to their chord length, while many wings have a wide span and short chord length. For fishes, this means that the flow that wraps around, above and below the body and fins can have a large impact on the flow near the horizontal midline. This effect should be particularly important for elongate fishes like lampreys. However, most previous studies of the flow patterns around fishes have used planar two-dimensional particle image velocimetry (PIV), a technique that resolves two components of the velocity vector in a plane. While useful, this approach provides little insight about the 3D flow patterns that must be important for the low aspect ratio fins and bodies of fishes. For elongate fish such as the long and approximately cylindrical lamprey, 3D information is essential to characterize how these fish interact with their fluid environment. This study presents 3D flow structures along the body and in the wake of larval lamprey, *Petromyzon marinus*, which are 10-15 cm long. Lamprey swam through a 1000 cm³ field of view in a custom made 60 cm long by 10 cm deep plexiglass tank, illuminated by a 532 nm wavelength green laser. Data were collected using a three component velocimetry V3V system by TSI, Inc. and processed using Insight 4G software. This study expands on previous works that show two pairs of vortices each tail beat in the mid-plane of the lamprey wake.

72-1 LEMA, SC*; CHOW, MI; RESNER, EJ; DITTMAN, AH; HARDY, KM; Cal Poly, San Luis Obispo, Univ. of Washington, NWFSC, NOAA Fisheries; slema@calpoly.edu

Thyroid hormone signaling and phenotypic divergence in a desert pupfish: interactions among thermal experience, metabolism and morphology

Hormone systems can act as mechanistic links between an organism's external environment and its internal physiological processes. When environments change, alterations in hormone signaling pathways may shift phenotypes rapidly via impacts on patterns of gene expression and, ultimately, development. Recently, we identified a population of Amargosa pupfish *Cyprinodon nevadensis amargosae* that experienced a decline in body size (e.g., 48% decline in mass) related to an increase in temperature that began in 2010 in their habitat, Tecopa Bore - a small thermal spring. This decline in body size was accompanied by the loss of pelvic fins in 34% of the population. Previous studies found that exposure to elevated temperatures during larval life inhibits pelvic fin development and implicated altered thyroid hormone (TH) status as a potential mechanism for these effects. Investigating that possibility, we documented elevated mRNAs encoding deiodinase type 3 (*dio3*) as well as depressed mRNA levels for deiodinase type 2 (*dio2*) and TH receptor (*tr*) in the liver of wild pupfish from Tecopa Bore compared to a nearby allopatric population in the cooler Amargosa River. The maintenance of adult pupfish from these two populations in captivity at 24°C or 34°C revealed that temperature influences on liver *dio2* and *tr* transcript abundance differed between populations, and that populations varied in how metabolism-associated gene expression responds to exogenous TH. These findings point to complex interactions between thermal experience, TH signaling and metabolism as contributing to energetic changes associated with morphological differentiation of *C. n. amargosae*.

21-6 LESSNER, E.J.*; STOCKER, M.R.; Virginia Tech; stockerm@vt.edu

The virtual endocranium of the basal-most phytosaur *Wannia scurriensis*

With increased use of virtual methods, large amounts of archosauriform endocranial data have been collected, focused on body size evolution, nerve pathways, and sensory abilities. However, much of that has focused on bird-line archosaurs, resulting in a skewed view of that diverse clade. Phytosauria is the sister taxon of Archosauria and provides a potential outgroup condition. Most previous phytosaur endocranial studies were executed without the use of modern technology and focused on derived taxa. We provide a comparative CT examination of the internal cranial anatomy of *Wannia scurriensis*, the most basal known phytosaur, providing a potential representative for the ancestral archosaur endocranial morphology. *Wannia* shows some overall similarity with extant crocodylians and derived phytosaurs in general endocranial shape, a large hypophyseal fossa, and trigeminal (CN V) innervation but with noticeable differences. The pineal region is expanded dorsally as in other phytosaurs but also laterally (previously unrecognized). CN V exits the pons in a more dorsoventral position than in *Parasuchus hislopi*, *Machaeropsopos mccauleyi*, or *Smilosuchus gregorii*. *Wannia* also exhibits a larger hypophyseal fossa relative to brain size than observed in *P. hislopi* or *S. gregorii*, which may indicate more rapid growth. The well-preserved semicircular canals have lateral canals that are angled more anteroventrally than in the derived taxa. Extensive facial innervation from the large CN V suggests increased rostrum sensitivity and mechanoreceptive abilities as in *Alligator mississippiensis*. These endocranial similarities among phytosaurs and with *Alligator* indicate conserved ecological and functional results of an aquatic lifestyle, and highlight a need for further exploration of endocranial anatomy among Archosauriformes.

131-6 LEVIN, I I*; FOSDICK, B K; ZONANA, D M; SONG, S J; KNIGHT, R; SAFRAN, R J; University of Colorado, Boulder, Colorado State University, University of California, San Diego; Iris.Levin@colorado.edu

Stress response, gut microbial diversity, and sexual signals correlate with social interactions: A social network study in North American barn swallows

Social network analysis is emerging as a promising tool for integrating behavior, phenotype, and physiology with relational data on animal interactions. We used proximity loggers to quantify interactions in a population of barn swallows (*Hirundo rustica erythrogaster*). Social networks were constructed from interactions at two different scales of spatial proximity, one consisting of all interactions between 0.1m and 5m ("social network") and the other based on all interactions within 0.1m ("contact network"). We used node-level analyses to ask what phenotypic and physiological traits correlate with individual network position and dyad-level analyses to understand patterns in the traits of individuals engaging in dyadic interactions. Males with dark ventral plumage, long tail streamers, and higher stress-induced corticosterone levels had more interactions with females in the social network. Interactivity in the contact network was positively related to stress-induced corticosterone levels for both sexes; however, there were sex differences in relationships between gut microbial diversity and interactivity.

120-2 LEVESQUE, DL*; TUEN, AA; LOVEGROVE, BG; University of Maine, Universiti Malaysia Sarawak, University of KwaZulu-Natal; danielle.l.levesque@maine.edu

Staying hot to fight the heat- High body temperatures in a tropical small mammal

The relationship between animals and their thermal environment has been gaining prominence in the fields of ecology and physiology with the increasing concern over climate change. Yet, despite a large body of knowledge on the thermoregulation of temperate and cold-climate endotherms, our functional knowledge of endotherms in the tropics remains incredibly scarce. As part of a long-term project investigating the effects of high ambient temperatures on small mammals in the tropical rainforests of Sarawak, Borneo, we recorded the body temperatures of free-ranging large treeshrews (*Tupaia tana*, order Scandentia). We also measured resting metabolic rates over a range of ambient temperatures to measure the thermoregulatory characteristics of this species. As well as showing some of the highest circadian body temperature variations (~5°C) of any small eutherian mammal, these animals had surprisingly high active body temperatures (~40°C), some of the highest recorded for an animal of their body mass (250-300g). We hypothesize that their high body temperatures would allow them to maintain a large enough gradient between ambient temperatures and body temperatures to allow passive heat dissipation, important in a high humidity environment where opportunities for evaporative cooling are few. A better understanding of the thermoregulation of this species, as well as that of tropical mammals in general will not only enlarge our understanding of endothermic temperature regulation, but will aid in the creation of accurate mechanistic models for predicting the effects of changes in global climates.

58-10 LEWIS, C.; Smithsonian National Museum of Natural History & University of Maryland BISI-BEES; amesc@si.edu

Differential expression of genes implicated in venom, vision and sex in the aggregating box jellyfish *Alatina alata*

The broadly distributed venomous box jellyfish *Alatina alata* is notorious for its painful and debilitating stings during monthly sperm casting aggregations along beaches in Atlantic and Indo-Pacific localities. This study provides a functional annotation of cubozoan transcriptomes sequenced from adult and larval *Alatina alata* individuals with a focus on the discovery of genes involved in nematogenesis and venom production, vision and the phototransduction pathway, and sexual reproduction. RNASeq with Illumina technology was used to sequence transcripts from tissue samples excised from an ovulating female *A. alata* medusa. A pooled transcriptome was assembled de novo (Trinity), and downstream analyses included transcript expression profiling (edgeR) and gene annotation (Trinotate) with a focus on differential expression of candidate genes implicated in venom, vision and sex determined from core gene sets and those reported in the literature. The high quality of these data and the depth of the affiliated gene discovery have the potential to contribute to our understanding of the molecular cues involved in complex sexual behavior of *A. alata*. These curated transcripts will complement further cnidarian genomics studies, and may help uncover the molecular underpinnings involved in early defense and sensory systems.

75-6 LEWIS, Z.R.*; DORANTES, J.A.; HANKEN, J.; Harvard University, Cambridge, MA; zlewis@oeb.harvard.edu

Neofunctionalization of a lung-gene paralog may facilitate respiration in lungless salamanders

Most terrestrial vertebrates use lungs to breathe. The few exceptions include lungless amphibians (hundreds of species of salamanders, but only two other amphibians), which breathe entirely through the skin and buccal cavity. How lungless amphibians are able to meet metabolic demands is a topic of considerable speculation. Lunglessness places theoretical limits on thermal tolerance and body size, but lungless salamanders paradoxically live across diverse thermal environments and reach relatively large body sizes. Lungless salamanders display a slight increase in vascularization of extrapulmonary tissues (the skin and buccal cavity) compared to some lunged species, but morphological differences alone do not explain observed increased extrapulmonary respiratory capacity. Molecular differences between lungless and lunged species may account for greater extrapulmonary respiratory capacity. We have discovered a novel paralog of a lung-specific gene that likely evolved in salamanders and may serve a unique function in lungless species. This paralog is expressed solely in the lungs in lunged salamanders, resembling the expression pattern of its ancestral gene. However, the expression site of this paralog in a lungless salamander is dramatically divergent: in embryos and larvae of *Desmognathus fuscus*, the paralog is expressed throughout the skin. At metamorphosis, expression shifts to the buccal cavity. We propose that the salamander-specific paralog is neofunctionalized in lungless salamanders to facilitate cutaneous and buccal respiration. Neofunctionalization of this gene and its dynamic expression pattern may help lungless salamanders adapt to shifting life history-related demands for gas exchange and may help account for the remarkable adaptive radiation of lungless salamanders.

33-1 LEYS, SP*; KAMARUL-ZAMAN, A; BOURY-ESNAULT, N; LEYS, Sally; University of Alberta, Université Aix-Marseille, France; sleys@ualberta.ca

Gastrulation in glass sponges: fate mapping in 3D

Gastrulation, the formation of multiple germ layers resulting in an epidermis, a middle layer, and a feeding gastrodermis, is disputed to take place in sponges, the earliest diverging metazoans. Glass sponges (Class Hexactinellida) are one of only two poriferan groups that form a feeding epithelium - flagellated chambers - during embryogenesis, as larvae. Can this be equated to gastrulation? The fate of the larval chambers and of other tissues during metamorphosis is unknown due to the difficulty of obtaining larvae from this deep-sea group. Also, understanding metamorphosis in glass sponges is challenging as very little tissue is present in late stages of metamorphosis and the syncytial nature of the tissue makes it difficult to trace cell fates. We studied metamorphosis in *Oopsacas minuta* a small hexactinellid that inhabits caves in the Mediterranean. We used three-dimensional models to map the fate of larval tissues through metamorphosis. Intriguingly, multiciliated cells that form a belt around the larva are discarded in the first stages of metamorphosis and do not appear to be involved in forming the flagellated chambers of the juvenile sponge. We found that larval flagellated chambers are retained throughout metamorphosis and become the first pumping and feeding chambers of the juvenile sponge. As *O. minuta* settles, larval flagellated chambers are enlarged by using the larval yolk supply. These observations suggest that in *O. minuta* the feeding epithelium - the flagellated chambers - are internalized, and the outer epidermis - the reticular syncytium - is externalized during embryogenesis and this relationship is retained through metamorphosis into the adult. In this way development of the germ layers in this hexactinellid sponge strongly resembles gastrulation processes in other animals.

95-5 LEWIS, GT*; KEMP, T; WHITE, C; CARTER, DJ; FISH, FE; BART-SMITH, H; University of Virginia, Charlottesville, VA, West Chester University, West Chester, PA; gt16eh@virginia.edu
Mapping Fluke Stiffness as a Measure of Biofidelity in Artificial Fins

The flukes of cetaceans deflect during the swimming stroke, creating curvatures in both the span- and chord-wise directions, and it is thought that this "cupping" mechanism increases the thrust and efficiency of the stroke. Artificially reproducing the swimming characteristics of these animals necessitates replicating this curvature, which depends on the stiffness of the fluke. However, no measurements of flexural stiffness across the whole fin have yet been undertaken. The purpose of this research was to create a map of flexural stiffnesses across various flukes, both biological and artificial. To accomplish this, a simple rig was built which deflects the fluke while recording force at multiple points across the fin, and the stiffness characteristics of the fins were determined from this data. The stiffness maps of the biological fins would then inform the design of artificial flukes and allow for comparison for biofidelity. Despite differences in tail structure, the same process can also be applied to other efficient swimmers. For example, in thunniforms the stiffness map would instead measure the passive stiffness at the peduncle.

38-2 LI, Y.*; KOCOT, K. M.; WHELAN, N. V.; HALANYCH, K. M.; Auburn University, University of Queensland; yz10084@auburn.edu

Phylogenomics of tubeworms (Annelida: Siboglinidae) facilitates comparative performance of supermatrix versus species tree phylogenetic approaches

Use of transcriptomic and genomic datasets has become increasingly common as researchers attempt to test phylogenetic hypotheses across the diversity of the tree of life. The size and complexity of these large datasets present analytical challenges such as detecting systematic errors and conflict in the data. Three approaches have been applied to phylogenomic data including supermatrix approaches that analyze all data partitions in a single matrix, coalescent-based approaches that examine individual partitions and seek to combine resultant gene trees into a species trees, and Bayesian concordance analysis (BCA). We explored the performance of these approaches using a 15 taxon transcriptomic data set for siboglinid annelids. Currently, Siboglinidae contains four major clades. Placement of *Osedax* has been controversial with some studies recovering it sister to Vestimentifera+*Sclerolium* while others recover it sister to Frenulata. In this study, every analysis conducted supported *Osedax* sister to Vestimentifera+*Sclerolium* clade, not Frenulata. Moreover, we recovered topologies that were largely consistent across different methods and datasets, which had different numbers of genes and varying amounts of missing data. *Spirobrachia* was unexpectedly recovered sister to all other siboglinids in BI supermatrix analysis and coalescent analyses of the smallest, most complete dataset (98 genes), whereas it was placed within Frenulata in ML and previous studies. Given that *Spirobrachia* contains the most missing data of all taxa sampled herein (75.5%), variations of placement are most likely due to lack of characters in alignment to inform placement of *Spirobrachia*.

97-7 LIAO, J.C.*; STEWART, W.J.; TIAN, F.B.; AKANYETI, O.; WALKER, C.; The Whitney Lab for Marine Bioscience/UF, University of New South Wales; jliao@whitney.ufl.edu
Trout selectively swim behind tandem cylinders in flow depending on gap spacing

We investigated the kinematics and preference of rainbow trout (*Oncorhynchus mykiss*, $n = 4$, body length = 18.9 ± 0.52 cm mean \pm SEM) to Karman gait behind two, 5cm diameter D cylinders arranged in tandem at Reynolds numbers ranging from 10,000-55,000. We used Digital Particle Image Velocimetry and computational fluid dynamics modeling to reveal that cylinder spacing strongly affects the overall strength and structure of the downstream flow field. For example, increasing L/D from 0.7 to 2.7 (where L = downstream spacing of cylinders and D = cylinder diameter) decreased the strength of the vortex street by an average of 53% for all speeds investigated. Likewise, for all speeds an L/D of 2.7 resulted in a 30% increase in the wake wavelength and a 20% decrease in the vortex shedding frequency as compared to a single cylinder. We found that trout Karman gait with similar kinematics across a wide range of L/D values. However, fish did not equally prefer all six of our cylinder spacing arrangements. For example, 73% of Karman gaiting occurred behind an L/D of 0.7, 1.1, and 1.5, while only 4% of Karman gaiting occurred at an L/D = 2.7. Flow visualization reveals that the strong and organized vortices produced by single cylinders or closely-spaced cylinders are what lead trout to prefer these environments. When L/D > 1.5, the upstream cylinder generates a vortex street that interacts destructively with the wake of the downstream cylinder, leading to the establishment of a co-shedding regime that produces weaker, more widely-spaced, and less organized vortices that discourages Karman gaiting.

54-4 LICHTENSTEIN, J.L.L.*; PRUITT, J.N.; MODLMEIER, A.; University of Pittsburgh, Pennsylvania State University; jll134@pitt.edu

Intraspecific variation in the collective behaviors of multiple interacting species predicts contest outcomes in acorn ants

Intraspecific variation in behavior has largely been neglected by community ecologists to date. Recently, however, a number of studies demonstrated that intraspecific variation can have profound consequences for species interactions and thereby alter community dynamics in solitary organisms. Here we study how intraspecific variation in collective behaviors (also called 'collective personalities') affect the outcome of resource contests between two co-occurring species of ants, *Temnothorax longispinosus* and *T. curvispinosus*. Our results revealed that intraspecific variation in colonies' exploration behavior and aggressiveness predicts the outcome of interspecific contests for food and nest sites. How exploratory behavior affected the outcome of the foraging and nest site contests depended on the species: exploratory behavior seemed to enhance performance in both contests in *T. curvispinosus*, but diminish it in *T. longispinosus*. More interestingly, whether a species was successful in nest site contests depended not only on its collective personality, but also on the personality of its opponent colony. *Temnothorax longispinosus* experienced greater success if its opponent colony had similar exploratory tendencies to its own. In contrast, *T. curvispinosus* performed best when its opponent colony exhibited a contrasting exploratory tendency to its own. Our data demonstrate that intraspecific variation in colony behavior can have consequences for contest outcomes and ensures that no one species or behavioral strategy consistently experiences superior success. This, in turn, might help to maintain variation in collective behavior in multiple interacting populations and prevent competitive exclusion of one of the species.

107-2 LIBBY, T*.; EDGERLY, J.S.; FULL, R.J.; Univ. of California, Berkeley, Santa Clara University; tlibby@berkeley.edu
Clumsy dynamics of rapid backwards running in tube-dwelling webspinners.

Tube-dwelling webspinners are among the few insects with front legs that produce silk, and the only taxa that routinely locomote using those highly modified limbs. Severe constraints on leg morphology likely impose constraints on locomotor mechanics that result in a strong preference for backwards running. Embiids, *Antipaluria urichi* (0.04 g; 13 mm body length), disturbed outside of their web tubes attained maximum speeds that were over 50% faster than when running forwards. Center of mass motion (COM) was highly exaggerated. Animals lost almost all their speed during each stance period, as their bodies frequently crashed against the ground. Even more strangely, COM oscillations took place at half the stepping frequency, with the body rising on one stance period and falling on the next. Unlike a walk, where the center of mass vaults over a stiff leg like an inverted pendulum, or a run, where the limb compresses mid-stride like a pogo stick, the embiid's gait had features of both, alternating between vaulting and compression phases in a single stride period. With an average Froude number ($Fr=2.7$) over double the theoretical limit for walking, embiids appear to fly off their stiff leg and crash to the ground. Despite the clumsy features of their locomotor dynamics, embiid escape speeds fell in the range of dynamic running gaits of other small insects (10-20 body lengths per second; 11 cm/s average speed, 20 cm/s peak instantaneous). The usual running gait of these tube-specialized, backwards running animals defies our definitions of effective running, but certainly appears just-good-enough to escape predators.

30-4 LIGOCKI, IY*.; EARLEY, RL; HELLMANN, JK; HAMILTON, IM; The Ohio State University, University of Alabama; ligocki.3@osu.edu

Variation in glucocorticoid levels in relation to direct and third-party interactions in a social cichlid fish

In complex animal societies, direct interactions between group members can influence the behavior and glucocorticoid levels of individuals involved. Recently, it has become apparent that third-party group members can influence dyadic interactions, and vice versa. Thus, glucocorticoid levels may vary depending on interactions of other members of the social group. Using the social cichlid fish *Neolamprologus pulcher*, we examined the relationship between levels of the glucocorticoid hormone cortisol in subordinate females and 1) direct interactions with dominant group members, as well as 2) dyadic interactions between the dominant male and female, in which the subordinate female was not directly involved. Subordinate females that frequently engaged in non-aggressive interactions with dominant females had lower cortisol levels. There was no relationship between subordinate female cortisol and agonistic interactions between the subordinate female and either dominant. Subordinate females had higher cortisol levels when in groups in which the dominant breeding pair behaved agonistically towards each other and performed fewer courtship behaviors. For subordinate females in this species, variation in cortisol levels is associated with their own affiliative behavior, but also can be explained by the broader social context of interactions between dominant members of the group.

19-4 LIN, Y.F.*; CHAPPUIS, A.; RICE, S.; DUMONT, E.R.;
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Burrowing performance in fossorial and semi-fossorial moles

The forelimb morphology and digging behavior of moles (Talpidae) are unique among fossorial mammals. Moles dig only with their forelimbs which are oriented laterally. Among mole species, musculoskeletal specializations of the forelimbs vary depending upon whether a species is aquatic/fossorial, semi-fossorial, or completely fossorial. To date, we do not know whether this morphological diversity is matched by disparity in performance. In this study, we compared burrowing performance between fossorial moles (Eastern moles, *Scalopus aquaticus*) and semi-fossorial moles (Hairy-tailed moles, *Parascalops breweri*) in soils of different compactness. We measured linear burrowing velocity, soil displacement, tunnel length, and the size of the area explored when the animals built their tunnels. We also investigated how these performance measures changed in response to loose, intermediate, and compact soils. Linear burrowing velocity did not differ between Eastern and Hairy-tailed moles, regardless of soil compactness. However, the highly fossorial Eastern moles moved more soil, built longer tunnels, and explored more area during tunnel construction. It appears that the ability to displace soil and construct tunnels, not the speed of movement in the soil, varies among mole species that differ in their dedication to fossoriality. With data from additional species, the results of this study may shed light on the evolution of morphological variation associated with fossoriality and fossorial ecology.

S2-1 LINDGREN, AR; Portland State University;
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Welcome and introduction to the symposium

Our objective in offering this symposium is to synthesize current knowledge of extremophile biology by uniting a diverse group of researchers who do not generally attend the same meetings, but ask similar questions regarding genomics, physiology, ecology, and evolution. For example, microbiologists and invertebrate biologists may both be working on organisms living under the same physiological conditions, but very little cross-communication occurs. Given the potential impacts of climate change on extreme habitats in particular, it is essential that researchers start to build larger collaborative networks. To increase connectivity across researchers, foster new collaborations, and expand the breadth of what is known about extremophile biology, experts from diverse taxonomic (from microbes to vertebrates to invertebrates) and academic backgrounds have been invited to participate in this symposium.

116-3 LIN, H-T*; LEONARDO, A; HHMI Janelia;
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Ready to launch: do target selective descending neurons prepare the dragonfly for prey pursuit?

Dragonflies are excellent aerial predators that capture flying insects on the wing. Their success hinges on both the prey pursuit strategy and the preparatory head tracking that centers the target in the visual fovea to extract prey information. The dragonfly selectively pursues prey satisfying a certain range of angular size-speed ratio, and we have shown that such a heuristic rule effectively implements prey selection that screens out uncatchable prey. What's the neural substrate for this heuristic? A class of target selective descending neurons (TSDNs) carry prey angular velocity information from the visual system in the head to the body and innervate various motor units such as wings and neck. TSDNs have receptive fields and directional selectivity that could guide the interception flight. One underappreciated feature of TSDNs is the coupling between the target size and speed preference. Specifically the target speed sensitivity depends on the target size and could contribute to the prey selection. To understand the visual-motor interactions required for prey pursuit, we first characterized the target size and speed tuning of TSDNs in an immobilized animal. Then, we used an RF powered telemetry backpack to record from TSDNs in the dragonfly during normal foraging behavior. The firing properties of TSDNs are consistent with the prey selection rule. By analyzing the timing of visual response relative to the motor activities of the head, we can determine whether TSDNs could drive the head tracking or collect target information after the prey has been centered. In addition, we can isolate the effect of head motor efference copy by replaying the reconstructed target projection to the eyes in a head-fix condition. Integrating these analyses will allow us to understand the true role of TSDNs in launching the dragonfly for a chase.

14-4 LINDSAY, TH*; DICKINSON, MH; Caltech;
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Functional imaging from the muscles of the fruit fly wing-hinge during tethered flight.

Animal movement emerges from a system of inner and outer-feedback loops by which sensory information directs and stabilizes motor output. Compared to our knowledge of coding within sensory systems, our understanding of how motor codes produce locomotion remains poorly understood. The agile aerial behaviors of flies present a prime example of this problem: using subtle changes in wing kinematics, flies respond to visual input and execute hairpin turns in milliseconds. Although flies are equipped with relatively few muscles with which to regulate wing motion, they nevertheless execute very precise maneuvers. As in other flies, in the fruit fly, *Drosophila melanogaster*, the 15 tiny control muscles of each wing are anatomically grouped according to the skeletal elements within the wing hinge on which they insert: the first, third, and fourth axillary sclerites and the basalare. Prior studies have recorded the activation of a small subset of these muscles during flight behaviors using fine metal electrodes however, the activity of the entire population has not been observed due the small size of most muscles and their complex overlapping pattern of insertion. To overcome these limitations, we expressed a genetically-encoded calcium indicator (GCaMP6f) in the steering muscles of *Drosophila*, and imaged their activity through the intact thorax of tethered, flying flies. During flight, activity was distributed broadly across the entire population of steering muscles. By presenting the flies with a set of large field visual motion, we have begun to map the tuning of individual muscles and muscle groups to the control of body translation and rotation during flight.

93-2 LIU, G*; LI, C; REN, Y; BABU, N; DONG, H; Univ. of Virginia; haibo.dong@virginia.edu

Wing-body interaction and new lift enhancement mechanism in cicada's free flight

In this work, a combined experimental and computational study is conducted to study the aerodynamics and force enhancement strategies in cicada flight. Flapping wing kinematics including all motion complexity was reconstructed based on the output of a high-speed camera system. Following the reconstruction, three computational models, i.e., wing-body, wings-only and body-only model, were developed and evaluated using an immersed-boundary method based incompressible Navier-Stokes equations solver. The effects of wing-body interaction (WBI) on aerodynamic performance and vortex dynamics were investigated and discussed. Results showed that, due to the wing-body interactions, significantly better lift production is observed in the wing-body model. Further analysis of the associated near-field and far-field vortex structures also showed a formation of two distinct vortices shed from the thorax and the posterior of the insect, respectively. These three-dimensional vortex dynamics analyses are expected to provide physical insight into the understanding of the body-involved lift enhancement mechanism in flapping wing flights.

76-1 LIWANAG, HEM*; CALLEJAS, B; LABIB, G; PAULY, GB; California Polytechnic State University, San Luis Obispo, Adelphi University, Natural History Museum of Los Angeles County; hliwanag@calpoly.edu

Thermal tolerance varies with age and gender for the nonnative Italian Wall Lizard (*Podarcis sicula*) in Southern California

Temperature has a substantial effect on both the physiology and behavior of ectothermic animals such as lizards. The Italian Wall Lizard (*Podarcis sicula*) is a widely introduced species that has demonstrated remarkable adaptability when introduced to new regions. We examined the thermal tolerances and preferred temperature of 28 *P. sicula* collected from an introduced population in California, USA. Critical thermal minimum (CT_{min}) and critical thermal maximum (CT_{max}) were determined as the temperatures at which the lizards lost their righting ability. Preferred temperature (T_{pref}) was determined using a linear thermal gradient. We compared the thermal tolerances and preferred temperatures of juveniles (N=12), adult females (N=7), and adult males (N=9). Adult females had a significantly wider thermal breadth ($CT_{max} - CT_{min}$) compared to adult males and juveniles ($P < 0.001$). Adults of both sexes were able to tolerate warmer temperatures than juveniles ($P < 0.001$), and adult females were better able to tolerate colder temperatures ($P < 0.001$). Interestingly, there was no significant difference among groups for preferred temperature ($P = 0.861$). This implies that thermal tolerance, a physiological characteristic, varies with age and gender for this population, whereas thermal preference, a behavioral characteristic, does not. Future work will compare the thermal tolerances and preferences of this population to those of a New York population, to examine whether these parameters shift with adaptation to different climates.

30-2 LIU, Y.*; JONES, C.D.; SUMMERS, K.; BURMEISTER, S.S.; Univ. of North Carolina, Chapel Hill, East Carolina University, Greenville; liuyy@live.unc.edu

Hippocampal transcriptomes are associated with spatial learning ability in frogs

An essential question on comparative cognition is what are the brain mechanisms for behavioral differences between species. Poison frogs (*Dendrobates auratus*) have evolved complex parental behaviors, including egg attendance and tadpole transport, which rely heavily on spatial memory. While sympatric túngara frog (*Engystomops pustulosus*) builds foam nests in ponds without any parental care. First, we tested their behaviors in a two-arm maze in which we provided visual cues to learn correct arm, which was rewarded with return to the home cage. Both species learned the task. However, a probe trial showed that the poison frog used spatial cues to learn the task while the túngara frog used local cues. Furthermore, when we reversed the reward-cue contingencies, we found that poison frogs learned reversal task, while túngara frogs did not. In order to study the brain mechanisms underlying these species differences in cognition, we took samples of the hippocampus (medial pallium) from naïve and trained poison frogs and from naïve túngara frogs, and sequenced their transcriptomes via RNASeq. We found that 54 genes were differentially expressed between naïve and trained poison frogs. BLAST results show that these genes facilitate neural proliferation, dendrite growth, neural survival, and synthesis of neurotransmitters and neurotrophic factors. Reciprocal BLAST between the 54 genes in poison frog and the transcriptome of naïve túngara frog detected 39 matches. More than 70% of the 39 genes show the same expression pattern between naïve and trained poison frogs as that between naïve poison frogs and naïve túngara frogs. Therefore, we conclude that these species differences in spatial cognition result, at least in part, from differential hippocampal neurogenesis.

106-1 LOCKEY, J.K.*; WILLIS, M.A.; Case Western Reserve University; jklockey@case.edu

Bunches of hunches: agent-based models of insect odor tracking based on behavioral experiments.

American cockroaches, *Periplaneta americana*, can track an odor plume even when all but a small portion of one antenna has been lost. Our previous behavioral work shows that bilateral symmetry is not predictive of behavior. Tracking performance improves with increasing amounts of antenna present whether bilateral symmetry is preserved or not. Moreover, published neural recordings and histological data suggest there is a spatial map of the antenna in the antennal lobe of the animal's brain. These observations, combined with our behavioral data lead us to propose a heuristic featuring spatial integration across an antenno-topic map to describe how *P. americana* tracks an odor plume. Here we use an agent-based model to test our proposed heuristic along with several other heuristics describing classic tracking strategies. Preliminary results have shown greater success rates across heuristics when using odor-on vs odor-off antenna units, than when using relative concentrations measured by each antenna unit. *This study was supported by NSF grant IOS-1121498 to MAW.*

130-6 LOCKWOOD, B. L.; University of Vermont;
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Natural variation in embryonic thermal tolerance among populations of *Drosophila melanogaster* along a thermal gradient
Early development is predicted to be canalized to produce discrete phenotypes even in the face of environmental perturbation. Contrary to this paradigm, we find that there is significant variation in nature for tolerance to acute thermal stress in embryos of *Drosophila melanogaster*. We also find that phenotypic variation in embryonic thermal tolerance is continuous, not discrete. We discuss the implications of these findings in the context of natural selection for increased embryonic thermal tolerance in spatially and temporally variable thermal habitats. Ultimately, our results suggest that natural selection leads to population divergence of a developmental physiological trait.

114-3 LOGAN, M.L.*; CURLIS, J.D.; MINNAAR, I.A.; MCGLOTHLIN, J.W.; CLUSELLA-TRULLAS, S.; COX, R.M.; Stellenbosch University, Georgia Southern University, Virginia Tech, University of Virginia; mike.logan1983@gmail.com
Phenotypic correlations suggest that thermal adaptation is constrained in lizards and ladybugs

Evolutionary adaptation of the 'thermal performance curve' (TPC) to changes in the thermal environment may be an important avenue by which ectotherms can avoid extinction in the face of climate change. Indeed, studies have shown that many populations have sufficient phenotypic variation in TPCs, and that selection can target them when the environment shifts. Nevertheless, very little is known about the heritability of these traits, or whether their genetic architecture is conducive to rapid adaptation. This represents a critical gap in knowledge because genetic correlations between parameters that define the shape of a TPC may hasten or constrain evolutionary change. We measured the thermal sensitivity of locomotor performance in lab-reared populations of a vertebrate, the lizard *Anolis sagrei*, and an invertebrate, the globally invasive beetle *Harmonia axyridis*. We discuss how correlations among thermal performance traits may constrain evolutionary responses to climate change in these species, even when TPCs are heritable and under strong selection in nature.

90-1 LOHMANN, K.J.*; PUTMAN, N.F.; LOHMANN, C.M.F.; Univ. North Carolina, Chapel Hill, Univ. Miami;
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Born to Navigate: Inherited Oceanic Magnetic Maps in Young Sea Turtles and Salmon

Sea turtles and salmon are iconic long-distance migrants in which the young travel along vast, population-specific routes through the open sea, unassisted by older conspecifics. How such animals complete their first migration, sometimes crossing an entire ocean basin before returning, has long intrigued biologists. Experiments have revealed that loggerhead sea turtles (*Caretta caretta*) from eastern Florida begin their migration with a 'magnetic map' in which regional magnetic fields function as navigational markers and elicit changes in swimming direction at crucial locations along their trans-Atlantic migratory route. The direction of swimming elicited by each field appears to be suitable for helping turtles remain within the warm-water currents of the North Atlantic subtropical gyre and advance along the migratory pathway. Similar responses have been found in juvenile Chinook salmon (*Oncorhynchus tshawytscha*), which respond to fields like those at the latitudinal extremes of their Pacific Ocean range by orienting in directions that would, in each case, lead toward their marine feeding grounds. In both turtles and salmon, the magnetic map that guides juvenile animals appears to be inherited, inasmuch as regional magnetic fields elicit orientation responses in individuals that have never migrated or even been in the ocean. The existence of similar magnetic navigation strategies in young salmon and sea turtles suggest that this mechanism is phylogenetically widespread and may explain how diverse marine animals complete long, complex journeys through the sea despite lacking migratory experience.

77-3 LOHR, B*; HULSE, S; University of Maryland Baltimore County; blohr@umbc.edu

Vocal "mistakes" and insights into song function and the song learning process in songbirds: case studies.

We examine two case studies of vocal "mistakes" produced by wild songbirds that can lead to insights into the development and function of song. Both examples occur in a species that learns its song through improvisation or invention rather than through imitation, the Grasshopper Sparrow (*Ammodramus savannarum*). In one case, a male of the Eastern subspecies in Maryland produced an atypical crystallized song structurally very different from normal adult song, though its duration and bandwidth were species-typical. The song resembled some elements of vocalizations produced during the plastic song phase of song development. In the second case a bird of the Florida subspecies produced a song that resembled that of another emberizid in its habitat, the Bachman's Sparrow (*Peucaea aestivalis*). These cases suggest different types of learning errors that can occur under natural circumstances, and that may contribute to Allee effects in a species with small and declining populations. We tested the effects of such atypical songs on song function in the Maryland case by performing a song playback test. Results suggest that natural song learning errors may be more detrimental in intersexual contexts than in intrasexual contexts.

21-1 LONG, J.*; BERNATSKIY, A; BONGARD, J; LIVINGSTON, N; SCHWARZ, J; SMITH, M; LIVINGSTON, K; Vassar College, University of Vermont; jolong@vassar.edu

Robotic Connectomes: Chasing Evolvability with Evolving, Mobile Robots

Evolvability is the theoretical concept that attempts to capture the potential for populations to undergo future evolutionary change. Genetic variation, gene-to-phenotype mapping, and phylogenetic inertia are all thought to be important. Grounding evolvability in quantitative metrics and testable hypotheses is the goal of our research. It has been proposed that conditions of the agents and the environment that favor the evolution of modular neural connectomes will also create populations with enhanced evolvability. We test this hypothesis using Tadros, physically embodied robots inspired by the tadpole larvae of ascidians, which are autonomous surface swimmers. Tadros have a genome that encodes for a neural network that connects sensors to the tail-flapping motor, coordinating motor responses to changes in sensory input. We examine the structure and function of this evolving connectome as we apply selection for enhanced light gathering to a population of Tadros. Funded by the National Science Foundation (INSPIRE, Special Projects 1344227).

52-3 LOUDER, MIM*; VOSS, HU; MANNA, T; CARRYL, S; LONDON, SE; BALAKRISHNAN, CN; HAUBER, ME; East Carolina Univ., Weill Cornell Medical College, Hunter College, CUNY, Hunter College, CUNY, Univ. of Chicago; mckimlouder@gmail.com

Shared neural substrates for species recognition in parental and brood parasitic songbirds

In many social animals, early exposure to conspecific stimuli is critical for the development of accurate species recognition. For example, songbirds rely on conspecific tutors' for appropriate species-specific song development. Obligate brood parasitic birds forego parental care and young are raised by heterospecific hosts. Having evolved from non-parasitic ancestors, how do brood parasites recognize their own species? In non-parasitic parental songbirds (e.g. zebra finch), the primary and secondary auditory forebrain areas are critical in the differential processing of conspecific vs. heterospecific songs. Here we demonstrate that the same auditory brain regions underlie species recognition in adult pin-tailed whydahs (*Vidua macroura*), a brood parasitic songbird that is a member of the sister family to non-parasitic estrildid finches, including the model species zebra finch (*Taeniopygia guttata*). Whydahs showed stronger behavioral responses to playbacks of con- vs. heterospecific song playbacks. Using functional magnetic resonance imaging (fMRI), we detected an increase in the mean volume of the blood oxygenation level dependent (BOLD) response to con- vs. heterospecific songs within the auditory forebrain. We also found greater induction of the immediate early gene ZENK within the auditory forebrain following exposure to con- vs heterospecific songs. The evolutionary transition to brood parasitism, therefore, likely involved changes to existing proximate mechanisms-"evolutionary tinkering"-rather than wholesale reworking of neural substrates for species recognition in songbirds.

113-5 LONGO, S.J.; University of California, Davis; sjlongo@ucdavis.edu

Power-amplified feeding in snipefish (*Macroramphosus scolopax*)

Nearly all syngnathiforms (seahorses, pipefishes, and their relatives) are characterized by a long snout, which they employ in an unusual motion called pivot feeding, or rapid dorsal rotation of the head to bring the mouth closer to prey. Previous research has shown that pivot feeding is further specialized in seahorses and pipefish by using power amplification to achieve head rotational velocities faster than should be possible by direct muscle activation. Among all ray-finned fishes, seahorses and pipefish possess the only known power-amplified mechanism, although it has not yet been tested for in other syngnathiforms. I collected high-speed video of feeding strikes from the snipefish, *Macroramphosus scolopax*, which prior studies have indicated may possess morphological traits thought to be important in power amplification. I used a combination of kinematics, biomechanics, and micro-CT to characterize snipefish feeding and ask whether snipefish have power-amplified head rotation. I find that they have extremely fast strikes (as fast as 2.5ms) with very little change in gape but near-simultaneous head elevation and hyoid depression. The anterior epaxial muscles appear to be specialized for feeding, while the underlying bones are apparently reinforced to resist bending. Measurements on micro-CT images show that lengths and orientations of the four-bar linkage coupling head elevation to hyoid-depression are consistent with a bistable-locking mechanism, although it is unclear what triggers the apparatus to unlock. Power calculations suggest that observed rotational velocities of the head and body would require power inputs physically impossible based on muscle mass. Kinematics, biomechanics, and morphology therefore support claims that snipefish use a "hyoid lock" and power-amplify their feeding strikes.

97-14 LOUDON, C.*; BUSTAMANTE, J.; Univ. of California, Irvine; cloudon@uci.edu

Cuticle indentation and morphology of bed bug tarsi visualized using a nanomanipulator and focused ion beam milling

Plant trichomes (sharp microscopic hairs) on leaves from bean plants pierce and entrap insect pests. Coincidentally, although bed bugs (*Cimex lectularius* L.) are not naturally found in association with bean plants, they are also pierced and entrapped by these trichomes. The trichomes pierce the cuticle of the bed bug tarsi as the bugs walk on the leaves. The mechanical properties of bed bug tarsi were investigated in order to evaluate their vulnerability to piercing. This information will help inform development of physical methods for control of insect pests such as bed bugs. In order to interpret the forces measured during nanoindentation of cuticle at different locations on the bed bug tarsi, scanning electron microscopy was used to visualize the process of indent formation while poking the cuticle with a nanomanipulator on live, restrained bed bugs. Focused ion beam milling (with gallium ions) was used to selectively remove cuticle from different parts of the tarsi to visualize the complex way in which cuticle varied in thickness for different regions including the pretarsal claws. Cuticle of the tarsal subsegments showed permanent (plastic) deformation for small indentation depths of only 1 micron, while the area of the pretarsal claws that is usually pierced (the "membrane with microtrichia") showed no plastic deformation until a minimum indentation depth of 8 microns was reached. Therefore, the areas of the tarsi that differ in vulnerability to piercing also differ in mechanical properties and behavior.

7-2 LOUISON, M.J.*; ADHIKARI, S.; SUSKI, C.D.; STEIN, J.A.; University of Illinois-Urbana Champaign, Illinois Natural History Survey; louison2@illinois.edu

The role of boldness and cortisol responsiveness in determining vulnerability to angling in a popular sportfish species

Recent work suggests that fisheries-induced selection may act on directly on behavioral characteristics in addition to life history traits. These behavioral tendencies, which may include correlated levels of boldness and activity as well as underlying stress-hormone responsiveness, are often referred to as "behavioral syndromes" or "stress coping styles". It was the goal of this study to measure boldness and cortisol responsiveness to stress in largemouth bass *Micropterus salmoides* taken from an experimental population selected for differential vulnerability to angling, and to determine if these traits influenced the likelihood of capture. Fish were subjected to an open-field test to evaluate boldness, then had blood drawn to determine levels of plasma cortisol in response to an air-exposure challenge. The fish were then stocked into an experimental pond where a week-long series of angling sessions took place. Binary logistic regression modelling was run following these trials to evaluate the effects of fish size, selected line, boldness, and baseline/post-stress cortisol levels on the probability of capture. Of these, post-stress cortisol levels emerged as a significant negative predictor of whether the fish was captured ($p < .03$). Cortisol levels (baseline and post-stress) were not correlated with boldness levels in bass in this study. Our findings that fish with higher post-stress cortisol levels were less likely to be captured provides further evidence that fisheries-induced selection may act on behavior and physiology in addition to life-history traits.

132-6 LUCAS, KN*; DABIRI, JO; LAUDER, GV; Harvard University, Stanford University; klucas@fas.harvard.edu

Pressure field measurements in the study of fish-like swimming

Pressure fields around the body provide a key avenue for fish to interact with their fluid world. Perhaps the most iconic examples are embodied by the fish's lateral line sensory system and respiratory buccal pump, but pressure gradients are equally important in locomotion. To swim, fish pass a sinusoidal wave of bending down their bodies, creating localized regions of high and low pressure, and shaping this pressure field to promote favorable generation of locomotor forces and torques. Yet, since the seminal works of Dubois and colleagues in the 1970s, there has been little experimental mapping of pressure fields in studies of fish-like propulsion. This is owing in part to the difficulty in producing an accurate pressure measurement, and further difficulty in producing a map on a fine scale. Here, we use a non-invasive approach to calculate detailed, 2D pressure distributions based on digital particle image velocimetry (DPIV) measurements of velocity vector fields. To evaluate the accuracy of this approach, we apply this technique in the study of a fish-like mechanical model for which true forces and torques could be directly measured. Moreover, we identify limitations of this approach by examining static bodies and 3D flows, conditions under which this analytical approach would not be expected to perform well. In many cases, we were able to predict time-dependent patterns of swimming forces and torques with considerable accuracy. We conclude by providing a preliminary example of the pressure field around a freely-swimming fish and discussing the implications of this new approach for understanding the functional design of fishes.

34-8 LOVE, A.C.*; LOVERN, M.B.; DURANT, S.E.; Oklahoma State University; ashley.c.love@okstate.edu

Captivity influences immune responses, stress endocrinology, and organ size in house sparrows (*Passer domesticus*)

Studies using wild animals in laboratory-based research require bringing wild-captured organisms into a novel setting, which can have long-lasting impacts on physiology and behavior. In several species, captivity stimulates stress hormone production and can alter immune function. Despite this, little is known about how captivity influences stress hormone regulation, or if captivity-induced changes in stress hormone production and regulation mediate changes in immune function. In this study, we investigate the influence of captivity on the physiology of a wild bird commonly-used in laboratory-based research, the house sparrow (*Passer domesticus*). We tested how captivity influences stress endocrinology, immune responses, and organ mass, and also investigated if the production or regulation of corticosterone, the main stress hormone in birds, mediated changes in immunity or organ size. We found that baseline and ACTH-induced corticosterone levels increase following captivity and remain elevated after 9 weeks of captivity. Wound healing also was influenced by time spent in captivity, with birds taking 2 days longer to heal if they were wounded after 3-6 weeks in captivity when compared with birds that were wounded immediately upon capture. Additionally, captivity caused notable reductions in spleen, liver, and brain mass within 24 days of captivity, and this reduction persisted for at least 9 weeks. Together, these results imply that captivity can have long-lasting effects on house sparrow corticosterone release and immune function, and suggest that, even after 9 weeks, house sparrows do not acclimate physiologically to life in captivity.

94-8 LUDINGTON, TS*; MOORE, PA; Bowling Green State University; tluding@bgsu.edu

Turbulent exposure to pollution alters the responses of crayfish: Understanding the impact of real distributions of toxins on ecosystem functioning

Anthropogenic toxins in solution have detrimental effects on aquatic organisms. Within lotic systems, these toxins are dispersed and move through the environment due to turbulent mechanics. The physical properties of a habitat (flow speed, substrate, and in particular obstacles in the flow) can alter, enhance, or diminish the dynamic concentrations impacting both physiological and behavior functions of key organisms. This study was designed to quantify how the changes in dynamic toxic exposure, due to turbulent flow, will impact behavioral and physiological responses of a keystone species. Crayfish (*Orconectes virilis*) were exposed to sublethal levels of the insecticide Carbaryl in a naturalistic flow through stream. Crayfish were placed at different distances away from a source of pollution and either upstream or downstream from an obstruction. We quantified the influence of turbulent flow on the distribution of toxins in the experimental flow channel before exposing crayfish. After 48 hours of exposure to an insecticide, crayfish were evaluated on their ability to locate a food odor in a Y-maze arena. In addition to this behavioral assay, the physiological impact of exposure was examined by comparing the hepatosomatic index (HSI). Results indicate that the addition of turbulence alters the dynamic fluctuations in toxic concentrations, thereby generating significant differences in physiology (HSI) of exposed animals between exposure paradigms. Differences in behavior also appear to be present in the foraging ability test. The findings of this study indicate that exposure to toxins in a natural environment varies and this variance of exposure allows for animals to experience a range of exposures based on the environment.

115-3 LUTTRELL, S.M.*; GOTTING, K.; ROSS, E.; ALVARADO, A.S.; SWALLA, B.J.; University of Washington, Seattle, Stowers Institute for Medical Research, Kansas City; shawnl2@uw.edu

Head Regeneration in a Stem Deuterostome

Head and central nervous system (CNS) regeneration has proven to be an elusive trait in the deuterostomes. No chordate has been shown to be able to regenerate a complete anterior head or CNS. The hemichordate *Ptychodera flava*, on the other hand, has been shown to reliably regenerate all anterior structures, including their anterior proboscis and their hollow, dorsal neural tube. Both structures have been shown to have homologies with the chordate head and CNS, so insight into their regeneration may allow insight into chordate brain and CNS regeneration. Solitary hemichordates are marine invertebrates that have a tripartite body plan. The anterior proboscis is used for digging and burrowing in the sand and mud and the mouth is found at the proboscis-collar boundary. The middle collar or neck region houses the neural tube and the posterior trunk contains dorsal and ventral nerve cords that run the full length of the trunk. We have carefully analyzed anterior regeneration in *P. flava* and report the spatial and temporal formation of internal and external structures. Furthermore, we have sequenced, assembled, and analyzed the transcriptome for eight different stages of anterior regeneration and show that several chordate forebrain genes are expressed very early during regeneration, as the proboscis is beginning to form. Hemichordates are a key link between the deuterostome ancestor and the chordates and as such, may reveal vital steps to unlocking more extensive CNS regeneration in the chordates.

74-2 MA, X.; JOHNSON, K.B.*; Florida Institute of Technology; johnson@fit.edu

A Comparative Study of Copepod Phototaxis: Modern vs. Ancestral Photic Conditions

A comparative taxonomic approach is used to test the phototactic Sensitivity Hypothesis (SH), i.e. that light response reflects habitat photic conditions. Alternatively, if a species has relatively recently adopted a new habitat, light responses may reflect ancestral photic conditions. A series of laboratory experiments were conducted to determine phototactic polarity, spectral responses and intensity thresholds for four species of copepods, each representing different habitat-lineage combinations. Phototaxis was examined for two calanoid and two harpacticoid species. *Parvocalanus crassirostris* is a typical calanoid in that it lives in the water column, while *Pseudodiaptomus pelagicus*, also calanoid, is unusual in having a benthic association. In an analogous cross-comparison of species, *Tisbe biminiensis* is a typical harpacticoid in living on the benthos, while *Euterpina acutifrons*, also harpacticoid, lives in the water column. This is the first phototaxis lab study to include harpacticoid copepods. The benthic copepods, regardless of taxonomic lineage, displayed negative phototaxis. The pelagic species, in contrast, showed positive phototaxis. The polarity of phototaxis for all species was consistent with the SH in that the direction of movement is likely to sustain them in their respective habitats. Spectral sensitivity, however, may reflect ancestral preferences rather than the most readily available wavelengths for copepods in derived habitats. *Pseudodiaptomus pelagicus* had a peak response to 540 nm, not too dissimilar from the other calanoid in this study and many from the literature. *Euterpina acutifrons* had peak responses at 500 nm, similar to the other harpacticoid in this study when light-adapted. Intensity thresholds were highly variable and could reflect a complex combination of ancestry, depth distribution, habitat preference, and water quality conditions.

126-2 MA, Y.M.*; PEREZ, C.R.; BRANFIREUN, B.A.; GUGLIELMO, C.G.; Univ. of Western Ontario, Canada, Univ. of Nevada, Reno, USA, Univ. of Western Ontario, Canada; yma286@uwo.ca

Flight Performance In A Migratory Songbird Exposed To Elevated Dietary Methyl-Mercury

Many songbirds migrate long distances and may be exposed to different dietary methyl-mercury (MeHg) concentrations during their annual cycle. There is ample evidence that environmental MeHg exposure can cause reductions in avian fitness, particularly in aquatic species during breeding. However, recent work indicates that terrestrial songbirds that live in association with MeHg contaminated environments can bioaccumulate significant MeHg in tissues. How the MeHg levels we observe in migratory songbirds affect flight performance and migration is still unknown. We conducted a MeHg dosing experiment (0.5ppm in wet weight, relevant to contaminated environment) with yellow-rumped warblers (*Setophaga coronata*) while they were in a hyperphagic, migratory state. Warblers rapidly bioaccumulated dietary MeHg to 10 to 20 fold in blood, approximately 60 fold in liver, 40 fold in brain and muscle, and over 100 fold in kidneys over after 2 weeks. There was no significant effect of MeHg on vertical takeoff ability. In 2-hour wind tunnel flights, MeHg treated warblers had a significantly greater median of numbers of strikes (landing or losing control), longer strike duration, and shorter flight duration than control birds. There was also a positive correlation between total blood Hg concentration and the median of strikes in the MeHg treated warblers. In terms of energetics MeHg treated warblers had a nearly significant greater cost of transport (2-tailed P = 0.065), which may have been caused by their poorer control in flight. In conclusion, hyperphagic migratory birds rapidly accumulate MeHg from the diet, which has the potential to affect flight performance and migration ability.

130-7 MABRY, K.E.*; HAMMOND, J.I.; MCCAULEY, S.J.; New Mexico State Univ., Univ. of New Mexico, Univ. of Toronto Mississauga; kmabry@nmsu.edu

Effects of increased temperatures and increased thermal variation on development and survival of an aquatic insect

The effects of climate change on plants and animals are pervasive. Importantly, climate change is expected to increase the thermal variation experienced by organisms, in addition to an overall increase in mean temperature. Because their body temperatures are heavily influenced by environmental temperatures, ectotherms are highly vulnerable to the effects of climate change. To investigate the effects of increased temperature and increased thermal variation on survival, emergence phenology, and developmental rates of an ectotherm with a complex life cycle (the dragonfly *Erythemis collocata*), we manipulated the temperatures experienced by developing larval dragonflies. In our first experiment, we elevated mean temperature by either 2.5 or 5° C, simulating predicted temperatures in 50 and 100 years, respectively. In our second experiment, we exposed dragonfly larvae to temperatures that were constantly 3.5° C above ambient, or to an "increased variation" treatment in which a mean increase of 3.5° C was achieved by alternating between 1° and 6° C above ambient. When mean temperatures were elevated but tracked ambient variation, we found that dragonflies emerged earlier, but did not experience differential survival. Similarly, when we manipulated thermal variability, larvae in both warmed treatments developed more rapidly than controls. However, larval survival decreased for animals that experienced increased thermal variability. Taken together, our results suggest that the effects of increased thermal variability may have negative effects on organisms that go beyond the effects of increased mean temperatures alone.

58-9 MACKESSY, Stephen P.; University of Northern Colorado; stephen.mackessy@unco.edu

Colubrid snake venoms as a source for understanding biological roles of venoms among advanced snakes

Snake venoms represent an adaptive trophic response to the challenges confronted by a limbless predator for overcoming fractious prey, and this chemical means of dispatching prey shows several dominant phenotypes. Many front-fanged snakes, particularly vipers, feed on a variety of vertebrate and invertebrate prey species, and some of their venom components (e.g., cobratoxin, metalloproteinases) appear to have been selected for "broad-brush" incapacitation of differing prey taxa. Using a number of proteomic and genomic-based techniques, the compositional diversity of front-fanged snakes is becoming well characterized; however, this is not the case for many rear-fanged colubroid snakes, which include a variety of diverse taxa world-wide. Because these species show a very high diversity of prey preferences, and because venoms are primarily a trophic adaptation, it is argued here that important clues for understanding specific selective pressures favoring venom component composition will be found among rear-fanged snake venoms. Rear-fanged snakes typically (but not always) produce venoms with lower complexity than front-fanged snakes, and there are even fewer dominant (and, arguably, biologically most relevant) venom protein families. We have demonstrated taxon-specific toxic effects, where lizards and birds show high susceptibility while mammals are largely unaffected, for both Old World and New World species of rear-fanged snakes, strongly indicating a causal link between toxin evolution and prey preference. Relatively few rear-fanged snake venoms have been characterized, and basic natural history data is often lacking, but directed sampling of specialized species indicates that novel compounds are likely among these specialists, particularly among those species feeding on archaic prey such as scorpions and centipedes.

61-6 MADELAIRE, CB*; GOMES, FR; SOKOLOVA, IM; University of São Paulo, Brazil, University of North Carolina at Charlotte, USA; cmadelaire@yahoo.com.br

Effects of extreme seasonality on metabolism and immunity of amphibians in a tropical semi-arid zone (Caatinga)

The rate and severity of the climate change vary across the globe, and a major challenge is therefore to understand how climate affects regional ecosystem patterns. To achieve this aim it is crucial identify and link ecological processes and physiological mechanisms on more susceptible ecosystems, such as tropical biodiversity hotspots. Our study aims to determine the role of bioenergetic mechanisms on survival and fitness of amphibians from the semi-arid Caatinga region of Brazil, which is considered one of the hot-spots of climate change in South America. In order to determine the effects of seasonality and physiological stress on key metabolic regulatory pathways and immunocompetence of amphibians, we assessed the role of the key metabolic regulators, AMP-activated protein kinase (AMPK), Protein Kinase B (AKT), Eukaryotic Initiation Factor (eIF), and Heat Shock Proteins (HSP 60,70,90) in seasonal metabolic adjustments, and determined the links between the bioenergetic status and immunocompetence of the amphibians in response to seasonally elevated temperatures and drought. Samples were collected from three anuran species *Pleurodema diplolister* (a summer estivating species), and *Rhinella granulosa* and *R. jimi* (species that are active the year round) during the dry season and the rainfalls and used to test the links between metabolic status and immunocompetence in amphibians from this extreme environment.

67-2 MACRANDER, J*; BROE, M; DALY, M; The Ohio State University; macrander.1@osu.edu

A High-Throughput Investigation into the Tissue Specific Venom Composition and Differential Gene Expression in Three Species of Sea Anemone

Cnidarians are the only group of venomous animals that lack a centralized venom transmission system. Instead, they are equipped with stinging cells collectively known as cnidocytes. Cnidocytes vary in abundance and type across different tissues, often being attributed to tissue specific functions even though the venom composition in most species remains unknown. Within Cnidaria, sea anemones have been the best characterized group when it comes to venom diversity and function; however, previous studies have focused on venom isolated from cnidocytes or whole tentacle extracts from relatively few species. Depending on the tissue type, the venom composition may be vital for predation, defense, or digestion. To investigate tissue specific variation in venom we constructed partial transcriptomes for three different tissue types (tentacles, mesenterial filaments, and column) across three species of sea anemone (*Anemonia sulcata*, *Heteractis crispa*, and *Megalactis griffiths*). For each species we determined the tissues specific abundance of toxin-like sequences and investigated differential gene expression to identify non-venom transcripts outside expected expression levels. The species specific venom repertoire was similar across tissues, with notable differences in tissue specific abundance. When comparing across species, however, there were major differences in venom composition in addition to overall abundance estimates across similar tissue types. Our results show that evolutionary history may play a more significant role in sea anemone venom composition than the inferred functional roles of venom across different tissue types within a single polyp.

111-5 MADY, R*; GRAHAM, J; LELLO-SMITH, A; PEDERSEN, A; THOMASON, C; GERLACH, N; KETTERSON, E; GREIVES, T; Towson Univ., North Dakota State Univ., Univ. of Edinburgh, Texas Tech Univ., Univ. of Florida, Indiana Univ.; rmady1@students.towson.edu

Nest Identity Crisis: The Relationship between Predator Abundance and Nest Site Selection in the Dark-eyed Junco

In dynamic environments, it is essential for organisms to possess plastic behavioral traits that allow them to react to changes. One such trait that is essential to reproductive success is nest site selection. For the dark-eyed junco (*Junco hyemalis*), a songbird that primarily nests on the ground, nest site may be influenced by varying levels of predation pressure. Previous work suggests that the abundance of the primary nest predator, the eastern chipmunk (*Tamias striatus*), along with other rodents fluctuates in response to varying levels of acorn mast production and influences nest success. Varying small rodent abundance and the resulting predation pressure may favor an ability of female juncos to assess and adjust their nest site to the optimal location from year to year to maximize fitness. To determine if predation pressure influences nest site selection and nest success, we compiled data from previous studies on small rodent predator abundance and nest sites at Mountain Lake Biological Station. As predation pressure is not the only dynamic factor that may influence nest site location, we also investigated the role of weather. Here, we demonstrate that rodent abundance significantly predicts when the first off-ground nest is found as well as the proportion of off-ground nests found within a given year. Weather, in terms of temperature and precipitation, did not predict the prevalence of off-ground nests. Surprisingly, off-ground nests were not more likely than on-ground nests to be successful, even in years of high rodent abundance. We discuss possible explanations for this finding.

8-5 MAGAÑA, J.L.*; LOVERN, M.B.; Oklahoma State University; jmagana@okstate.edu

Small and large lizards agree in defeat but react differently to victory.

In territorial species, contest outcome should affect how individuals allocate energy to current and future reproduction. *Anolis sagrei*, the brown anole, is a small lizard species that defends territories containing food resources against conspecific intruders during the breeding season. Previous work showed that female winners and losers of staged intrasexual contests allocated energy differently: losers produced eggs that hatched more quickly than the eggs of winners, indicating lower yolk provisioning in losers' eggs. Contest outcome affected reproductive outcome, but it was unclear whether winners and losers allocated energy uniformly. We compared offspring traits to maternal snout-vent length, a measure of body size that increases linearly with age. We found that although losers' investment in reproduction was unrelated to body size, winners' reproductive investment varied with maternal size. Small winners produced eggs that hatched quickly whereas large winners produced eggs that hatched later. We interpret this strategy to be related to potential future reproduction; a large (old) winner should invest in current offspring whereas a small (young) winner should invest in potential future offspring.

97-8 MAIA, A*; PROBST, B; FOSTER, A; REEVES, JD; Eastern Illinois University; amresendedamaia@eiu.edu

Function of the spiny dorsal fin of bluegill sunfish in turbulent conditions

Derived bony fishes have a spiny portion of the dorsal fin which has been proposed to have either a defense or stability function. We used bluegill sunfish to investigate how this structure functions during steady swimming at $1\text{BL}\cdot\text{s}^{-1}$ in the presence or absence of turbulence. We collected kinematic data with the fin intact (injection of saline) and after the injection of flaxedil - a muscle relaxant - or lidocaine - an afferent nerve blocker. We hypothesize that there will be no differences during steady swimming with the sensory nerves blocked or with the muscle function impaired by flaxedil. However, when exposed to turbulence, we expect the fish to lose its heading more often when deprived of the sensory information and even more frequently when the muscle relaxant is applied. Flaxedil, lidocaine, and Ringer's saline solutions were injected at three points on either side of the base of the spiny dorsal fin. Fish were allowed to recover in a flow tank and made to swim at $1\text{BL}\cdot\text{s}^{-1}$ in quasi-laminar and turbulent flows while collecting high speed video. Turbulence was generated upstream from the fish with two rotating turbines. In control conditions (saline injection), the spiny dorsal fin is normally collapsed with no turbulence, but becomes erected in the presence of turbulence to aid in recovery from spills. Fish injected with flaxedil are unable to raise their spiny dorsal fin as expected. Fish injected with lidocaine also fail to deploy the spiny dorsal fin in response to perturbations. When exposed to turbulent conditions, fish injected with lidocaine and flaxedil increased spill rate and have decreased stability. These results support our hypothesis of a stabilizing role of the spiny dorsal fin under unsteady flows.

126-1 MAGGINI, I.*; KENNEDY, L.V.; MACMILLAN, A.; ELLIOTT, K.H.; MACCURDY, R.B.; PRITSOS, C.; DEAN, K.; GUGLIELMO, C.G.; Univ. of Western Ontario (UWO), UWO, McGill Univ., Cornell Univ., Univ. of Nevada-Reno, Abt Associates; cguglie2@uwo.ca

The effects of crude oil contamination of feathers on takeoff and endurance flight in a shorebird, the Western Sandpiper

The fate of birds that become oiled during oil spills such as the 2010 Deepwater Horizon (DWH) spill in the Gulf of Mexico is an important aspect of assessing environmental impacts. Dead birds can be counted, but understanding the fitness costs of exposure to small amounts of crude oil that are not lethal is difficult and often ignored. We studied the effects of DWH oil applied to wing, tail and body feathers on the flight of the Western Sandpiper (*Calidris mauri*). Flight energetics and biomechanics were measured using quantitative magnetic resonance analysis, high-speed video, and accelerometry. Takeoff speed was reduced by over 30 %, and takeoff angle was reduced in trace-oiled birds compared to controls. Oiled birds would require twice the time to reach cruising speed, and fly lower to the ground, potentially making them more vulnerable to aerial predators. Wind tunnel flights showed that trace/moderate oiling increased flight energy costs by up to 41 % relative to controls. Oiled birds also had decreased flight ability and decreased voluntary duration of flight. The flight power curve, as indicated by wingbeat frequencies at different flight speeds, was altered in moderately oiled birds. Oiling resulted in faster wingbeat frequencies, and there was an increase in wingbeat amplitude at low speeds in trace and moderately oiled birds. Thus, migration would be slower and/or more costly for an oiled bird. Our results suggest that trace to moderate amounts of crude oil (oiling categories widely observed in live resident and migratory birds in the aftermath of the DWH spill) negatively affect the aerodynamic properties of feathers, substantially reducing takeoff and endurance flight performance with associated fitness costs.

73-3 MAIE, T.; Lynchburg College; maie.t@lynchburg.edu

Effects of contaminated water due to mining activities on the vertebrae in fishes: Evaluation of correlation between material properties and predator evading performance

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 parts of the Midwestern United States. Although not yet operational, environmental risks would be predicted. Lakes and rivers 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, I evaluated a series of force-bearing capacities (strength, Young's modulus of elasticity, yield strength and yield strain) 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 *Perca flavescens* from a mining-influenced lake produced much more elevated level of strength than those from a spring-fed lake. Consistently with the strength, the vertebrae of *Perca flavescens* from the mining-influenced lake showed partly but significantly elevated Young's modulus. However, the degree of deformation that the vertebrae could resist and recoil back from appeared to be increased in *Perca flavescens* from the mining-influenced lake. Through analysis of high-speed videos, differential contributions of these body regions to kinematics and performance of predator evasion, such as angular excursion of the spinal column, were tested. This study provides insights into how biomechanics of vertebrae informs us about ecotoxicology in fishes.

65-4 MAJORIS, J. E.*; CATALANO, K. A. ; ATEMA, J.; BUSTON, P. M.; Boston University; jmajoris@bu.edu
The Tortoise and the Hare: Development of Critical and Sustained Swimming Abilities in Larvae of Two Coral Reef Fishes with Short Distance Dispersal

Reef fish larvae were once considered passive particles dispersed by currents for 10's to 100's of km. However, recent studies using genetic parentage analyses reveal that the larvae of several fish species rarely disperse farther than 10 km from their natal origin. This gap between predicted and observed patterns of larval dispersal suggests that other factors, such as swimming and orientation behavior, play a role in shaping the pattern of dispersal. Yet, few studies have investigated the development of swimming abilities in reef fish larvae. In this study, the development of critical and sustained swimming abilities was measured in the larvae of two species of reef fish with similar patterns of short distance dispersal. Specifically, we investigated the effect of i) species, ii) age, and iii) morphology on the development of critical and sustained swimming abilities in lab-reared *Amphiprion percula* and *Elacatinus lori* larvae from hatching through settlement. To test critical swimming speed, larvae were exposed to incremental increases in current speed at 2 min intervals until they could no longer maintain position in the flume. To test sustained swimming performance, replicate trials were conducted at 2, 4, 6, 8 and 10 cm s⁻¹ and the time until exhaustion was recorded. For both species, swimming abilities increase with age, standard length and propulsive area. Swimming abilities differed substantially between species, with *A. percula* displaying greater critical and sustained swimming abilities than *E. lori* at all ages. This dramatic difference in larval swimming abilities is surprising given the similarity in the pattern of dispersal and suggests that these species may use different behavioral strategies to remain close to their natal reef.

9-2 MALONE, MA*; WESTNEAT, MW; Univ. of Illinois at Chicago, Univ. of Chicago; mmalon29@uic.edu
Skull Morphometrics and Feeding Biomechanics in a Global Clade of Wrasses

A major aim in evolutionary biology is to explain the origin of morphological diversity. Many studies attribute morphological diversity to adaptations for particular ecological niches, with divergent selection enhancing adaptive differences. While natural selection may occur throughout the life history of an organism or at specific stages, few studies focus on ontogeny of morphological diversity and its role in adaptive divergence. In this study I investigated the ontogeny of wrasse functional morphology within a group that demonstrates diverse and novel adult feeding: the *Thalassoma* and *Gomphosus* clade within the Labridae. We utilized museum collections to compile morphometric data on an ontogenetic series of nine wrasse species. Dissections were performed on the right side of the head to expose the adductor mandibulae complex and record 20 functionally relevant, homologous landmarks. Geometric morphometric analyses and a phylomorphospace approach reveal patterns of divergence and convergence in skull shape across the phylogeny of *Thalassoma*, and show that the novel biomechanics of *Gomphosus* correlate with occupation of novel morphospace. Biomechanical modeling using the apps MandibLever 3.2 and JawsModel 4.0 was used to investigate differences in feeding kinetics throughout ontogeny and phylogeny, revealing that novel mechanics in *Gomphosus* are associated with changes in jaw levers while leaving the anterior jaws four-bar linkage static. High-speed video of feeding reveals an unusual two-stage biting strategy in these fishes that is also highly divergent in *Gomphosus*, reflecting these morphometric changes. These results shed light on rapid evolution of jaw mechanics at the interspecific level as well as important stages of selective pressure that may occur throughout the complex life cycle of wrasses, and its role in adaptive divergence of this diverse group. Supported by NSF DEB-1112763 and IOS-1425049.

4-2 MALISCH, J.L.*; JOHNSON, E.; DOAN, P.; TANG, A.; HUMPHRIES, T.J.; CRINO, O.L.; BREUNER, C.W.; The Claremont Colleges, University of Montana, Pitzer College, Scripps College, University of California, San Diego, Deakin University; jessica.l.malisch@gmail.com

Acute stress decreases corticosterone-binding globulin for 24 hours and a second stressor during this time increases sleep disruptions in Mountain White-crowned Sparrows

Corticosterone-binding globulin (CBG) is a potential potent modulator of the glucocorticoid (GC) response to stress. CBG binds the majority of circulating GCs, increasing GC solubility in plasma, while potentially sequestering GCs from receptors. For a given concentration of GC, higher CBG levels reduce free GC (unbound) while lower CBG levels increase free GC levels, and therefore increase GC binding to receptors. CBG levels can fluctuate acutely (within 60 min) in some species, while other species have a delayed CBG response to acute stress. 24 hours following standardized stressors, both rats and Japanese quail have a significant reduction in circulating free GC, leading to a significant increase in free baseline GC a full 24 hours after the acute stressor. Here we examine the effect of acute stress on GC, CBG, and free GC over a longer timeframe, up to 72 hours following the stressor in a free-living vertebrate, the Mountain White-crowned Sparrow, *Zonotrichia oriantha leucophrys* (WCSP). We found a decrease in CBG and an increase in free GC 24 hours following acute stress. We also explored potential behavioral ramifications of experiencing a second stressor while CBG is depressed. WCSP acutely stressed twice within 24 hours had an increase in the number of sleep disruptions compared to a single-stressor. Furthermore, WCSP acutely stressed prior to inclement weather also experienced more sleep disruptions as compared to WCSP that were not acutely stressed prior to the storm. This research is particularly relevant because of climate change with increased frequency and intensity of snow storms later into the WCSP breeding season.

117-2 MANDRE, S.*; DIAS, M.; SINGH, D.; BANDI, M. M.; VENKADESAN, V.; Brown University, Aalto University, Okinawa Institute of Science and Technology, Okinawa Institute of Science and Technology, Yale University; shreyas_mandre@brown.edu
Evolution of the transverse arch made the human foot stiffer

When humans push off against the ground during locomotion, the foot transmits the ground reaction force from the forefoot to the heel joint. Such loading causes the foot to bend in the longitudinal direction, severely so for other primates and people with flat feet. We find that the transverse arch is the key structural element of the foot that stiffens it to such deformation and thereby facilitates propulsion. Our primary means to determine the contribution of the foot arches to the stiffness is to model it as a curved elastic shell. Structural analysis of a shell reveals an amplification of its stiffness above that of a flat plate depending on a dimensionless morphological parameter $\kappa = L^2/t$, where κ is the transverse curvature, L the length of the shell, and t its thickness. For small κ , the shell approaches a flat plate and the amplification factor approaches unity, but as κ increases beyond 10, the amplification factor increases steeply as $\kappa^{3/2}$. Application of this relation to human feet implies an approximately 6-fold increase in stiffness compared to flat feet purely because of its transverse curvature. On one hand, this contribution explains the difference between the experimentally observed foot stiffness and the contributions from the longitudinally oriented arch, ligaments, and aponeurosis. On the other hand, the dimensionless morphological parameter provides a quantitative functional interpretation of the transverse arch, and allows us to compare its role across hominin fossil feet without access to the soft tissue. In particular, the κ for the foot of an unknown hominin species found in Burtelle is estimated to lie in the range from 10 to 16, which is suitable for bipedal terrestrial locomotion.

94-4 MARAN, A.M.*; PELINI, S.L.; Bowling Green State Univ.; audreym@bgsu.edu

Predator Contributions to Belowground Responses to Warming

Identifying factors that control soil CO₂ emissions will improve our ability to predict the magnitude of climate change soil ecosystem feedbacks. Despite the integral role of invertebrates in soil systems, they are excluded from climate change models. Soil invertebrates have consumptive and non-consumptive effects on microbes, whose respiration accounts for nearly half of soil CO₂ emissions. By altering the behavior and abundance of invertebrates, predators may have indirect effects on microbial soil respiration. We examined the effects of a generalist predator on soil respiration under warming. Based on research suggesting invertebrates may mediate soil CO₂ emission responses to warming, we predicted that predator presence would result in increased emissions by negatively affecting these invertebrates. We altered the presence of wolf spiders (*Pardosa spp.*) in mesocosms containing a community of soil invertebrates. To simulate warming, we placed mesocosms of each treatment in 10 open-top warming chambers ranging from 1.5-5.5° C above ambient at Harvard Forest, MA. As expected, CO₂ emissions increased under warming and we found an interactive effect of predator presence and warming, though the effect was not consistent through time. The interaction between predator presence and warming was the inverse of our predictions: mesocosms with predators had lower respiration under warming than those without predators. CO₂ emissions were not significantly associated with microbial biomass. We did not find evidence of consumptive effects of predators on the invertebrate community, suggesting that predator presence mediated response of microbial respiration to warming through non-consumptive means. We found a significant interaction between warming and predator presence that warrants further research into mechanism and generality of this pattern to other systems.

SI-7 MARKHAM, Michael R. *; MALTBY, Rosalie; RIEDMANN, Hiliary L; SINNETT, Philip M.; BAN, Yue; The University of Oklahoma; markham@ou.edu

Energetic adaptations and constraints in active sensory and communication signals

The metabolic costs of animal communication signals range from trivial to a significant fraction of the animal's energy budget. Signals with the highest costs are typically intermittent and can be stopped entirely to reduce ongoing metabolic demand. Doing so eliminates the benefits associated with social signaling (e.g., territorial defense, mate attraction) but allows a shift to other beneficial activities such as foraging. When metabolically costly communication signals are coupled to active sensory systems, reducing or ceasing signaling effort to conserve energy also degrades or eliminates sensory performance, potentially interfering with navigation and foraging. This is the case for weakly electric fish that generate high-frequency electric organ discharges (EODs) which serve as both an active sensory signal and a social communication signal. I will present studies addressing adaptations and constraints imposed by these energetic demands in this system. At the organismal level, some species modulate signal amplitude on a circadian rhythm to conserve energy and also regulate signal amplitude on the timescale of days to weeks to reduce energetic demands in response to chronic metabolic stress. These effects arise from two different hormonal factors that modulate the electrical output of the electric organ cells. We also find a suite of cellular and molecular adaptations in the electric organ cells that allow the maintenance of this high-frequency, high-cost signal while also providing mechanisms for signal reduction during periods of acute metabolic stress. Taken as a whole, these findings reveal how energetic constraints and adaptations have shaped the physiology of an active sensory and communication signals at the organismal, cellular, and molecular levels.

S3-7 MARCOGLIESE, D. J.; Environment Canada, Montreal; david.marcogliese@ec.gc.ca

The distribution and abundance parasites in aquatic ecosystems in a changing climate: more than just temperature

Most research into effects of climate change on parasitic organisms concerns pathogens of man or commercially important species. Most of these parasites are terrestrially-based in whole or in part. Yet parasites themselves are important components of biodiversity and affect food web structure and function, as has been shown in numerous freshwater and marine ecosystems. Parasites in aquatic systems will respond directly to changes in temperature but also indirectly to changes in other abiotic parameters that are mediated directly on the parasite or indirectly through changes in the distribution and abundance of their hosts. Clearly effects of temperature are best studied and understood, but it is imperative to explore effects of contaminants, eutrophication, habitat fragmentation, stratification, ice cover, acidification, water levels and flow rates, oceanic currents, ultraviolet-light penetration, invasive species, weather extremes, and other forms of anthropogenic interference on the distribution of both hosts and parasites, as these biotic and abiotic factors and stressors do not operate independently of climate. Herein, effects of some of these on the distribution and abundance of parasites in aquatic ecosystems will be examined and discussed, often with counterintuitive consequences. Evaluation of the potential response of parasites of aquatic organisms to climate change illustrates the complexity of host-parasite systems and the difficulty of making accurate predictions for biological systems.

60-4 MARRANZINO, AN*; WEBB, JF; University of Rhode Island; amarranzino@my.uri.edu

Novel observations on the mechanosensory lateral line system in stomiiform fishes

The mechanosensory lateral line system of deep-sea fishes, especially that of the Stomiiformes, is relatively unknown. Unlike melamphids and gadiforms, which have obvious widened cranial lateral line canals with large neuromasts, stomiiforms are reported to have less prominent (and fewer) lateral line canals and few superficial neuromasts. We examined two important, commonly caught, and widely distributed stomiiform taxa: hatchetfishes (*Argyropelecus*: Sternoptychidae) and bristlemouths (*Cyclothone*: Gonostomatidae). Fish were recently collected at sea (Tucker trawl) or obtained from museum collections and examined using clearing and staining, whole mount hematoxylin staining, histology, μ CT imaging, and SEM. Contrary to Handrick (1901), who reported the presence of an unusually small number of neuromasts in *Argyropelecus*, we observed discrete vertical lines and clusters of small, densely placed superficial neuromasts above and below the eye, on the cheek, along the mandible, and in lines on trunk. In addition, canal neuromasts were identified in the partially enclosed and largely unossified supraorbital canals. In contrast, *Cyclothone* has no cranial lateral line canals, but has small superficial neuromasts in similar locations on the head and trunk, although they are not as highly proliferated as in *Argyropelecus*. The ability to obtain high quality specimens is critical because the skin of these fishes is extremely thin and easily subject to damage during collection. Our novel observations have radically changed our view of the non-visual sensory biology of these important fishes of the deep sea. Funded by an NSF Graduate Research Fellowship (Award #ADW03561), an ANMH Lerner Gray Fund Award, and the University of Rhode Island.

103-1 MARSHALL, CD*; ROSEN, D; TRITES, AW; Texas A and M University, University of British Columbia; *marshalc@tamug.edu*
Feeding Kinematics and Performance of Basal Otariid Pinnipeds, Steller sea lions, and Northern Fur Seals: Implications for the Evolution of Mammalian Feeding

Feeding performance studies can address questions relevant to feeding ecology and evolution, but current understanding of feeding mechanisms for aquatic mammals is poor. We characterized the feeding kinematics and performance of 5 Steller sea lions (*Eumetopias jubatus*) and 6 northern fur seals (*Callorhinus ursinus*). We tested the hypotheses that both species use suction as their primary feeding mode, and that rapid jaw opening was related to suction generation. Steller sea lions were found to use suction as their primary feeding mode, but also used a biting feeding mode. In contrast, northern fur seals only used a biting feeding mode. Steller sea lion kinematics were indicative of suction feeding (i.e., a small gape, small gape angle, large depression of the hyolingual apparatus and lip pursing). However, jaw opening as measured by Gape Angle Opening Velocity (GAOV) was relatively slow in Steller sea lions. Steller sea lions, the GAOV of Northern fur seals was extremely fast, but their kinematics indicated a biting feeding mode (i.e., northern fur seals exhibited a greater gape, a greater gape angle, and minimal depression of the hyolingual apparatus compared to Steller sea lions). Steller sea lions produced both subambient and suprambient pressures at 45 kPa, respectively. In contrast, northern fur seals produced no detectable pressure measurements. Steller sea lions have a broader feeding repertoire than northern fur seals, which likely enables them to feed on a greater variety of prey, in more diverse habitats. Based on the basal phylogenetic position of northern fur seals, craniodental morphological data of the *Callorhinus* lineage, and the performance data provided in our study, we suggest that northern fur seals may be exhibiting their ancestral feeding mode.

92-8 MARTIN, C.H.; University of North Carolina at Chapel Hill; *chmartin@unc.edu*

Cameroon crater lake cichlids: a model for examining the ecological, behavioral, and genomic conditions necessary for sympatric speciation

One of the most celebrated examples of sympatric speciation in nature were believed to be four sympatric radiations of cichlid fishes endemic to three crater lakes in Cameroon. Here I critically examine the evidence for sympatric speciation in these cichlids, combining measurements of natural selection and assortative mating in the field with population genomics using restriction site associated DNA sequencing to evaluate the evidence for secondary gene flow. First, I found considerable evidence of gene flow between all four radiations and neighboring riverine populations after initial colonization. In a few cases, some sympatric species were more closely related to outgroups than others, consistent with secondary gene flow facilitating their speciation. Second, many sympatric species complexes exhibited a unimodal distribution of phenotypes, suggesting that sympatric divergence is slow or incomplete. I found evidence of significant disruptive selection on trophic morphology in two lakes, but models suggest it is not strong enough to drive the speciation process to completion. In contrast, assortative mating was extremely strong along two independent axes and was primarily driven by breeding coloration. Overall, this suggests that sympatric divergence in these craters is driven by sexual selection, not natural selection, and may have benefited from secondary gene flow. These results do not rule out sympatric speciation in Cameroon cichlids, but instead reveal a complex history of speciation with gene flow, including allopatric and sympatric phases, resulting in both reproductively isolated species and incipient species complexes. Future work will aim to pinpoint where sympatric divergence may have occurred and continue to measure the relevant ecological, behavioral, and genetic variables to test existing models for this process.

S9-10 MARSHALL, Katie E.*; HARLEY, Christopher D. G.; SINCLAIR, Brent J.; University of British Columbia, University of Western Ontario; *kmarshall@zoology.ubc.ca*

Integrating the effects of repeated cold exposure from transcriptome to species distribution in the eastern spruce budworm
 Organisms live in complex worlds where environmental stresses can be more or less intense, occur for longer or shorter periods, and repeat more or less frequently. Yet while single stress events have been well-studied, the physiological and fitness effects of these more complex patterns of stress are not well understood. The eastern spruce budworm, *Choristoneura fumiferana*, is an important forest pest of the boreal forest and previous studies have shown the importance of low temperature stress in regulating its population and range. In this study we manipulated the number of low temperature exposures budworm received, while controlling the intensity and total length of time of exposure. We found that while spruce budworm that received repeated low temperature events had significantly greater cryoprotectant content (at a cost to glycogen reserves), survival to eclosion was significantly impacted. We also examined transcriptomic responses to low temperature stress, and found that while only a few transcripts were significantly differentially regulated following a single low temperature stress event, hundreds were differentially regulated following repeated low temperature stresses. These included transcripts for antifreeze proteins, several heat shock proteins, and electron transport chain proteins. We also modelled the spatial distribution of spruce budworm and found that species range was significantly impacted by retaining terms related to number of cold stress events. These results suggest that current studies that focus on single stress events may be missing the full range of potential stress responses, and that fluctuating stress may be an important determinant of species ranges.

39-4 MARTIN, L.A.*; DAS, S.; MYKLES, D.L.; Colorado State University, Fort Collins; *Linds@RLmartin.com*

De novo transcriptome assembly and analysis of the molting gland in blackback land crab, *Gecarcinus lateralis*, throughout various molt stages

In *Gecarcinus lateralis*, molting is stimulated by ecdysteroids, hormones produced in the Y-organ (YO). Animals spend a majority of time in the intermolt stage, when hemolymph ecdysteroid levels are low; the YO is in the basal state. In preparation for molting, the YO becomes activated; ecdysteroid titers increase and the animal enters the premolt stage, which is comprised of three substages: early premolt, mid premolt, and late premolt. At mid premolt the YO transitions to the committed state and ecdysteroid titers reach a peak in late premolt. To better understand the genetic networks that drive the YO through the basal, activated, and committed states, a transcriptome from intermolt and the three premolt substages was generated. Following Illumina sequence a reference transcriptome was assembled *de novo* using trimmed reads. Sequences were annotated using BLASTx against the NR and Swissprot databases. Expression levels for each sequence were calculated by mapping reads from each library to the reference transcriptome. To validate the reference transcriptome, we compared genes identified in *G. lateralis* using traditional sequencing to transcriptome sequences using local BLAST searches. *Gl-Rheb*, *Gl-mTOR*, *Gl-S6K*, and *Gl-Akt* were present in the transcriptome with over 99% similarity to genes obtained through traditional sequencing. These genes are components of the mechanistic target of rapamycin pathway (mTOR), which is required for sustained YO ecdysteroidogenesis. Relative expression analysis is being used to identify genes characteristic of each of the YO physiological state. Supported by NSF (IOS-1257732).

512-9 MARTIN, LB*; BARRON, DG; BURKETT-CADENA, ND; BURGAN, SB; GERVASI, SS; UYSAL, AK; SHIMIZU, T; Univ. of South Florida, Arkansas Tech Univ., Florida Medical Ento Lab; lbmartin@usf.edu

Individual variation and covariation in vector-borne disease directed behaviors

Individuals differ greatly in their propensity to transmit parasites (i.e. host competence); 20% of individuals are often responsible for 80% of transmission events, justifying the new moniker, superspreader. Such differences are underlain by at least two groups of traits: i) the physiological factors that mitigate parasite reproductive success and the host defenses against parasites, and ii) the behaviors that influence how hosts cope with infections and are exposed to parasites in the first place. In spite of a growing recognition for a role of superspreaders in the emergence and spread of many diseases, we still know little about what traits comprise them. Here, we investigated the organization of behavioral defenses against vector-borne diseases in a songbird. We first sought to reveal how behaviors that impact exposure (i.e., general activity, timing of activity, response to novelty, and active and passive behaviors directed at live mosquitoes) are correlated within individuals; strong positive covariation among particular behaviors could dispose some individuals to act as superspreaders. We also queried plasticity in behavior involved in competence, as flexibility could enable individuals to augment or damp their potential to generate new infections upon subsequent exposures. Lastly, we investigated how their brains responded to mosquito exposure in order to identify the brain regions responsible for processing this stimulus, and to determine whether neural variation underlies individual differences in anti-vector behavior.

55-3 MARTINEZ, C.M.*; SPARKS, J.S.; American Museum of Natural History; cmartinez@amnh.org

Covariation of Body and Oral Jaw Shapes in Malagasy and South Asian Cichlids

Etroplinae and Ptychochrominae represent two subfamilies of the highly diverse family Cichlidae. Occurring in Madagascar and South Asia, these groups are less species rich and much less studied than their relatives in the Neotropics and Africa. Our research focused on understanding the relationship between overall body shape, which varies from deep to shallow-bodied, and oral jaw shape. We used geometric morphometrics to evaluate shape variation among species for both the body and the jaw. Jaw shapes were approximated using the oral jaw four-bar linkage, which is often used as a model for jaw mechanics in teleost fishes. Although the ptychochromines displayed a larger overall range of body forms, variation in etroplines was similar and parallel in direction. A significant relationship was found between body and jaw shape in Etroplinae, but not in Ptychochrominae. Our results suggest that while body shape evolution may have influenced jaw form, it did not appear to impact its functionality (as measured by maxillary kinematic transmission, MKT). Overall, research of this nature is necessary for a better understanding of the evolution and diversity exhibited in two groups that include a number of endemic species, many of which are rare or even extinct.

101-6 MARTIN, M.D.*; SCHLENKE, T.A.; Reed College; mdmartin7@gmail.com

Characterizing the genetic basis of behavioral immunity in fruit flies

The genetic basis of cellular immunity has long been a focus of immunological research. While mounting a successful cellular immune response has obvious fitness benefits, cellular immunity can be energetically costly and only functions as a reactive strategy to infection. There is a growing understanding that behavioral immune defenses are a common strategy that hosts employ to avoid and treat infection. However, the genetic mechanisms underlying these behavioral strategies remain largely uncharacterized. *Drosophila melanogaster* and their parasitoid wasps offer a unique opportunity to understand the genetic and neural mechanisms of behavioral immunity in an ecologically relevant context. These wasps lay their eggs inside fly larvae and eventually consume fly hosts from the inside out. Fly larvae can mount a cellular immune response to encapsulate and kill the wasp egg, but adult wasps inject virulence proteins with their eggs to suppress host cellular immunity. As a supplement to this imperfect cellular immune response, female flies sense the presence of wasps by sight and reduce oviposition, effectively reducing the exposure of offspring to infection. We are conducting a genome-wide association study (GWAS) using the *Drosophila* Genetic Reference Panel to identify candidate polymorphisms affecting this oviposition reduction behavior. Our screen has uncovered candidate genes expressed in the central nervous system and the reproductive tract. Functional tests of these candidates using available mutants, including knockdown and overexpression, will be used to confirm our GWAS results, leading to a novel understanding of how environmental stimuli can alter an organism's physiology and behavior.

74-4 MASON, B.M.*; MILLER, D.J.; KOYANAGI, M.; TERAKITA, A.; Stanford University, James Cook University, Osaka City University, Osaka City University; bmason2@stanford.edu
Coral opsins: photosensitivity and partial characterization of five opsins from *Acropora millepora*

Reef-building corals lack even basic visual structures, yet display notable photosensitivities. Light influences tentacle movement, regulates circadian clocks, and influences the timing of spawning. Light also influences the behavior of coral larvae. Putative opsins have been identified in corals and implicated in these processes. However, the biochemistry and whether these receptors function as light receptors, remains unknown. The characterization of cnidarian opsins, in general, has proven challenging, and, to date, only one cnidarian opsin (a green-sensitive, Gs-coupled opsin) has been characterized in a jellyfish. Also, previous analyses of predicted cnidarian opsins suggest that anthozoan opsins are more diverse and likely signal via multiple pathways. We have identified six putative opsins in the Indo-Pacific coral, *Acropora millepora*. Phylogenetic analysis of the predicted proteins indicates they represent three distinct groups of anthozoan opsins identified previously. We heterologously expressed these receptors in mammalian cells and demonstrated photosensitivity of five opsins. Using the Glosensor cAMP luciferase reporter assay we determined the spectral sensitivity for three receptors. All three appear to couple to Gs and have absorption maxima in the blue-green region of the spectrum (471, 473 and 476nm). A fourth opsin activated Gi in a light-dependent manner, and a fifth produced a calcium response upon stimulation with light, consistent with Gq signaling. Our results support that hypothesis that anthozoans opsins signal through multiple G protein signaling pathways. Additional biochemical experiments and immunohistochemistry are in progress.

84-1 MATLOFF, I.*; STOWERS, AK; LENTINK, D; Stanford University; imatloff@stanford.edu

How feather movement allows shape shifting in avian wing morphing

Feathers are unparalleled structures optimized for flight. They stitch together to form aerodynamic wings that can morph and change shape, allowing birds to execute nimble maneuvers in flight. Exactly how feathers move relative to each other is not well known. To understand the orchestrated interaction between feathers and the musculoskeletal system, we corroborate a kinematic model by tracking feathers and skeletal motion of a racing pigeon wing with a motion capture camera system. We hypothesize that feather motion can be closely estimated by a passive model that achieves similar representative wing planforms observed in flight. With this model, we can further explore the group dynamics of the primary and secondary feathers as well as the effects of absent feathers, for example during molting. The findings also have implications for bio-inspired robot design.

S7-3 MATSON, K.D.*; VAN DIJK, J.G.B.; Wageningen University, University of Cambridge; kevin.matson@wur.nl

Let's get physical! Viewing ecological immunology through the lens of exercise physiology to disentangle the effects of movement and migration.

Animal migration is a complex phenomenon with many physiological mechanisms and consequences. The act of moving, or locomotion, is only one part of migration. But even on its own, locomotion has the potential to impact the immune systems of animals. Studying non-migrating animals that are locomoting, exercising, or otherwise physically exerting themselves can provide insights into relationships between animal movement and disease resistance and susceptibility, as well as other disease-related processes such as tolerance and inflammation. Yet many questions remain unanswered: What qualifies as physical exertion in animals? How is physical exertion and its immunological effects in animals best measured? To address these questions and others, we review studies exploring the links between exercise and the immune system in free-living and captive animals. Furthermore, we explore the realm of human exercise physiology to see what insights this branch of biomedical science can offer to researchers in fields such as ecology and evolution, which emphasize animal diversity, interactions, and adaptations.

29-8 MATSUDA, SB*; GOSLINER, TM; Hawai'i Institute of Marine Biology, California Academy of Sciences, California Academy of Sciences; shayle@hawaii.edu

Glossing over cryptic species: molecular phylogenetic analyses reveal true identities of *Glossodoris nudibranchs*

Chromodorid nudibranchs (Mollusca: Gastropoda: Nudibranchia) are tropical sea slugs that exhibit diverse coloration, key bioindicators of climate change, and coveted by pharmaceutical and cosmetic companies for their chemical properties. Despite the growing attention, the evolutionary history and taxonomy of this group remains poorly documented, leading to underestimation of biodiversity and false generalizations about biomedical potential. Advances in molecular systematics have allowed for new insights and higher taxonomic resolution, leading to a significant increase in the discovery of cryptic species within previously defined taxa across all Animalia. Nudibranchs in the genus *Glossodoris* exhibit a wide range of color patterns from aposematic coloration to camouflage, and are a model group for understanding cryptic diversity. In this study, 80 individuals comprising 38 species in 12 genera were used to build the most robust phylogenetic tree of *Glossodoris* and related genera using mitochondrial genes cytochrome c oxidase subunit I (COI) and 16S, and nuclear 28S. Maximum likelihood and Bayesian Inference statistical analyses identified four cryptic species within *Glossodoris*, including three nested within *Glossodoris cincta* alone. The discovery of cryptic species within *Glossodoris* accentuates the likelihood that more species are hidden within previously defined taxa. Nudibranch biodiversity is likely much greater than currently estimated, and the discovery of cryptic species has profound implications for the evolution of color pattern and chemical defense sequestration as well as biomedical prospecting and conservation of biodiversity.

118-7 MATTHEWS, PG; University of British Columbia; pmatthews@zoology.ubc.ca

Gas exchange in developmentally amphibious insects

The insects have successfully reinvaded the aquatic environment numerous times, adapting their air-filled respiratory systems to function underwater. The evolution of tracheal gills enabled insects to exploit the aquatic environment as water-breathing animals, but they all must still transform back into air-breathers when they metamorphose into flying adults. Dragonflies are developmentally amphibious insects that spend the majority of their life as aquatic nymphs, breathing water using a rectal gill, and a few months as adults, breathing air using an open tracheal system. We have begun to investigate the respiratory physiology of the water-breathing nymphs, and the physiological changes that occur during their transition to life in air. Measurements on the total CO₂ content of nymph and adult haemolymph reveal that nymphs have a higher total CO₂ compared to water-breathing vertebrates, but it is not significantly different to that of an air breathing adult dragonfly. The significance of these findings will be discussed in relation to the efficiency of the rectal gill as a gas exchange organ.

24-3 MATTSON, E.E.*; MARSHALL, C.D.; Texas A&M University at Galveston; *mattson@tamug.edu*
Innervational and Microanatomical Support for Functional Compartmentalization within the Mystacial Vibrissal Sensory System of Pinnipeds

Vibrissae, or whiskers, are largest among pinnipeds and essential for prey capture. Behavioral data from pinniped and rodent vibrissal studies indicate that functional differences exist between medial and lateral vibrissae. However, comparative data are lacking and current pinniped studies have only focused on large, lateral vibrissae. Consequently, we investigated the medial-to-lateral innervation and microanatomy of harp seal (*Pagophilus groenlandicus*) vibrissal Follicle-Sinus Complexes (F-SCs). Harp seals possessed 88-105 F-SCs, which exhibited a tripartite organization. Hair shafts were circular medially but became more elliptical laterally. Medial F-SCs had symmetrical dermal capsule thicknesses and distributions of major branches of the deep vibrissal nerve, but these symmetries diminished in lateral F-SCs. Medial-to-lateral axon counts ranged from 550 ± 97 to $1,632 \pm 173$ axons/F-SC, respectively, indicating a total of 117,235 axons/snout. Lateral F-SCs alone possessed a mean of $1,533 \pm 192$ axons, similar to counts in other pinniped vibrissal innervation studies. Conventional studies that only examine lateral F-SCs likely overestimate total innervation by ~20%. Moreover, we counted axons with and without silver staining and determined that unstained sections yielded more accurate and ~10% greater axon counts. Consequently, conventional studies likely only overestimate innervation by ~10%. The relationship between axon count and F-SC surface area was non-linear, presumably from mechanoreceptors reaching carrying capacity, and axon densities were consistent across the snout. Our data agree well with behavioral research on pinnipeds and rodents that documents functional compartmentalization between micro-(medial) and macrovibrissae (lateral).

98-3 MAY, M.A.*; RAWSON, P.D.; University of Maine; *melissa.may@maine.edu*

Differential expression of calmodulin and calmodulin-like genes in larval and juvenile blue mussels exposed to osmotic stress
 Calmodulin (calcium-modulated protein, or CaM) is an important cellular signaling molecule and is integral in modulating stress responses. In some marine invertebrates, calmodulin gene expression is upregulated during larval development, growth, and environmental stress; the latter suggests that changes in CaM transcription are part of the cellular stress response. Our research investigates the genetic and physiological basis of low salinity tolerance in larval and juvenile blue mussels (*Mytilus edulis*). We have found evidence for gene-specific patterns of expression for CaM and other calmodulin-like (CaM-like) genes over 48 hours of hypoosmotic stress. As expected, CaM is upregulated in the gills of stressed, juvenile mussels, however, its expression is downregulated in mussel larvae following low salinity exposure. The CaM-like genes also show differential patterns of expression during development, suggesting that larval osmotic stress responses do not mimic those of their post-metamorphic counterparts. To further explore the spatial and temporal expression of these genes during osmotic stress, we will present results from fluorescent in situ hybridization (FISH) experiments and comparisons of transcriptional patterns in the tissues of juvenile mussels.

70-1 MATZ, MV; Univ. of Texas at Austin; *matz@utexas.edu*
Extent and evolutionary significance of heritable variation in reef-building corals.

Corals are excellent subjects for quantitative genetics: one can fragment the same colony into clonal replicates and expose them to various treatments, and generate thousands of offspring according to a desired crossing scheme to measure parental effects and even map quantitative trait loci. Our recent experiments along these lines brought several important insights. Individual colonies of the same coral species can differ by the expression of more than 25% of the genome, with up-regulated expression of hundreds of genes directly inherited by the offspring from their parents. Maternal effects vary but can influence thousands of genes, and are particularly prominent for energy-related traits such as oxidative metabolism. Other fitness-related physiological traits are also highly heritable: heat tolerance of coral larvae can vary up to ten-fold depending on the parents, and there is considerable variation in larval settlement, growth rate and disease susceptibility among coral genotypes. This variation represents raw material for natural selection, potentially capable of fueling both local adaptation and evolution in response to climate change.

78-2 MAYERL, C.J.*; BRAINERD, E.L.; BLOB, R.W.;

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XROMM visualization of pelvic girdle mobility in turtles: implications for locomotion in aquatic and terrestrial environments
 Many tetrapods can increase the length of hind limb strides by bending the body axis, and/or by rotating the pelvis in conjunction with each step. In turtles, however, the vertebrae are fused to the shell, immobilizing the body axis. To what extent can pelvic movements contribute to stride length in turtles? The two extant lineages of turtles differ in pelvic structure: pleurodires show a derived fusion of the pelvis to the shell, whereas cryptodires have unfused contacts between the pelvis and shell that may retain the capacity for movement. However, with the pelvis surrounded by the bony shell in turtles, visualization and comparison of such movements across taxa have been impeded. We used marker based X-Ray Reconstruction of Moving Morphology (XROMM) to test whether the differences in pelvic girdle morphology between pleurodires and cryptodires are associated with differences in girdle mobility and contributions to locomotor strides. We filmed representative cryptodire (*Pseudemys concinna*) and pleurodire (*Emydura subglobosa*) species while walking and swimming. We found that the pleurodire pelvis did not move in either environment, but the cryptodire pelvis yawed, pitched and rolled in both environments, with more movement during walking than swimming. These rotations increased cryptodire femoral excursion by up to 20 degrees. In addition, the ilio-sacral joint in *P. concinna* translated antero-posteriorly in conjunction with pelvic rotation. These differences in pelvic mobility may contribute to observed differences in aquatic locomotor stability between these lineages, with the derived reduction in pelvic mobility in pleurodires facilitating more stable swimming.

132-2 MAZOUCHOVA, N.*; HSIEH, S.T.; Temple University, Philadelphia; tue61612@temple.edu

Semi-aquatic turtles use multiple gaits when moving under water
Water and land transitions often require gait changes specific to the environment. For example, on land, animals walk by supporting their body weight with their limbs, but when underwater, their body weight is at least partially supported by the surrounding fluid. Studies have shown that semi-aquatic animals use different gaits when under water, such as swimming or bottom walking. However, little is known about how size can affect gait choice while fully submerged. To address this gap in knowledge, we filmed fourteen semi-aquatic red-eared slider turtles (*Trachemys scripta elegans*), divided into small, medium and large size classes (mass: 6.2 - 106.8 g, carapace size: 3.0 - 9.8 cm), while moving under water. A principal components analysis revealed that 80.1% of variation in gait patterns was explained by two principal components (PC), revealing distinct clustering of three gait patterns: bottom walking, swimming and hind limb pushing (hind limbs are walking, while the front limbs are swimming). Velocity (Pearson $R^2=0.68$) and stride length (Pearson $R^2=0.70$) loaded high on PC1, whereas stride frequency (Pearson $R^2=0.74$) loaded high on PC2. We used relative limb phases to characterize the onset of the stance for each leg relative to a reference leg. In synchronous gaits, diagonal limb pairs move together, resulting in a phase of zero - such as what is observed during bottom walking and swimming. This differs for hind limb pushing, where the relative limb phasing of diagonal limbs is shifted by 17 +/- 6%. However, we only observed hind limb pushing for small and medium sized turtles - large turtles exclusively swam or bottom walked. We conclude that different size turtles use three distinct locomotor modes (or gaits) to move effectively under water, with hind limb pushing reserved for smaller size classes.

68-4 MCCLEARY, RJR*; SRIDHARAN, S; DUNSTAN, NL; MIRTSCHEIN, PJ; ALEWOOD, PF; KINI, RM; Utah State University, National University of Singapore, Venom Supplies Pty Ltd, Venom Supplies Pty Ltd, University of Queensland; 19venom84@gmail.com

Proteomic comparisons of long- and short-term captive eastern brown snakes (*Pseudonaja textilis*)

Snake venoms are highly variable, and their variation and rapid evolution possibly driven by external factors such as environment and diet make them fascinating phenotypic characters with human health implications. Because anti-venom is generally produced using venom from captive animals, understanding the effects of captivity on venom composition is important. We evaluated venom proteins from long-term (LT) captive and recently wild-caught (RC) eastern brown snakes, *Pseudonaja textilis*, utilizing protein gel electrophoresis, HPLC-MS, and shotgun proteomics by HPLC-tandem MS. We evaluated twelve (6 LT and 6 RC) individual venoms of snakes from South Australia. We identified proteins belonging to the three-finger toxin, cysteine-rich secretory protein, factor V-like and factor X-like subunits of the group C prothrombin activator, Kunitz-type serine protease inhibitor, phospholipases A₂, and snake venom C-type lectin-like protein families, among others. Although crude venom HPLC analysis showed long-term captives to have higher amounts of some small molecular weight proteins, presence/absence patterns showed no correlation with time in captivity. Shotgun proteomic analyses indicate similar toxin family types across individuals, but with variation in isoforms present. These results indicate that captivity may have limited to no effect on venom composition, that venom diversity is high even within the same species, and that individuals from the same geographic region tend to have more similar venoms.

25-3 MCBRAYER, LD*; KAUNERT, MD; PARKER, SE; Georgia Southern Univ.; lancemcbrayer@georgiasouthern.edu

Population ecology of the Florida Scrub Lizard in scrub and longleaf pine habitats

Florida Scrub is a unique, xeric habitat type found only in central and southern peninsular Florida. This habitat harbors substantial biodiversity and numerous endemics, yet has experienced substantial loss and degradation in the last 150 years. Virtually all of the remaining Florida Scrub exists in a few large public or privately held tracts (e.g. Archbold Biological Station, Avon Park Air Force Range, Ocala National Forest, etc.) The Florida Scrub Lizard (*Sceloporus woodi*) is a small, rare, endemic lizard under conservation concern. Scrub Lizards are generally common in the Ocala National Forest, yet sizable populations have become increasingly scarce in scrub stands since 2009. In contrast, Scrub Lizard populations in long leaf pine stands have remained healthy in ONF. Here, we examine differences in stand characteristics, population density, and lizard behavior (flight distance, distance to refuge) among populations of longleaf and scrub. We show that population densities differ between scrub and longleaf stands when key management criteria alone are used for site selection. Furthermore, the natural surface roads found throughout the forest are shown to be critical 'habitats' that Scrub Lizards use extensively and hence may allow for their persistence across the forest. Yet, we also show that when management criteria are coupled with management history, scrub and longleaf sites do not differ in density. Our results highlight the importance of history, habitat connectivity, and stand management over both time and space. The combination of these variables is crucial for the persistence of this rare species in its namesake habitat, the Florida Scrub.

20-5 MCCORD, CL*; WESTNEAT, MW; University of Chicago; charlene.l.mccord@gmail.com

Phylogenetics and jaw biomechanics of balistid fishes: Evolutionary patterns of functional change in a unique feeding mechanism

Aquatic organisms have evolved a spectacular array of mechanisms for generating suction, accelerating the jaws at high speed, and applying force for prey capture. The diversity of jaw closing muscles in fishes and their subdivision into multiple actuators for powering feeding may play a significant role in key evolutionary changes in feeding mechanics. Here, we analyze the evolutionary functional morphology of the feeding apparatus of 27 triggerfish species and use these data to explore the anatomical basis of balistid biomechanical diversity. A computational model of triggerfish jaws was developed and used to explore the biomechanical consequences of the unique triggerfish "clamshell bucket" jaw mechanism and identify the functional role of each muscle in the subdivided jaw adductor complex. Biomechanical variables of jaw performance were combined with analyses of trophic ecology and morphological observations, and then optimized onto a phylogenetic tree to identify patterns of structural and functional change in triggerfish feeding biology through evolution. This work shows that the evolution of a novel sliding jaw linkage and multiple jaw adductor muscle subdivisions in the triggerfish lineage have directly influenced several key aspects of bite performance. We also find that each of the six adductor mandibulae muscles are optimized for different functions and therefore differentially contribute to bite force and jaw rotation. In this way, triggerfishes are biomechanically capable of producing high bite force as well as high jaw closing velocity, and have a method of coping with the functional trade-off of force versus velocity. This work was supported by NSF IGERT grant DGE-0903637, a 2011 NSF EAPS grant to C. McCord, and NSF grant DEB 1112763 to M. Westneat.

15-6 MCCORMICK, G.L.*; ROBBINS, T.R.; CAVIGELLI, S.A.;
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Developmental and cross-generational history with stress affect the physiological stress response and immune function in lizards

Exposure to stress during an organism's development or in previous generations can have important lasting effects on physiology and immune function. Prolonged exposure to stress-relevant hormones (e.g. corticosterone, CORT) can have fitness costs such as suppressed immune function. We may thus expect that the physiological stress response, and its effect on other parameters, may be altered to reduce associated costs in high stress populations. We investigated the effects of developmental stress and cross-generational exposure to stress on the physiological stress response and immune function. We collected gravid lizards (*Sceloporus undulatus*) from populations with long histories of invasion by predatory fire ants (*Solenopsis invicta*) and from uninvaded sites. Resulting hatchlings were exposed weekly to stress (fire ant attack or topical CORT) until maturity, and blood samples were obtained several months later. Developmental stress did not directly affect baseline or handling-induced levels of CORT. Offspring from high stress (fire ant invaded) populations, however, had a more robust CORT response to handling than did those from low stress sites. Among lizards treated with CORT during development, offspring from high-stress populations had higher hemagglutination scores (more robust immune response) than did those from low stress sites. No differences in bacterial killing ability were observed. These results suggest that selection may favor elevated stress responses at these high-stress sites and up-regulated immune function in response to developmental stress. At high-stress sites where immune function is frequently activated (e.g. by fire ant attacks), it may be adaptive to up-regulate immune function in response to developmental stress.

51-3 MCCUE, MD*; BOARDMAN, L; KLEYNHANS, E;
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High temperature reduces the energy and duration required for blood meal digestion, but compromises starvation resistance in tsetse flies

The increased metabolism during digestion, known as specific dynamic action (SDA), has been measured in hundreds of animal species, but only a few insects. Newly emerged adult tsetse flies are voracious feeders consuming a blood meal equal to half of their own body mass every other day. We measured the SDA at different ambient temperatures (25, 30, 35°C) and found that it decreased in duration from ~48h at 25°C to ~24h at 35°C - a response seen in other animals. However, unlike most animals the SDA response was also significantly smaller at the higher temperatures suggesting that warmer temperatures speed digestion and minimize costs. We also measured the $\delta^{13}\text{C}$ in the breath of flies fed blood meals labeled with ^{13}C -leucine and ^{13}C -glucose to measure the rates at which they oxidized these dietary nutrients. The ^{13}C in their breath of both groups peaked within the first couple of hours after feeding and then rapidly declined. As the flies became postabsorptive the oxidation of the leucine tracer approached zero and the flies at 35°C and 25°C succumbed to starvation by 36h and 96h, respectively. The increased starvation tolerance at 25°C was correlated with an increase in breath $\delta^{13}\text{C}$ in the glucose tracer flies presumably as they oxidized newly synthesized lipids. We are now testing whether the flies actually prefer to digest meals at warm temperatures and then retreat to cool temperatures while fasting if given a range of temperatures to choose in a behavioral thermal gradient.

83-3 MCCORMICK, S.D.*; REGISH, A.M.; BERNIER, N.J.;
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Relaxed selection, hormones and life history traits: Differential stimulation of the Hypothalamic-Pituitary-Interrenal axis in anadromous and landlocked salmon.

Cortisol plays a critical role in controlling ion regulation in fish, including preparatory adaptations for seawater entry (smolting) that occur just prior to downstream migration and ocean entry of juvenile anadromous salmon. Landlocked Atlantic salmon migrate from streams to lakes, resulting in relaxed selection on traits associated with salinity tolerance but not on other life history changes such as downstream migration and imprinting. In this study anadromous and landlocked strains of Atlantic salmon were reared under identical conditions and examined for differences in seawater performance and its underlying endocrine control during smolt development. Salinity tolerance, survival and growth in the first two weeks of seawater exposure were greater in the anadromous strain. Gill Na^+/K^+ -ATPase (NKA) activity and the abundance of the seawater isoform of gill NKA increased in spring in both strains but were greater in the anadromous strain. Plasma cortisol levels increased in spring in both strains but were 5-fold higher in the anadromous strain in April. Pituitary POMCA1, A2 and B mRNA levels increased in spring but were only slightly different between strains. Hypothalamic mRNA levels of Corticotrophin Releasing Factor (CRF) and Urotensin I (UI) increased in spring and were higher in the anadromous strain. CRF and UI mRNA levels in the preoptic area changed seasonally but were not correlated with circulating cortisol in either strain. The results provide evidence that hypothalamic CRF and UI are involved in increased plasma cortisol during smolting and that the HPI axis has been altered by relaxed selection in landlocked salmon

79-2 MCCULLOCH, KJ*; OSORIO, D; BRISCOE, AD; Univ. of
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Photoreceptor Cell Sensitivity and Sexual Dimorphism in the Compound Eye of the Butterfly Heliconius erato

Butterflies are colorful insects with diverse color visual systems. The diversity found in this group relies primarily on opsin proteins, which together with the chromophore 11-cis 3-hydroxy retinal form the visual pigments, and are responsible for converting light into a bioelectric signal. Three opsin genes are found in most insects, and except for *Drosophila*, duplications of UV opsin genes are relatively rare. *Heliconius* butterflies have a UV opsin duplication that arose in the ancestor of the genus just before the genus underwent an adaptive radiation. However it is unclear whether the two UV opsin proteins, UVRh1 and UVRh2, are expressed in different R1 and R2 photoreceptors or co-expressed in the adult compound eye. We aimed to characterize the retinal mosaic of adult *H. erato* using antibodies against the ultraviolet, blue and long wavelength opsins and to identify individual photoreceptor cell spectral sensitivities with intracellular recordings. We unexpectedly discovered that the *H. erato* compound eye is sexually dimorphic with respect to opsin protein expression. Males do not express UVRh1 while females express both UVRh1 and UVRh2 in tightly regulated cell combinations. This sex difference extends to the types and proportions of photoreceptor cells and ommatidia in the compound eye. Electrophysiological recordings confirm that the female has three spectrally distinct short-wavelength photoreceptor cells while the male has two types. Both males and females also have two types of LW photoreceptor cell, a green receptor and a red-shifted LW sensitive photoreceptor cell, which is responsible for red color discrimination previously found in this species. This is the first evidence of sexual dimorphism with respect to UV expression in the *Heliconius* eye, and the first evidence of five distinct cell types in females, with four types in males.

9-4 MCCURRY, M.R.*; EVANS, A.R.; FITZGERALD, M.G.; SHAW, M.; MCHENRY, C.R.; The National Museum of Natural History, Smithsonian Institution, Monash University, Museum Victoria, The University of Newcastle ; *m.r.mccurry1@gmail.com*
The ecomorphology and biomechanics of crocodylians and odontocetes

Extant crocodylians and odontocetes exhibit a similar range of cranial morphology, including, rostra that are similarly elongate to robust. Why have these two groups, which have been phylogenetically separate for 250 million years, diversified in such a similar way within the aquatic environment? Here we present the results from a quantitative analysis of morphology, performance, and feeding ecology within extant crocodylians and odontocetes. Our analysis sheds light on the constructional morphology of these taxa and offers an explanation for this ecomorphological convergence. Furthermore this study provides a robust foundation for predicting ecological traits in extinct marine reptiles such as ichthyosaurs, mosasaurs and sauropterygians. Raw data were collected in the form of CT and 3D laser scans from a wide range of extant taxa for use in morphometric and biomechanical analyses. We used 1) 3D geometric morphometrics to assess variation in morphology, 2) finite element analysis to quantify the ability of the skulls to resist loading, and 3) computational fluid dynamics to quantify the drag induced by the head of three species of crocodylians during sweep feeding. We also compiled dietary data from relevant literature to produce quantitative numerical data on prey type and size. Our results show that cranial morphology is highly associated with biomechanical capabilities and feeding niche. Elongate and dorso-ventrally compressed taxa have evolved for hydrodynamic efficiency and feed on lower minimum prey sizes. In contrast robust morphotypes have evolved to increase skull strength in some taxa as well as to increase suction ability in others.

59-2 MCENTIRE, K.D.; University of Georgia; *mcentire@uga.edu*
Estimating Salamander Activity Time using Individual Based Biophysical Models

Climate interacts with an organism's physiology to influence its distribution and fitness. For animals with well understood physiologies, this interaction allows for prediction of distribution or fitness of an organism under certain climatic conditions through biophysical models. However, these models can be limited by not including geographic variation in physiologies and differences in behavior. Individual or Agent Based Models (IBM/ABM) combined with biophysical models allow for incorporation of geographic, individual, and behavioral differences. The high variance in elevation in Southern Appalachia has created broad moisture gradients throughout the landscape. Within these gradients exists a patchy distribution of midstory canopy plants. Midstory canopy plants are known to buffer climatic variation, however the influence of the midstory canopy has not been studied for many fauna. Salamander activity is governed by water loss and their well-studied physiologies make them ideal test subjects to study midstory canopy effects on fitness and survival along a moisture gradient. I report on a preliminary biophysically based IBM for *Plethodon shermani*. This model suggests a strong influence of the presence of a midstory canopy on salamander fitness, especially for juveniles. Using an IBM framework allows for future inclusion of behavioral, geographic, and individual variation.

43-4 MCELROY, EJ*; MCBRAYER, LD; CLEMENTE, C; BERGMANN, PJ; College of Charleston, Georgia Southern University, University of the Sunshine Coast, Clark University; *mcelroye@cofc.edu*

Does evolutionary convergence of ecomorphology result in convergence of performance capacity? A test using Australian and North American lizards

Convergence of morphology and ecology is a well-described evolutionary phenomenon. Whole-animal performance capacity is a key linkage between morphology and ecology; thus one might expect convergence in morphology and ecology to also be linked to convergence in performance capacity. Previous work has demonstrated evolutionary convergence of morphology and ecology between Australian agamid lizards and North American iguanid lizards. Furthermore, several species pairs within these lineages also exhibit convergence in ecology and morphology. Therefore, we hypothesized that locomotor performance and function has converged in these groups. To test this hypothesis, we measured locomotor morphology and performance in 12 Australian agamid species and 9 North American iguanid species. We tested for convergence in function by estimating partial regression coefficients between morphology and performance using phylogenetically generalized least squares. We then assembled those coefficients into an F-matrix for each clade and tested the relationship between F-matrices. Next, we generated a performance space for all species to test clade-wide convergence. Finally, we used the Euclidean distance between species pairs in the performance space coupled with evolutionary simulations to test for transcontinental convergence of performance for each species pair. We found that Australian agamids and North American iguanids occupy similar regions of performance space and that several species pairs have converged in locomotor performance. However, F-matrices were not related suggesting that the functional link between morphology and performance has evolved differently in these lizard clades.

43-6 MCGEE, MD*; FAIRCLOTH, BC; BORSTEIN, SR; ZHENG, J; HULSEY, CD; WAINWRIGHT, PC; ALFARO, ME; Institute of Ecology and Evolution, University of Bern, Department of Biological Sciences and Museum of Natural Science, Louisiana State University, Department of Ecology & Evolutionary Biology, University of Tennessee, Department of Ecology and Evolutionary Biology, University of California, Los Angeles, Department of Biology, University of Konstanz, Department of Evolution and Ecology, University of California, Davis; *mcgee.matthew@gmail.com*

Replicated divergence in cichlid radiations mirrors a major vertebrate innovation

Decoupling of the upper jaw bones - jaw kinesis - is a distinctive feature of the ray-finned fishes, but it is not clear how the innovation is related to the extraordinary diversity of feeding behaviors and feeding ecology in this group. We address this issue in a lineage of ray-finned fishes that is well-known for its ecological and functional diversity - African rift lake cichlids. We sequenced ultraconserved elements to generate a phylogenomic tree of the Lake Tanganyika and Lake Malawi cichlid radiations. We filmed a diverse array of over fifty cichlid species capturing live prey and quantified the extent of jaw kinesis in the premaxillary and maxillary bones. Our combination of phylogenomic and kinematic data reveals a strong association between biting modes of feeding and reduced jaw kinesis, suggesting that the contrasting demands of biting and suction feeding have strongly influenced cranial evolution in both cichlid radiations.

45-7 MCGOWAN, C.P.; University of Idaho;
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Muscle Dynamics During Level and Incline Hopping

Bouncing gaits such as running, trotting and hopping are believed to be efficient because they enable animals to utilize elastic energy storage and recovery, much like a bouncing ball. However not all bipedal hoppers have compliant tendons that can serve as springs. Although considerably smaller, kangaroo rats use a bipedal hopping gait that is very similar to that of kangaroos and wallabies. Yet their ankle extensor tendons are relatively thick and stretch very little during hopping. Inverse dynamics analyses suggest that while at the joint level kangaroo rats maintain spring-like behavior, this does not reflect the mechanical output of the underlying muscle-tendon units. Rather, dynamic coupling of the joints via biarticular muscles enables muscles to behave as pure motors or dampers. In this study, we use in vivo measurements of muscle dynamics from the lateral gastrocnemius (LG) to test the hypothesis that the ankle extensor muscles of kangaroo rats behave as motors, actively shortening during stance, across multiple grades. Data were collected while animals hopped on a treadmill inclined to 0, 10 and 20 degrees. Preliminary results of this study support our hypotheses. The LG undergoes active net shortening at all grades and the magnitude of net shortening increases with increasing grade. While there were no direct measurements of muscle force, these data suggest that the LG generates net positive mechanical work during hopping and is a primary contributor to generating the positive work necessary to raise the center of mass when hopping up an incline.

102-3 MCHORSE, B.K.*; PIERCE, S.E.; BIEWENER, A.A.;
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Evolutionary digit reduction and beam mechanics in fossil and extant horses

Though extant horses consist of a single genus that is large, cursorial, and grazing, their fossil record shows considerable diversity and repeated evolution in these traits. Digit reduction is a key feature of surviving equids and has been hypothesized to be a result of increased body mass, emphasis on straight-line locomotion, and locomotor economy linked to the spread of grasslands. To investigate potential mechanical drivers of digit reduction, we explored evolutionary changes in the beam mechanics of horse metacarpals. To assess internal geometry along the length of each bone, we used micro-CT scans of fossil horse and extant tapir metacarpal III. Taxa included *Hyracotherium* (tetradactyl), *Parahippus* (tridactyl), *Equus* (monodactyl), and extant tapir (tetradactyl). Stress in compression and AP and ML bending were analyzed assuming body-weight load, adjusted for the estimated percentage supported by metacarpal III. For most loading conditions, *Equus* experienced lower stresses than tetra- or tridactyl species. When assuming that the central metacarpal primarily carries the load, *Equus* experienced as little as 50% of the stress of others. Stress was more similar when loads were distributed more evenly among all digits in multi-toed species, but *Equus* metacarpals still often outperformed earlier horses. The relative gracility of tridactyl horses (e.g., *Parahippus*) or increased athletic performance in *Equus* may explain these results. Future work will incorporate anatomical and gait data from extant tapir and horse, providing more accurate values for moment arms, forces, and pressure distribution among toes. Data from additional fossil species, including those with large body size that retained side digits, will also shed more light on the biomechanical implications of evolutionary digit reduction in horses.

S12-7 MCGRAW, K.J.*; WEAVER, M; HUTTON, P;
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Urban impacts on avian life-history variation: integrative approaches to studying sex, stress, sleep, signaling, and sickness in the city

Rapid urbanization subjects wildlife to unique environmental pressures, some of which can be harmful and others beneficial. Several different life-history adaptations and acclimations to urban conditions have been revealed in a variety of animals, but few investigations in this area have considered a broad suite of fitness-related traits simultaneously. Here we summarize findings from a long-term investigation of behavioral and ecological responses to urbanization in a native desert songbird (the house finch, *Haemorrhous mexicanus*). City finches are consistently less colorful and more heavily parasitized than rural birds; interestingly this effect is stronger in female finches than in males. Urban finches show indications of reduced behavioral stress (e.g. responsiveness to an approaching human), but also can be more physiologically stressed (e.g. elevated breath rate when in a human hand). Human disturbance also has a weaker effect on problem solving ability (in a foraging context) and sleep patterns of city finches. Taken together, the composite set of urban pressures appear to more negatively impact house finches, yet we see their populations persist and even expand in some North American cities. We discuss these patterns in light of potential plasticity and naturally and sexually selected adaptations in this common species.

I-2 MCINROE, B*; GONG, C; KAWANO, S; ASTLEY, H; BLOB, RW; CHOSSET, H; GOLDMAN, DI; UC Berkeley, CMU, NIMBIOS, Georgia Tech, Clemson University;
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Robotic and mathematical modeling reveals principles of appendage coordination in terrestrial locomotion

In the evolutionary transition from an aquatic to a terrestrial environment, early stem tetrapods were faced with novel challenges involving locomotion on complex, flowable substrates (e.g. sand and mud). Our previous studies demonstrated that locomotion on such substrates is sensitive to both limb morphology and kinematics. Although reconstructions of early vertebrate skeletal morphologies exist, general principles of appendage control remain challenging to extract. Furthermore, the complex substrates on which these organisms moved lack constituent equations, limiting the efficacy of computational models. To elucidate limb control strategies that may have facilitated the invasion of land, we employed robotic modeling coupled with a computational model based on geometric mechanics. Robotic experiments reveal that an active tail is a crucial feature for robust locomotion on granular terrain, enabling effective locomotion even with poor foot placement and limited ability to elevate the body. Implementing this morphology in a simplified geometric mechanics model, we are able to replicate the results of our robotic experiments by varying a single parameter (body drag-thrust ratio), showing that moving limbs and tail in phase is most effective and suggesting a robust biological template. By varying limb trajectories and contact times, we constructed gaits for which tail use is harmful, neutral, and beneficial, suggesting that limb-tail coordination is a nontrivial aspect of effective locomotion. Our findings demonstrate that terrestrial locomotion on granular media provides an excellent model system to reveal general principles of limb-tail control and coordination.

9-1 MCLAUGHLIN, W.N.F.*; DAVIS, E.B.; HOPKINS, S.S.B.;
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Total occlusal area rather than number of teeth as a constrained dental feature in *Odobenus rosmarus*

In contrast to the high degree of complexity exhibited in most terrestrial mammals teeth, marine mammals have undergone a simplification. Most toothed whales and pinnipeds have simple conical teeth suitable for grasping and holding prey. Yet how the number and placement of these teeth evolved and varies in many species is problematic. From the early 1900's, a variety of studies ranging from the subspecies- to subpopulation-level of walrus have attempted to discern a dental formula for juvenile and adult members of *Odobenus rosmarus*. While varying conclusions were reached, each study notes between 10-25% of individuals that do not conform to observed patterns for number or placement of teeth. Determining the homology of teeth in Odobenidae is complicated by several factors. Previous work on fetal to juvenile individuals records some individuals with three sets of teeth over life history (milk, deciduous, adult) while others are born toothless and only develop the later two sets. Furthermore, juvenile dentition is observed forming both in alveolar and gingival settings, with some alveolar teeth forming in sockets later containing adult teeth while others are reabsorbed. We suggest, rather than a standard number of teeth present in a breeding age individual, there is a standard total occlusal area (TOA) relative to skull proportions of each individual. To measure occlusal area skulls and mandibles are photographed and measured using ImageJ. Preliminary data suggests that TOA of upper teeth normalized against palate length, and total TOA of lower teeth normalized to the length of the right mandible, is more consistent across the species than tooth number. Furthermore, males thus far have a lower number of individuals deviating from previously published standard dentition than females.

5-4 MCQUEEN, E. W.*; GLASSFORD, W. J.; REBEIZ, M;
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Using genetically-induced variation in genitalia to examine functional effects of trait variation.

Genitalia are some of the most rapidly evolving structures in the animal kingdom, and sexual selection is thought to be the primary driver of genital diversity. One promising approach to the study of genital evolution is to explore whether and how selection acts on standing intraspecific variation. This includes female structures, which are traditionally underrepresented in the literature, as well as male structures. Using *Drosophila melanogaster* as a model system, I explore how variation in a male genital structure, the posterior lobe, and a recently discovered female structure, the oviscapt pouch, affect copulatory behavior. Morphometric analyses of isogenic lines suggest that genetic variation in structure size and shape is present in natural populations. Field-sampling efforts further confirm a substantial amount of phenotypic variation is present in most wild populations. Using variants of a gene enhancer region that controls both posterior lobe and oviscapt pouch development, I generated fly lines with measurable differences in lobe and pouch dimensions. This fine-scale manipulation of male and female traits has minimal additional pleiotropic consequences. I found sex-dependent effects of morphological changes on trait function during courtship and copulation. These data represent a fundamental link between specific gene enhancers and genital structure function, and are especially novel in their application to female genitalia. This connection illuminates the interplay between small molecular changes and whole-organism performance.

121-2 MCNABB, N.*; MIYAGAWA, S.; IGUCHI, T.;
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Investigating Estrogenicity of Oil Dispersant COREXIT® EC9500A in the American Alligator and Diamondback Terrapin

Estrogens play critical roles in differentiation and growth of the reproductive system via the estrogen receptor (ESR) as well as temperature-dependent sex determination (TSD) in some turtles and all crocodylians. In TSD, egg-incubation temperatures determine sex of the embryo during a thermosensitive period (TSP). An exposure to exogenous estrogen during TSP leads to sex reversal or skewed sex ratios by inducing ovarian development at a male-producing temperature. Due to this sensitivity to estrogen, reptiles that exhibit TSD, including the American alligator (*Alligator mississippiensis*) and diamondback terrapin (*Malaclemys terrapin*), can be used as sentinel species to investigate chronic exposure to estrogenic environmental contaminants. During the 2010 Deepwater Horizon oil spill in the Gulf of Mexico, COREXIT® EC9500A (COREXIT) was applied to the surface water and at the wellhead to disperse the oil. Using luciferase transactivation assays, we found that COREXIT demonstrates estrogenic activity by inducing transcription via alligator estrogen receptor 1 (ESR1) in vitro. Thus, the estrogenic potential of COREXIT needs to be investigated further in both *A. mississippiensis* and *M. terrapin*. ESR1 and ESR2 were cloned and sequenced from diamondback terrapins. Both terrapin ESRs were highly homologous to painted turtle ESRs and will be characterized using transactivation assays with 17 -estradiol, bisphenol A (BPA), and COREXIT. These results will help to understand the potential effects of COREXIT exposure on the reproductive health of coastal aquatic reptiles.

97-16 MEHTA, R/S*; DILUZIO, A/R; WILLIAMS, R; SINERVO,
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Springing to Safety: Aerial acrobatics of the California slender salamander, *Batrachoseps attenuatus*

Salamanders are common prey items for many species of vertebrates. Not surprising, salamanders have an arsenal of behavioral strategies with which to elude their predators. One of the more impressive and energetically expensive antipredator strategies reported is tail autotomy. In the California slender salamander, *Batrachoseps attenuatus* (Eschscholtz, 1833), the tail is nearly twice as long as the trunk. A previous study on *B. attenuatus* revealed that tail autotomy inhibits reproduction in some individuals and limits the reproductive output for individuals that do reproduce when their tails are partially regenerated. As Maiorana pointed out in 1977, loss of a feature that has other critical demands such as fat storage and locomotion is perplexing. Inspired by the reported antipredator behaviors (i.e. the "watch-spring") for the recently described *B. robustus* and other *Batrachoseps* species, we used high-speed video to examine antipredator strategies for 7 individuals of *B. attenuatus*. A 9-inch metal spoonula was used to induce antipredator behavior by tapping an individual salamander on the tail. We recorded these small, gracile, and cryptic-looking plethodons performing impressive aerial acrobatics to move away from the stimulus. One of these behaviors was what we interpret as the "watch-spring" behavior where an individual coils its body and then uses its axial skeleton to launch its body up to 6 cm off the substrate. These dynamic behaviors suggest that as a species, *B. attenuatus* has a diverse and presumably effective behavioral repertoire for evading predators and that tail autotomy may be a last resort.

106-5 MEKDARA, PJ*; COUGHLIN, LL; SCHWALBE, MA; TYTELL, ED; Tufts University; prasong.mekdara@tufts.edu
The effects of lateral line ablation and regeneration on schooling in giant danios

The maneuvers in fish schools reflect remarkable coordination. Fish within schools swim while matching speed and maintaining a specific distance from their neighbors. Fish schools can also perform complex maneuvers such as obstacle avoidance, which require quick responses to changes in velocity and direction. The mechanisms underlying this uniform schooling structure are not well understood. Fish use both vision and the flow-sensing lateral line system to maintain the structure of a school, but we do not know very much about the role of the lateral line in schooling. Previous studies have shown that one fish with a partially ablated lateral line can still school in a group of normal fish, but that it maintains a different position relative to its neighbors than the normal fish do. These studies only show the effects of a partial ablation of the lateral line and do not clearly show the effects when the entire lateral line is ablated. To examine the role of the lateral line in fish schools, we completely ablated the lateral line of individuals using gentamycin and observed their behavior as they reintegrated into a school of normal untreated fish. Lateral line hair cells regenerate from this treatment in approximately one week. As the treated fish swims within a school of normal fish, we observed the overall schooling structure and quantified the behaviors by calculating the nearest neighbor distance, bearing, and elevation between each pair of closest neighboring fish. We found that the treated fish was able to maintain a normal position within the school immediately after lateral line ablation, but the structure of the school changed over time as the hair cells regenerated. This result suggests that the fish may take time to relearn how to process the lateral line signal from the newly regenerated hair cells.

64-1 MENSINGER, AF; MENSINGER, Allen; University of Minnesota Duluth; amensing@d.umn.edu
Grounding the flying carp: Applied neuroethology

The silver and bighead carp are invasive fish species that have spread throughout the Mississippi River drainage and are threatening the Laurentian Great Lakes. These filter feeding fishes have negatively impacted aquatic ecosystems, and with few natural predators, are often the dominant species in infected areas. The silver carp has a unique jumping strategy when startled which has been well documented in popular videos, however the factors that initiate the jumping remain poorly understood. Laboratory and field studies were conducted on the silver carp in an attempt to isolate the factors mediating this behavior and perhaps find the fish's Achilles fin. As the startle response often is triggered by passing watercraft, underwater audio of motorboats were recorded and played back to the fish. These broadband sounds proved more effective than pure tones in repelling the fish. Sound playbacks also significantly reduced the number of crossing attempts by the fish through a small channel in a barrier. Therefore, bioacoustics shows promise as a means of managing these invasive fish species.

75-3 MELICHER, D*; MEIER, R; SU, KFY; BOWSHER, JH; North Dakota State University, National University of Singapore; dacotah.melicher@ndsu.edu

Exploring the evolutionary history of a novel trait

Sepsid flies (Diptera: Sepsidae) have a novel abdominal appendage used for courtship and mating. This appendage is sexually dimorphic occurring only in males and is a jointed, mobile brush-like structure mounted on a highly modified sternite. The appendage develops from the 4th abdominal histoblast nest rather than an imaginal disc. Our objective is to identify the genes in the 4th histoblast nest that pattern the appendage and to compare histoblast nest size and structure between species to identify differences in the evolutionary history of the appendage. We developed a transcriptome for the sepsid fly *Themira biloba* and performed Illumina sequencing on the 3rd male, 4th male, and 4th female larval segments and identified transcripts which are differentially expressed in the 4th male segment which produces the appendage. We then collected larval epidermal tissue from 16 species across Sepsidae and one outgroup to test whether the complex evolutionary history of gain, secondary loss, and recovery of the appendage are the product of different mechanisms. We characterized the histoblast nests in all segments and both sexes, determining the nest size as well as the number and size of cells. The appendage-producing histoblast nest is sexually dimorphic in species after primary gain. Loss of the appendage shows a return to ancestral state while regain shows an increase in nest size in both sexes.

S7-6 MERKLE, J.M.*; CROSS, P.C.; SCURLOCK, B.M.; KAUFFMAN, M.J.; Univ. of Wyoming, U.S. Geological Survey, Wyoming Game and Fish Dept., Wyoming Cooperative Fish and Wildlife Research Unit; jmerkle@uwyo.edu

Linking plant phenology and elk migratory behavior to predict brucellosis risk in the Yellowstone ecosystem

Brucellosis is a bacterial disease resulting in abortions for some ungulates. It remains endemic to elk and bison in the Greater Yellowstone Ecosystem and can be transmitted to cattle via comingling between March and May when most abortions occur. Concurrently, elk migrate from low-elevation areas featuring private lands and cattle to higher-elevation public lands. Thus, the spatio-temporal dynamics of elk migration have the potential to mediate brucellosis transmission to cattle. Elk migration patterns are being altered by climate change and understanding how these patterns are shifting is important for managing brucellosis transmission risk to cattle. We used GPS collar data from 253 adult female elk captured on winter feedgrounds in Wyoming to a) develop a movement model for elk, b) simulate elk distribution under varying annual weather patterns, and c) map areas of high risk for interspecific brucellosis transmission. As the abortion season progresses, elk behavior shifts from a reliance on supplemental feed and avoidance of deep snow to tracking an elevational wave of green vegetation. Simulations suggest that elk distribution is related to snow dynamics; in late April during drought years most elk use higher elevation public lands, whereas during heavy snow years elk remain congregated at feedgrounds with some individuals moving to lower elevation private lands to exploit initial green-up. Predicting variation in migratory behavior enables managers to identify where proactive management can mitigate risks posed by brucellosis.

77-2 MERRILL, L.*; NAYLOR, M.F.; GRINDSTAFF, J.L.;
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A trade-off between sexual signals in the zebra finch: is it mediated by early life immune challenge?

Sexual signals are thought to convey information about an individual that others can use to assess his quality. Different signals convey different information, however; static signals likely reflect developmental conditions, whereas dynamic signals are thought to reflect current conditions. In zebra finches, male beak color and song repertoire size are used by females to select mates. We previously documented both short and long-term effects of early life immune challenge on beak color in zebra finches, in which birds exposed to keyhole limpet hemocyanin (KLH) had less red beaks than birds that were not exposed to KLH. We also found that the birds' beaks became less red when challenged with KLH as adults. In this study, we examined aspects of song complexity in these same birds and found that birds exposed to KLH as nestling had more unique song elements and more song phrases than birds not exposed to KLH. Moreover, we found a negative correlation between the number of unique song elements and beak redness, as well as a negative correlation between the number of song phrases and beak redness. Haptoglobin levels were also negatively correlated with aspects of song complexity, suggesting a trade-off between song complexity and beak color that may be mediated by early life immune challenge.

91-6 MEYER, E*; KIRK, NL; Oregon State University;
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Genomic analysis of hybrid vigor in the Pacific oyster: genetic distance and ribosomal protein stoichiometry

Hybrid vigor has important consequences for fitness in natural populations and production in crop species, but its functional basis remains poorly understood. We used genome-wide SNP genotyping and global gene expression profiling to investigate the functional genomic basis for growth advantages in multiple hybrid crosses produced from inbred lines of the Pacific oyster *Crassostrea gigas*. Larvae from hybrid crosses showed the expected growth advantages, growing 18-75% faster than the corresponding parental lines. To investigate the genomic basis for this variation among hybrids we genotyped each parent using a sequencing based approach (2bRAD), identifying >4,000 polymorphisms (SNPs) among inbred lines. Genome-wide analysis of SNP genotypes revealed a strong relationship between genetic distance and hybrid vigor: offspring of genetically dissimilar lines grew more rapidly than offspring of genetically similar lines. Here we describe ongoing locus-by-locus analysis of these genetic data in the context of the genome assembly in search of the functional basis for variation in growth performance among hybrids. In parallel, we profiled gene expression in the same families using RNASeq to test for genes differentially expressed in hybrids than inbreds. Previous analysis of gene expression in hybrid oysters has implicated ribosomal protein (RP) genes in hybrid vigor. In this study we found similar patterns: "balanced" expression of RP genes in hybrids and "unbalanced" expression in inbreds. Our findings support the RP balance model of hybrid vigor, in which stoichiometric expression of RP genes in hybrids contributes to efficient ribosome assembly and growth while their uneven expression in inbreds contributes to reduced metabolic efficiency and growth.

5-1 MESNICK, S.L.*; ORBACH, D.N.; DANIL, K.; CHIVERS, S.J.; ROBECK, T.R.; MONTANO, G.A.; GULLAND, F.; MARSHALL, C.D.; DINES, J.; DEAN, M.D.; RALLS, K.; DIXSON, A.F.; Southwest Fisheries Science Center, NOAA, Texas A&M Univ, Southwest Fisheries Science Center, NOAA, Southwest Fisheries Science Center, NOAA, SeaWorld & Busch Gardens Reproductive Research Ctr, The Marine Mammal Center, Texas A&M Univ., Natural History Museum of Los Angeles County, Univ. of Southern California, National Zoological Park, Victoria University of Wellington; sarah.mesnick@noaa.gov

Coevolution of Female and Male Reproductive Tract Anatomy in Cetaceans

Female cetaceans exhibit unusual vaginal morphology that varies in complexity across species. Multiple transverse folds typically project from the walls of the vagina into its lumen. The function of these folds and associated fornices is unknown. They may serve to exclude the entry of seawater into the female reproductive tract or affect the ability of the male to gain access to the cervical os during copulation. Transverse vaginal folds are present in some terrestrial artiodactyls, such as pigs, and in the hippopotamus, a species that appears most closely related to the Cetacea. However, transverse folding is notably absent in non-ungulate mammals, including other species that mate in the water (e.g. otters, a sea lion, and amphibious rodents examined to date). We report details of vaginal anatomy for 21 species representing 15 genera of cetaceans and explore the possibility that complexity has been influenced by sexual selection. Based on variation in the number, shape, width and depth of the folds, we constructed a vaginal complexity index and tested for a correlation with residual testes mass among species. Larger relative testes sizes are indicative of sperm competition in cetaceans, as in many other mammals. Using phylogenetic comparative methods, we found that more complex vaginas tended to be associated with larger relative testes across the cetacean phylogeny (PGLS $F_{1,19}=7.42$, $p=0.01$). These comparisons provide a framework within which the anatomy of additional species can be integrated to address the question of whether sexual selection has influenced the evolution of complex vaginal morphologies.

69-4 MIDDLEBROOKS, ML*; MOLINE, RE; PIERCE, SK; Univ. of Tampa, Univ. of South Florida; mmiddlebrooks@ut.edu
The Photosynthetic Sacoglossan Sea Slug Elysia clarki Displays Strong Positive Phototaxis

Certain species of sacoglossan (Opisthobranchia: Mollusca) sea slugs are able to photosynthesize by way of kleptoplasty, where chloroplasts stolen from prey algae are sequestered inside of the slugs' own cells. The duration of photosynthesis is quite variable among species as are their methods of maintaining sequestered chloroplasts by incorporating a variety of physiological, behavioral, and biochemical mechanisms. *Elysia clarki* is a sacoglossan sea slug capable of maintaining functional chloroplasts for 3-4 months of starvation. Previous studies have shown that the slug is capable of synthesizing chlorophyll a, which likely aids in prolonging photosynthesis and maintain chloroplasts. However, the slug may also employ additional methods to reduce the degradation of chloroplasts. To determine if behavioral methods, such as limiting light exposure, may be involved in prolonging photosynthesis, the phototactic response of *E. clarki* was tested at 4 week intervals using time lapse photography over an 8 week period of starvation. The slug displays highly positive phototaxis, spending the vast majority of its time exposed to light and avoiding shade. As the duration of starvation increases the slug does not decrease the amount of time it spends in the light. This suggests that the slug seeks to maximize light exposure regardless of nutritional state in order to fully capitalize on its ability to photosynthesize.

S2-3 MIKUCKI, JA*; TULACZYK, S; AUKEN, E; LYONS, B; DACHWALD, B; CHUA, M; PURCELL, A; Middlebury College, Univ. of California, Santa Cruz, Aarhus University, Ohio State University, FH Aachen, Univ. of Tennessee; jmikucki@middlebury.edu

Geomicrobiology, Engineering and Geophysics: Enabling the exploration of the subglacial microbial community in Antarctica's Blood Falls

We now know that groundwater, saturated sediments and hundreds of subglacial lakes exist below the ice sheets of Antarctica. These unique subglacial environments are one of the most difficult portions of the cryosphere to access. These unexplored ecosystems are 'hot spots' for microbial life and will allow for the study of the persistence and evolution of life in icy, dark, isolation. The exploration of subglacial habitats requires an integrated, interdisciplinary approach. This talk will describe how geophysics, drilling and geomicrobiological analyses come together to enable sampling of the subglacial biosphere. The focus will be on the Blood Falls ecosystem, an iron-rich, saline feature at the terminus of Taylor Glacier in the McMurdo Dry Valleys, Antarctica that appears to be sourced from a much deeper aquifer. We will also highlight recent results from an Antarctic drilling project that sampled Subglacial Lake Whillans, a fresh water lake under the Whillans Ice Stream. Both of these ecosystems appear to persist independent of photosynthetically derived carbon inputs. Molecular data and biogeochemical measurements that indicate chemoautotrophic activity is present with energy derived in part by cycling iron and sulfur compounds. The collaborative efforts of exploring these isolated microbial habitats help enable the development of relevant tools for geomicrobiological examination of other subglacial environments on Earth and prepare us for the exploration of icy extraterrestrial targets.

25-7 MILLER, L.P.*; DOWD, W.W.; San Jose State University, Loyola Marymount University; millerlp@gmail.com

Field-based measurements of behavioral and biophysical contributions to body temperature variation among intertidal mussels

Heterogeneity of abiotic environmental conditions manifests at a variety of spatial scales, and organisms may experience substantially different conditions compared to neighbors even over small distances of a few body lengths. The rocky intertidal zone represents an extreme case of such micro-scale variation. Here, we present field-based, continuous measurements of live mussel (*Mytilus californianus*, n = 30) body temperatures, valve gaping behavior, and body orientation from three micro-sites on a rocky shoreline: one at the upper limit of the mussel zone, one near the lower limit of this zone, and a third micro-site continuously submerged in a tidepool. These data were obtained with a custom, modular data acquisition system on an Arduino-based platform. As expected, differences in shore height of only a meter lead to drastically different mean thermal histories and opportunities for feeding or recovery from thermal stress events. On the scale of centimeters within a single mussel bed, we also observe a wide range of maximum temperatures achieved by individual mussels of the same body size (up to 13.75 °C difference during one low tide). An individual's body temperature depends on its position in the bed and its body orientation. Notably, body temperatures of live mussels can depart substantially from thermal mimics deployed in the same bed. These data provide a comprehensive record of micro-scale spatial and temporal variation in thermal history experienced by organisms within a single population. When coupled with measures of physiological status, these field measurements will allow us to examine the contributions of spatial variation to patterns of survival, growth, and, ultimately, community structure up and down the shore.

32-7 MILES, DB; MILES, Donald; Ohio University; urosaurus@gmail.com

Phylogenetic structure of passerine bird communities along a Sonoran Desert elevational gradient

Recent interest in the application of phylogenetic analyses to community data has allowed the ability to tease apart the relative contribution of ecological and evolutionary processes in structuring local species richness. In addition, comparing communities along an elevational gradient provides the opportunity to test hypotheses regarding the control of local species richness, because of the change in abiotic factors and turnover of species in a restricted geographic region. I quantified passerine bird species diversity along an elevational gradient in the Sky Islands of southeastern Arizona. I censused birds along a series of transects located in 5 different habitats types: Sonoran Desert, Oak Woodland, Oak-Pine Woodland, Pine Forest, and Fir Forest. I first estimated conventional patterns of species richness and species turnover. I next estimated the patterns of phylogenetic structure and diversity among the communities. I also quantified phylogenetic beta diversity to examine turnover in richness. The advantage of phylobetadiversity is that it measures the phylogenetic distance among communities as species composition changes. Moreover, the index links local processes, e.g., biotic interactions, with regional processes, e.g., speciation rates. Bird species richness and phylogenetic diversity exhibited a unimodal distribution with a peak at mid-elevations. Passerine bird communities exhibited phylogenetic overdispersion at the low elevation habitat and phylogenetic clumping at high elevation habitats. Compositional similarity declined with elevation. The phylogenetic distance-decay curve also declined with elevation and differed from significantly from the null expectation, which suggests strong spatial structure along the gradient. These patterns suggest that biotic interactions structure communities at low elevations whereas environmental filtering characterizes the structure of high elevation communities.

68-2 MILLER, D.W.*; ROWE, A.H.; ROWE, M.P.; Michigan State University; millerdy@msu.edu

Gender differences in stinging behavior, venom composition, and venom function in the striped bark scorpion (*Centruroides vittatus*)
Bark scorpions (*Centruroides* spp.) are a large group of 40+ species in the family Buthidae whose center of distribution is west-central Mexico. Some species represent the most lethal scorpions known, causing ~ 1000 human deaths per year. It is not surprising that venoms of the most toxic members of this genus have been well characterized. Surprisingly little is known, however, regarding the ecology and evolution of their toxins. An ultimate explanation for the dramatic differences in toxicity observed across species, for example, has never been attempted. There are interesting intraspecific differences as well. The striped bark scorpion (*C. vittatus*) of New Mexico exhibits sexual dimorphism, with the tails (metasomas) of males being significantly longer and thinner than females. Males also sprint significantly faster, but are significantly less likely to sting when threatened by a simulated predator. Why? Venom is metabolically costly, and these costs may be different for males and females. Perhaps males have fewer feeding opportunities, a different suite of prey, or need to reserve their venom for the stings they deliver to females during courtship. Such hypotheses predict there might be gender differences in the composition and function of venoms. We here report our preliminary results. HPLC analyses suggest differences in both specific venom constituents and their concentrations. Proteomic and transcriptomic analyses of the venom glands are underway. And while we have yet to examine gender differences in toxicity, male venom is significantly more painful than female venom, as revealed using a paw-licking assay with domestic mice.

62-7 MIRANDA, R.A.*; MARTINEZ-ACOSTA, V.G.; Univ. of the Incarnate Word; rmirand1@uiwtx.edu

Lumbriculus variegatus as a model organism for wound healing and regeneration

Animals vary in their ability to regenerate and restore tissue function after traumatic injury. Many invertebrates, such as hydra and planarians, display an exceptional ability to regenerate lost body parts while most vertebrates possess limited regenerative abilities, typically leading to the formation of non-functional scar tissue. The annelid *Lumbriculus variegatus* has become a useful model system for studies of body axis development, wound healing and regeneration. Lumbriculus is capable of regenerating a new worm from three segments of the original worm and can recover structure and function along the anterior-posterior axis. Using this species, we aim to understand cellular and molecular mechanisms that regulate wound healing and regeneration within the central nervous system and wound blastema. Previous studies in our lab found elevated levels of beta-catenin protein in regenerating heads. Beta-catenin is known to function as a transcription factor activated by members of the Wnt signaling pathways or function as a component of E-cadherin-based adherens junctional coupling between cells. Increased protein expression of beta-catenin suggests it plays an important role during Lumbriculid regeneration. Genomic work is limited in Lumbriculus. To further dissect the role of beta-catenin, we are developing a real-time QPCR assay to measure beta-catenin mRNA levels during regeneration. In the future we plan to evaluate transcripts of other Wnt signaling proteins as well as other putative regenerative proteins. Our results may provide a more effective way of directly measuring the contributions of different regenerative genes utilized by Lumbriculus and could subsequently identify cellular and molecular regeneration mechanisms that have been conserved in annelids and across animal phyla.

44-3 MITCHELL, JM*; NICHOLS, SA; University of Denver; yinnismc@gmail.com

Examining the roles of -catenin/vinculin related proteins in sponges and choanoflagellates

Understanding the evolution and ancestral functions of cell-cell adhesion proteins promises to shed light on how animal multicellularity evolved, and how the first animal tissues were assembled. Here, we examined the function of α -catenin/vinculin-related proteins (Vin-family proteins) in choanoflagellates and sponges. Two questions of particular interest are 1) how do Vin-family proteins function in the colonial life stages of choanoflagellates? And 2) how do Vin-family proteins function in the choanoderm tissue (the feeding epithelium) of sponges, which has long been hypothesized to be an ancient animal tissue type based upon its cytological similarities with choanoflagellates? In bilaterians, Vin-family proteins function to regulate actin-based structures, including cadherin- and integrin-based cell adhesions. Our results point to a novel role for a choanoflagellate Vin-family protein that is unrelated to either actin regulation or colony formation. Instead, we find evidence for a discrete cellular population adjacent to the nucleus, a pattern consistent with a role at the centrosome. In sponges, we examine a putative vinculin ortholog (Vin1) and find evidence for at least three different cellular populations that function in adherens junctions (cadherin-based cell adhesion), focal adhesions (integrin based adhesions), and co-localized with actin at roots of microvilli in the choanoderm. These data contribute to a new hypothesis about how Vin-family proteins may have functioned in an ancestral, unicellular context, and provide a new, structural context for understanding the evolutionary links between sponge and bilaterian tissues.

114-6 MITCHELL, T. S. *; IVERSON, J. B.; JANZEN, F. J.; Auburn University, Earlham College, Iowa State University; tsmitchell09@gmail.com

Abiotic conditions influence winter nest temperatures and hatchling mortality in the painted turtle (Chrysemys picta)

Some ectotherms have evolved remarkable adaptations for survival at cold temperatures, and cold-hardiness influences the distribution of many ectotherms at high latitudes. Hatchlings of some temperate aquatic turtles have been well-studied ecophysiological models for vertebrate cold tolerance because of their interesting subterranean overwintering behavior. After hatching from eggs, many temperate hatchlings remain in the terrestrial nest over winter, emerging the following spring. These turtles employ multiple strategies (supercooling and freeze tolerance) to survive subzero temperatures. Despite these remarkable adaptations, many hatchlings perish due to harsh abiotic conditions during winter. While the physiology of cold tolerance has been the focus of much research, important ecological considerations remain understudied. Here we present results from parallel multi-year observational studies of two painted turtle (*Chrysemys picta*) populations located in Nebraska and Illinois. We examine the intersection of maternal nest-site choice and abiotic conditions (snow cover, ambient temperature, etc.) on temperatures within painted turtle nests during winter, and the relationship between winter nest temperatures and sex-specific offspring mortality in those nests. Preliminary results suggest maternal nest-site choice has little influence on winter nest temperatures, whereas ambient temperature and snow cover are essential for predicting nest thermal environments and pre-emergence hatchling mortality. These findings suggest that estimates of mortality can be obtained during this life stage from weather data.

21-3 MIYASHITA, T*; FANTI, F; MINELLI, D; LAROCCA CONTE, G; University of Alberta, University of Bologna; tetsuto@ualberta.ca

An Exceptionally Preserved Eocene Shark Reveals the Rise of Modern Predator-prey Interactions in the Coral Reef Food Web

Following extreme climatic warming events, the Eocene epoch saw a shift toward modern marine faunas characterized by the prevalence of acanthomorph teleosts and a trophic network crowned by carcharhiniform sharks. However, the reliance on isolated teeth has limited the systematic and paleoecological understanding of the early Cenozoic sharks, and predator-prey dynamics in the Eocene marine food web remain poorly understood.

We report an exceptionally preserved fossil school shark (*Galeorhinus cuvieri*) from Pesciara di Bolca, Italy – a *lagerstätte* documenting a coral reef fish assemblage near the end of the Early Eocene Climatic Optimum. In addition to the spectacular preservation of soft tissues including the brain, muscles, and claspers, this male juvenile shark has stomach contents clearly identifiable as a sphyraenid acanthomorph (barracuda). This association provides evidence that a predator-prey relationship between *Galeorhinus* and *Sphyraena* in the modern coral reefs has an Eocene root.

A growth curve of the living species of *Galeorhinus* fitted to *G. cuvieri* indicates that all six specimens of *G. cuvieri* from the lagoonal deposits of Bolca represent juveniles younger than 5 years in age. This biased representation is consistent with the living species of *Galeorhinus* in which juveniles occupy 'nursery' habitat.

We suggest that, following the early Cenozoic thermal events, modern trophic relationships between acanthomorph fishes and carcharhiniform sharks developed in the recovering scleractinian coral reef communities. Predator-prey relationships across multiple trophic levels likely played a role in shaping the modern coral reef communities.

2-2 MOHREN, TL*; DICKERSON, BH; PRATT, BG; DANIEL, TL; Delft Univ. of Technol., Delft, Cal. Inst. Technol., Pasadena, Univ. Washington, Seattle, Univ. Washington, Seattle; daniel@uw.edu

Sensing wing deformation: it's about spike time

Flying insects rely heavily on mechanoreception for flight control. True flies use halteres to provide feedback on body rotations. Recent behavioral and theoretical evidence suggest that wings, antecedents of the halteres, might also serve a similar sensory function. Both wings and halteres have mechanoreceptors called campaniform sensilla. In halteres those sensors are believed to be directionally sensitive, allowing them to detect exceedingly tiny out of plane deformations that arise from Coriolis forces. Similarly, sensilla could detect tiny deformations that are present as torsion in flapping wings subject to simultaneous body rotations. We combine theoretical and experimental analyses of flapping wings in the hawkmoth *Manduca sexta*. Like halteres, their sensilla respond to local strains which result from the combination of inertial, aerodynamic and gyroscopic forces acting on the wings. Their spike timing is exceedingly precise with sub-millisecond variability in response to mechanical stimuli. We ask whether the nervous system could determine body rotations based on spike arrival times, not requiring high directional sensitivity of individual sensilla. Combining structural simulation and electrophysiological measurements, we find that the resulting spike timing differences depend linearly on rotation rate. Moreover, rotation rates above $2130^\circ \text{ s}^{-1}$ result in spike timing differences larger than the median 160 microsecond spike time variability of single units. These data suggest an alternative hypothesis for the neural basis of gyroscopic sensing, based on spike timing rather than on extreme directional sensitivity of campaniform sensilla.

54-6 MONAENKOVA, D.*; LINEVICH, V.; GOODISMAN, M.A.D.; GOLDMAN, D.I.; Georgia Institute of Technology; dmonaen@physics.gatech.edu

Autonomous robotic diggers provide insight into the challenges of collective nest construction

The subterranean nests of *S. invicta* fire ants are stunningly sophisticated. Nest construction is accomplished through the collective effort of multiple workers. Our laboratory experiments revealed that the workload distribution within excavating groups of *S. invicta* was unequal. That is, a disproportionately large amount of effort is accomplished by a few workers, while the least active workers contribute to less than 1% of the collective effort. To better understand the challenges and advantages of such a workload organization we built robotic diggers. Small groups of fully autonomous robots governed by environmental clues were set to excavate simulated cohesive soil. The collective behavior within the group was coordinated by one of two social protocols. In groups governed by the first protocol all robots contributed to excavation continuously and equally. In groups governed by the second protocol the workload was asymmetrically distributed among workers. The experiments showed that with an increase in the size of the excavating group the amount of interactions between workers within the tunnel grew and led to traffic jams. The jamming slowed excavation rates while it amplified nest excavation costs. The asymmetric workload distribution resulted in the reduction of jamming. The largest tested excavating group with asymmetric workload distribution showed on average 35% higher excavation rates at 2.2 times lower excavation costs as compared to the equal workload distribution. We hypothesize that the asymmetric workload distribution could be beneficial for task performance when the resources for the task (space in our experiments) are limited.

S6-3 MOKKONEN, M.*; KOSKELA, E.; MAPPES, T.; Simon Fraser Univ. / Univ. of Jyväskylä, Univ. of Jyväskylä; mika@sfu.ca

Hormones mediate evolutionary conflict between the sexes

Understanding the maintenance of fitness-related traits remains at the very heart of evolutionary biology, with a wide variety of approaches focused on survival and reproductive processes. We have studied how hormones in the bank vole (*Myodes glareolus*) mediate phenotypic adaptation and trade-offs in the context of their social environment (density and frequency). Reproductive trade-offs within and between the sexes are mediated by hormones in this species: plasma testosterone (T) level and immunocompetence are both phenotypically and genetically negatively correlated. The benefits of greater T production on male reproductive success are balanced by both intrasexual (lower immunocompetence) and intersexual (lower reproductive success of daughters) fitness costs. T exerts sexually antagonistic effects on reproductive success through the opposing effects on female and male mating rates, thereby creating an evolutionary conflict of interest over this hormone. Given the various phenotypic effects and sexually dimorphic nature of T (and other hormone systems), we predict that most sexually antagonistic traits will be mediated by hormones and maintained by social factors of the environment.

2-4 MONGEAU, J.-M.*; KHAN, F.; SALOMON, A.; FRYE, M.A.; Univ. of California, Los Angeles; jmmongeau@ucla.edu

The dynamics and control of body saccades during visual fixation in *Drosophila*

During free flight in flies, body saccades account for the vast majority of the total net change in heading yet little is known about their control. Here, we studied visual fixation in magnetically-tethered *Drosophila* free to rotate about the vertical yaw axis. We hypothesized that flies rely on smooth and saccadic tracking of visual objects. However, when an object was rotated against a stationary visual landscape, tracking was dominated by sustained bouts of saccades, with little-to-no smooth pursuit between saccades. Object-tracking saccades were significantly smaller and slower than spontaneous saccades. The duration, amplitude, and peak angular velocity of saccades were tuned to object velocity, which rejects the hypothesis that saccades are reflexive, all-or-none motor actions; instead, saccades are precisely pre-programmed. Saccade dynamics are regulated such that the initial torque generated by the wings is tuned to object velocity while the counter-torque scales with initial torque amplitude. Saccades are triggered when the spatio-temporal integrated error between the object and the fly's heading reaches a fixed threshold. A reduced-order, switched, integrate-and-fire model predicts measured tuning and triggering dynamics. Object tracking saccade dynamics on a moving ground depend upon the ground speed whereas the initial trigger for a saccade depends only on the integrated object error. Collectively, our findings provide evidence that visual fixation in *Drosophila* is enabled by precise control of targeted body saccades. Our results provide testable hypotheses about the neural circuit function underlying visual programming and dynamic control of body saccades.

18-4 MOODY, E.K.*; CORMAN, J.R.; ESPINOSA-PEREZ, H.; RAMOS, J.; ELSER, J.J.; Arizona State University, University of Wisconsin, Madison, La Universidad Autonoma de Mexico; eric.k.moody@gmail.com

Stoichiometry in hot water: Does metabolism explain intraspecific differences in the elemental phenotype of a desert fish over a thermal gradient?

Intraspecific variation in the elemental phenotype, i.e., the elemental signature of biological processes such as growth, metabolism, and excretion, can form a foundation for linking evolution to ecosystem ecology. While intraspecific elemental variation is quite high in many species, the drivers of this variation are still poorly understood. Here we investigated developmental temperature as a source of intraspecific variation in the elemental phenotype of the poeciliid fish *Gambusia marshi*, which inhabit thermal springs in the Cuatro Ciénegas basin in Coahuila, Mexico. Developmental temperature can affect growth rate, metabolic rate, and size at maturity, which are all linked to the elemental phenotype under the theory of biological stoichiometry. Among adult females sampled from eight springs, we found that body %C and excretion N:P were lower and body %P was higher in fish at a given size from warmer springs. We then reared F1 fish from two populations on a single diet at both cool (25 C) and warm (33 C) temperatures and found that excretion N:P ratio was still higher in fish reared at the cooler temperature. We used growth data from laboratory-reared fish to apply bioenergetics models to each developmental temperature regime, which suggested that higher respiration and consumption rates of fish at warmer temperatures could explain our results. In the context of stoichiometric theory, these results suggest that fish at warmer temperatures have a lower gross growth efficiency for C and a lower maximum accumulation efficiency for N and/or P. Linking the environmental and genetic controls on metabolism through stoichiometry provides a tangible bridge between evolutionary and ecosystem processes.

50-3 MOORE, J. M.*; PAULAY, G.; Florida Museum of Natural History, University of Florida; jmoore@ufl.edu

On the biogeography, natural history, and invasive potential of the pantropical marine annelid *Chaetopterus longipes*.

Chaetopterus longipes is an epifaunal mucus filter-feeding annelid, which inhabits straight tubes on hard substrates, usually in coral reef environments. The species was formerly synonymized under the putatively cosmopolitan species *Chaetopterus variopedatus*, however, it has a markedly unusual habitat and natural history compared to most Chaetopteridae. *C. longipes* was described from the Republic of Maldives, and has been reported in Japan, Easter Island, and the Galapagos Islands, spanning the Indo-Pacific basin. Despite its apparent wide range, genetic confirmation of the range of this species has not yet been undertaken. Here, we investigate whether cryptic species exist within this apparently widely distributed morphological species using genetics, and assess its potential as a biological invader through observation of reproductive modes, habit, and range. Specimens of *C. longipes* were observed and collected from several localities spanning the Caribbean and Indo-Pacific, including the type locality. Additional specimens were examined from collections at the Florida Museum of Natural History and the Smithsonian Museum of Natural History. Genetic sequence data from COI, 28S, and 18S were collected to screen for cryptic diversity and to establish the extent of the geographic range of *C. longipes*. Our findings suggest that *C. longipes* constitutes a truly pantropical species exhibiting both asexual and sexual reproductive modes. *C. longipes* has strong potential for biological invasion in its capacity to colonize hard substrates in large numbers, flexible reproductive modes, and inferred broad thermal tolerances.

70-6 MOODY, KN*; KAWANO, SM; BRIDGES, WC; BLOB, RW; SCHOENFUSS, HL; PTACEK, MP; Tulane Univ., NIMBioS, Clemson Univ., Clemson Univ., St. Cloud State Univ.; kmoody3@tulane.edu

Opportunity for selection: the shape of the fitness landscape in an amphidromous waterfall-climbing Hawaiian goby *Sicyopterus stimpsoni*

Habitat heterogeneity can drive the evolution of locally specialized phenotypes and lead to adaptive diversification across an environmental gradient. Natural selection is a primary driver of adaptive evolution, and can be weakened by trade-offs between phenotypic traits that confer different performances. These trade-offs have the potential to generate complex fitness surfaces with multiple local optima in multivariate morphospace amongst different selection regimes. We tested for the presence of such fitness surfaces and their correlation with observed morphological differences among juveniles from subpopulations of the amphidromous Hawaiian waterfall-climbing goby, *Sicyopterus stimpsoni*. To examine the role of natural selection in promoting local adaptation of body shape in this species, we conducted laboratory experiments to compare linear and nonlinear selection and the opportunity for selection in fish from Kaua'i and Hawai'i due to the opposing pressures of predator evasion and waterfall climbing which vary in strength between the islands. We found that directional selection was strong in traits that enhance climbing or predator evasion, but the opportunity for directional selection was greatest for climbing in both subpopulations, but acted on different traits. Furthermore, the strength of directional selection was constrained by nonlinear stabilizing selection and potential trade-offs in functional capacities. These results demonstrate that natural selection can lead to locally adapted phenotypes because of differences in selective pressures. However, similar selection pressures can potentially produce comparable strength, modes, and opportunity for selection through many-to-one-mapping.

105-3 MOORE, M.S.*; POTEREWICZ, G.M.; DAVALOS, L.M.; Arizona State University, Mesa, AZ, SUNY Stony Brook, Stony Brook, NY; mar.su.moo@gmail.com

Genomic Inventories of Bat Antimicrobial Peptides: Implications for Resistance to White-nose Syndrome

The first opportunity for the immune systems of bats to recognize invasion by the white-nose syndrome (WNS) pathogen is in skin tissues where the fungus invades. Understanding skin immune defenses across bat species exhibiting differential disease and mortality is of critical importance. We hypothesize that immune defense proteins, known as antimicrobial peptides (AMPs), confer resistance to WNS because AMPs: 1) are abundant in skin, 2) are constitutively expressed and likely to remain functional during hibernation when invasion occurs, and 3) can have strong, immediate anti-fungal activities. The diversity of AMP repertoires and their antimicrobial functions are, however, unknown in species affected by WNS. To discover bat AMP repertoires, we deployed hidden Markov models calibrated using known, annotated AMP sequences from non-bat mammals. We applied this method to six bat and 21 non-bat mammal genome assemblies. We found >130 previously undiscovered AMP genes in bat genomes. We then modeled AMP evolution across all mammalian species. We found little diversification in bat alpha: (browser-check:)-defensins. In contrast, bat cathelicidin and beta: (browser-check:)-defensin diversity matches or exceeds diversity in other mammals. Additionally, AMP repertoires differed between two species variably impacted by WNS (*Myotis lucifugus* and *Eptesicus fuscus*). We hypothesize that differences in AMP diversity and function between bat species may explain differences in susceptibility to invasion and infection by the WNS pathogen and can lead to an effective control. We are currently exploring this question using proteomic analyses of skin tissues from five species variably impacted by WNS complemented by functional tests of bat AMP abilities.

S5-11 MOORE, BC*; SPEARS, D; KELLY, DA; Sewanee: The University of the South, University of Massachusetts Amherst; bcmoore@sewanee.edu

Morphological characteristics related to the expansion of the crocodylian glans for reproductive activity.

The distal part of the crocodylian phallus consists of a bulbous glans containing well-developed vascular tissues that can inflate prior to or during sexual activity, enlarging and elaborating the glans into a complex, though still functionally undefined, copulatory structure. An enlarged glans putatively interacts with the female cloaca and changes shape to facilitate insemination and increase the probability of fertilization. Here, we investigated the cellular-level properties of the glans and other inflatable phallic tissues associated with the sperm-conducting sulcus spermaticus in the American alligator (*Alligator mississippiensis*). Using histochemical staining and polarized light microscopy, we visualized and defined collagen and elastin fiber densities and orientations in these tissues. Extracellular matrix architectures provide insights about phallic glans material properties and how they may affect tissue strength and flexibility during inflation and in response to copulatory forces. We also investigated the potential sources of fluids that induce inflation in alligator phalli. Combining serial sectioning, in-vivo CT scans and three-dimensional reconstruction, we identified a pair of paralympathic bodies at the proximal end of the alligator phallus that extend distally adjacent to ventro-medial sulcus tissues. These structures are similar to those observed in ratite intromittent phalli that provide fluid for lymphatic erection, which suggests a shared homology for lymphatic erectile structures and a putative common role across archosaurian phalluses.

17-4 MORAN, C.J.*; O'NEILL, M.; GIBB, A.C.; Northern Arizona University; cmoran@fairfield.edu

Are Southwestern fishes specialized for a life in flow?

The lower Colorado River basin was once defined by seasonal flooding events. However, many of these waterways have been altered with the introduction of non-native fishes and hydroelectric dams. Are species which evolved in the river's mainstem under conditions of periodic high water flows better swimmers than non-native species? We predicted that fishes native to the main stem Colorado would have a higher maximum swimming speed and lower cost of transport than introduced fishes. To test this prediction, we examined swimming capabilities of individuals of the following species: the bonytail and Colorado pikeminnow from the main stem Colorado; the roundtail chub from smaller tributaries; non-native rainbow trout and smallmouth bass. Swimming step tests were performed and depletion of dissolved oxygen was measured. The native bonytail had the highest locomotor performance, as it was able to maintain the highest sustained swimming speeds with low costs of transport. The introduced rainbow trout, which is commonly found in rivers and streams with high flow rates, had a similar metabolic rate, maximum swimming speed and cost of transport to native Colorado pikeminnow and roundtail chub. However, the introduced and invasive smallmouth bass, commonly found in pools and lakes, had the lowest maximum sustainable swimming speed and metabolic rate at all speeds. Bonytail appeared to have the "best" locomotor performance of all fishes considered here and we note their morphological similarities to high-performance swimmers from the marine environment which may assist them in coping with flooding events. As a result of anthropomorphic changes to the river, non-native fishes, even those with relatively poor swimming performance, are able to thrive in the Colorado River.

61-4 MOORE CRISP, A.L.*; LEE, D.V.; Univ. of Nevada, Las Vegas; leximoore@gmail.com

To bite or to scratch?: Pocket gophers vary digging forces based on substrate parameters

Burrowing is a widely-used strategy for the survival of many groups of animals, but is particularly important for rodents. To study this essential behavior, we used 3D x-ray to measure burrowing kinematics and the Tunnel-Tube 3.0 to measure 3D burrowing dynamics. Here, we present the first complete 3D analysis of burrowing biomechanics in a vertebrate. Lessons from our earlier designs have led to the modular, streamlined Tunnel-Tube 3.0: Two interchangeable plastic tubes arranged in series and mounted on an ATI nano-17 6-axis load cell. The tube through which the animal enters is empty and aligned with a second, substrate-filled tube. The substrate-filled tubes are uniformly packed and can be exchanged between trials, allowing for a more consistent substrate over time. The dual-tube design allows us to measure forces produced by the animal's fore- and hindlimbs independently. Botta's pocket gophers (*Thomomys bottae*) are subterranean rodents which spend the majority of their lives underground, thus making them ideal test subjects for studies of burrowing biomechanics. Pocket gophers burrowed in four substrate conditions in order to assess the effects of substrate hardness and composition on burrowing mechanics. Substrate conditions included: Soft radiolucent substrate, hard radiolucent substrate, soft natural soil, and hard natural soil. Radiolucent substrates were made up of walnut shells and coconut fiber; Natural soils were collected from trapping sites. In soft substrates, pocket gophers exhibited scratch-digging, using the forelimbs to loosen and remove the substrate. In hard substrates, pocket gophers exhibited both chisel-tooth and scratch-digging, typically using the teeth to penetrate the hard substrate and the forelimbs to remove loosened substrate. Pocket gophers produced greatest force when using chisel-tooth methods in hard substrates.

S3-8 MORDECAI, E.A.*; WEIKEL, D.P.; GUDAPATI, P.; JOHNSON, L.R.; STEWART-IBARRA, A.; RYAN, S.J.; Stanford University, University of Michigan, University of South Florida, SUNY Upstate Medical University, University of Florida; emordecai@stanford.edu

Climate change and the future of vector-borne disease transmission

The geographic distribution of vector-borne diseases is shaped by many ecological and evolutionary factors, including the response of vectors and pathogens to environmental drivers. Environmental temperature strongly influences vector transmission by changing rates of development, reproduction, and survival of pathogens and their vectors. Global change could thus lead to substantial changes in disease distributions. Recent work on falciparum malaria showed that the influence of temperature on transmission is nonlinear. Including these nonlinear thermal responses is critical for accurately predicting transmission in the field. Here, we show that nonlinear thermal responses are also important for dengue, chikungunya, and yellow fever transmission by *Aedes aegypti* and *Ae. albopictus* mosquitoes. Although often considered tropical diseases, dengue, yellow fever, and chikungunya, like malaria, peak in transmission potential at intermediate temperatures of 25-29 degrees C, and decline steeply above 32-36 degrees C and below 15-17 degrees C. The model predictions match field case data much more accurately than previous models that used less realistic thermal responses. We then quantify sources of uncertainty in the model predictions and make prescriptions for future experimental work to resolve this uncertainty. Finally, we discuss implications of nonlinear thermal responses for potential shifts in transmission intensity with future climate change. In addition to predicting shifts in transmission of malaria, dengue, chikungunya, and yellow fever across temperatures, this data-driven modeling approach can inform temperature predictions for other mosquito- and fly-transmitted diseases.

116-1 MOREHOUSE, N.I.*; CRONIN, T.W.; TAYLOR, L.A.; BYRNE, K.; SULLIVAN, M.G.; ZUREK, D.B.; University of Pittsburgh, University of Maryland, Baltimore County, University of Florida, Gainesville; *nim@pitt.edu*

Spectral filtering enables trichromatic vision in the principal eyes of *Habronattus* jumping spiders

Jumping spiders are well known for their extraordinary modular visual systems, which enable complex vision-guided behaviors via a combination of wide-field motion sensitivity and exceptional front-facing visual acuity. However, to what extent jumping spiders see color has remained controversial, with the bulk of evidence suggesting that these spiders have only dichromatic UV-green vision in their principal eyes. This stands in contrast to the broad color palette used in male courtship in several genera, including the genus *Habronattus*. Dichromatic UV-green vision would be unable to discriminate the long-wavelength colors commonly found in these genera. In addition, our previous work demonstrates a clear role for long-wavelength colors in foraging, learning and mate choice in *Habronattus* spiders. We characterized the visual sensitivities of *H. pyrrithrix* to better understand their color vision. Using microspectrophotometry, we determined absorbance spectra of photoreceptors in the tiered principal eye retina, as well as transmittance spectra of optical elements in the light path. We discovered a trichromatic visual system limited to the acute zone of the principal eye retinas, composed of UV, green, and red-sensitive photoreceptors. Red sensitivity is provided by a combination of green photoreceptors and a previously undescribed red filter positioned distally in their light path. Visual modeling indicates that this filter-based trichromacy should enable increased discrimination of male color ornaments by females. Our findings thus reveal a novel mechanism for trichromatic vision in spiders, and may help us to understand the extraordinary radiation of species-specific male color patterns in *Habronattus* spiders.

1-7 MORINAGA, G*.; BERGMANN, P. J.; Clark University; *gmorinaga@clarku.edu*

Phenotypic variation affects burrowing performance in the Australian skink genus, *Lerista*

Lizards are morphologically diverse, exhibiting a wide range of sizes and shapes. Among these shapes, the snake-like form has evolved independently at least 25 times. Among many of these lizards, the snake-like form is thought to be an adaptation for fossoriality. Since these animals penetrate the substrate headfirst when burrowing, head shape variation may also play an important role in burrowing. We aimed to test what aspects of body and head shape affect burrowing performance in 12 species of *Lerista*. *Lerista* are a diverse clade of skinks endemic to Australia, which exhibit snake-like bodies, lizard-like bodies, and multiple intermediate forms. We recorded high-speed videos of burrowing behavior for 12 species of *Lerista* on fine and coarse sand substrates from the dorsal aspect. The species in our dataset encompassed six different digit morphs, ranging from robustly limbed with four digits on each limb to nearly completely limbless, the majority of body shape variation in *Lerista*. We tracked a point on the pelvic girdle to calculate maximum velocity and acceleration and average velocity as measures of burrowing performance. We hypothesized that traits associated with snake-like bodies would positively affect all of our measures of burrowing performance regardless of substrate coarseness. Our findings suggest that aspects of body shape do not affect either measure of burrowing velocity on either of the substrates. Maximum acceleration slightly increased with relative body length, relative hind limb length, and relative body width on the coarser substrate but decreased on the finer substrate. These results may indicate that in *Lerista*, snake-like body shape only affects some aspects of burrowing performance and that different body shapes are adapted to different substrates.

S2-12 MORENO, L.E.; Oregon Museum of Science and Industry; *lmoreno@omsi.edu*

Communicating Science in Informal Learning Environments

Informal learning environments, such as museums and libraries, facilitate and promote lifelong learning in the communities they serve. Partnerships between science museums and STEM (science, technology, engineering and math) researchers create avenues to engage citizens of all ages with current research. Informal learning experiences are well positioned to inspire participants, and leverage stories of discovery and enigmatic creatures, such as extremophiles, to spark interest in science. The Oregon Museum of Science and Industry's Science Communication Fellowship program helps scientists take a meaningful role engaging with the public. Through the Fellowship program, scientist volunteers participate in a series of professional development workshops focused on building the skills to effectively communicate with and engage public audiences. The professional development program is based on the nationally acclaimed model, Portal to the Public. Fellows at the Oregon Museum of Science and Industry also collaborate with museum educators to develop a unique, hands-on activity and display representing their profession and current work. Fellows also act as important role models for young visitors, reinforcing the idea that science careers are accessible and exciting. The Science Communication Fellowship program shows how, in partnership, researchers and museums can promote science literacy and build a community-wide awareness of current research and important scientific issues.

101-4 MOROZ, LL*.; KOHN, AB; Univ of Florida; *moroz@whitney.ufl.edu*

Can Synapses Evolve Independently?

Hypotheses of origins of neurons and synapses are controversial, mostly due to limited comparative data. Here, we investigated the genome-wide distribution of the bilaterian 'synaptic' and 'neuronal' protein-coding genes in basal metazoans (Ctenophora, Porifera, Placozoa, Cnidaria). (1) There are no recognized genes uniquely expressed in neurons across all metazoan lineages. (2) Our analysis of ~200 genes encoding canonical presynaptic and postsynaptic proteins in bilaterians suggests that there are no true 'pan-synaptic' genes or genes uniquely and specifically attributed to all classes of synapses. The majority of these genes encode receptive and secretory complexes in a broad spectrum of eukaryotes. (3) The majority of genes encoding ion channels and receptors are broadly expressed in unicellular eukaryotes and non-neuronal tissues in metazoans. Therefore, they cannot be viewed as neuronal markers. However, the co-expression of multiple types of ion channels and receptors does correlate with the presence of neural and synaptic organization. Analysis of transcriptomes from 24 different ctenophores and 4 ctenophore genomes indicate that this lineage has a distinct 'synaptic' organization compared to other animals. We did not detect recognized orthologs of synthetic enzymes encoding several classical, low-molecular-weight (neuro)transmitters: glutamate signaling machinery is one of the few exceptions. Novel peptidergic signaling molecules were predicted for ctenophores, together with the diversity of putative receptors, many of which could be examples of a lineage-specific expansion within this group. In summary, our analysis supports the hypothesis of independent evolution of neurons and, as corollary, parallel evolution of synapses. Both factors and models underlying origins of synapses will be discussed. We suggest that the formation of synaptic machinery might occur more than once over 600 million years of animal evolution. Supported by NSF, NIH NASA

48-3 MORRIS, J.S.*; CARRIER, D.R.; University of Utah; j.s.morris@utah.edu

Sexual selection on skeletal shape in Carnivora

Because lifetime reproductive success is often dependent upon the ability to compete for mates, males tend to be more specialized for physical competition than females. Among mammals, polygyny enforced by male-male competition is the most common mating system. However, variation in social structure may lead to differences in the relative importance of intraspecific aggression. Here we present a large comparative data set on sexual dimorphism in skeletal shape in Carnivora in order to test the hypothesis that male carnivorans are more specialized for physical aggression than females. We tested this hypothesis using a set of functional indices predicted to improve aggressive performance. Results from comparative analyses on 26 carnivoran species indicate that sexual dimorphism in skeletal shape is widespread. Phylogenetic model selection on a variety of life history traits suggests that the evolution of this dimorphism is best explained by sexual selection. Functional traits that are predicted to enhance aggressive performance are more pronounced in males. Importantly, these traits may entail functional trade-offs with locomotor performance, signifying the importance of aggression in the life history of carnivorans and perhaps mammals in general.

64-4 MOSELEY, DL*; JOSHI, NR; PRATHER, JF; PODOS, J; REMAGE-HEALEY, L; William and Mary, UMass Amherst, Univ. of Wyoming; dlmoseley@wm.edu

A neuronal signature of accurate imitative learning in a songbird

Individual performance in cognitive and learning tasks has been shown to correlate with attributes of the central nervous system, including neural morphology and function. However, it is essentially unknown whether cognitive or learning performance scales with the electrophysiological properties of individual neurons. Here, we address this interface by characterizing both learning accuracy and neurophysiology in a cohort of hand-reared swamp sparrows, *Melospiza georgiana*. We report the discovery, in the sensorimotor nucleus HVC, of 'bridge' neurons that simultaneously and selectively represent two critical learning-related schemas: the bird's own song, and the single tutor model from which that song was copied. Strikingly, both the prevalence and response properties of bridge neurons closely predict the accuracy of tutor song copying on a per-individual basis. Moreover, the spike waveform kinetics of bridge neurons are consistent with a corticostriatal projection neuron phenotype. Our findings indicate that accurate imitative learning depends on a successful bridge between the representation of learning models and their sensorimotor copies within single cortical neurons.

72-7 MORRISON, E.S.*; BADIYAEV, A.V.; University of Arizona; esmorr@email.arizona.edu

Metabolic flux and robustness: Targets of hormonal regulation and phenotypic change in biochemical networks

Change in mechanisms that underlie robustness of a phenotype during development and function is a common route for phenotypic diversifications. The integration of hormones in deterministic networks of genes, proteins and enzymes can influence the robustness of these networks, but efficacy of hormonal regulation varies with structural properties of network elements. Here we first examine the relationship between dynamic and static properties of metabolic networks and their robustness. Second, using a metabolic network that produces carotenoid coloration in birds, we investigated the relative contribution of dynamic and static aspects of network to within- and among-population divergence in an avian species. This study sheds light on the role of hormonal control in the stability of the underlying deterministic network of a phenotype and establishes the functional mechanisms by which metabolic flux can affect evolutionary diversification.

101-7 MOUCHKA, ME*; SCHLENKE, TA; Reed College; mouchkam@reed.edu

An omics' approach for dissecting a behavioral immune defense in *Drosophila melanogaster*

The fruit fly, *Drosophila melanogaster*, offers a highly tractable system to characterize the ecology and evolution of natural host-parasite interactions. *D. melanogaster* is host to a number of endoparasitic wasp species that routinely infect up to 80% of flies in natural populations. Wasps lay their eggs in fly body cavities and surviving wasp eggs complete their life cycle by consuming their fly hosts. Once infected, flies can initiate a cellular immune response that results in melanotic encapsulation of the egg and parasite death. However, flies can also employ several behavioral mechanisms to prevent and/or treat infections. For instance, female flies reduce oviposition rates when wasps are present, presumably foregoing immediate reproduction to find safer oviposition sites. Unlike the cellular immune response, however, virtually nothing is known regarding the genetic mechanisms underlying *Drosophila* behavioral immunity. To this end, we characterized the *Drosophila* oviposition reduction response at the genomic/proteomic level in both nervous system and reproductive tissues. We identified hundreds of differentially expressed genes between control and wasp-exposed flies, including several with functions in sensory perception. While we did not find differences between control and wasp-exposed flies at the protein level, the corresponding proteins for many of the highest differentially expressed genes were not detected via mass spectrometry, perhaps suggesting that the proteins that drive the oviposition reduction behavior are low in abundance and fall below the detection threshold. Functional validation of the candidate genes identified in this study will provide a better understanding of how flies sense parasites, summarize and process sensory information, and subsequently alter normal reproductive activity.

73-5 MOUNTCASTLE, AM*; GRAVISH, N; COMBES, SA; WOOD, RJ; Harvard University, Univ. of California, Davis; mountcastle@fas.harvard.edu
Collapsible wing joints reduce collision costs in insects and insect-scale microrobots

Inadvertent collisions with obstacles are inevitable for small insects flying in the natural world, where they are buffeted by unpredictable airflows and confronted with dynamic obstacles that can thwart even the best flight control systems. Despite the prevalence of collisions among insects, few studies have examined their consequences, or explored morphological features that help minimize their potentially detrimental effects. The wings of bees, and likely other insects, collide with vegetation frequently (once per second on average), and over time these collisions cause the wings to wear down, decreasing flight performance and increasing mortality. Prior work has shown that wasp wings contain a flexible resilin joint positioned distally along the leading edge of the wing, which allows the wing tip to reversibly collapse during collisions, thereby mitigating wing damage. To characterize the material properties of the costal break, we performed displacement-controlled bending tests of wasp wings. Stress-strain curves reveal that this joint exhibits non-linear, strain-weakening behavior, with an initial stiffness that rapidly diminishes beyond a particular load threshold. Inspired by the beneficial role that this joint plays in damage mitigation for wasps, we used a PC-MEMS manufacturing process to build similar strain-weakening flexure hinges into the artificial wings of an insect-scale microrobot. In addition to promising increased wing longevity for flapping micro-aerial vehicles, incorporating these bio-inspired joints into a robotic platform has enabled us to test the additional hypothesis that collapsible wing joints may also facilitate insect flight control in cluttered environments, by damping wing collision forces that are transmitted to the body.

58-4 MOYERS, S/C*; ADELMAN, J/S; FARINE, D/R; HAWLEY, D/M; MOYERS, Sahnzi; Virginia Tech, Blacksburg, Iowa State University, Ames, University of Oxford, United Kingdom; sahnzi@vt.edu

Intraspecific competition for food influences pathogen transmission in house finches *Haemorhous mexicanus*

Competition for food resources can alter behavior in ways that influence disease dynamics. Resource competition can increase the frequency and intensity of intraspecific aggression, or alternatively, reduce the propensity for individuals to be social. Such changes in sociality could augment or diminish direct transmission of pathogens respectively. Limited resource availability can also increase indirect contact among individuals, thus facilitating environmental sources of pathogen transmission. Here we experimentally manipulated intraspecific competition and assessed effects on host behavior and pathogen transmission in a naturally occurring host-pathogen system. We varied the number of bird feeders available to captive flocks of 8-9 house finches *Haemorhous mexicanus*, and inoculated one bird per flock with *Mycoplasma gallisepticum* (MG), a bacterial pathogen that is transmitted both via direct contact and indirect exposure at bird feeders. Birds were fitted with passive integrated transponders to continuously track foraging behavior and social interactions at radio-frequency-identification equipped feeders. We found that the likelihood of MG transmission was significantly higher within low-competition flocks (4 feeders/flock) than high-competition flocks (2 feeders/flock), despite a significantly lower rate of intraspecific aggressive interactions within low-competition flocks. Here we discuss possible mechanisms for this transmission discrepancy including pathogen tolerance, increased sociality, and the relative frequency of exposure at bird feeders harboring MG.

72-6 MOUTON, J.C.*; DUCKWORTH, R.A.; MARTIN, T.E.; MTCWRU, Univ. of Montana, Missoula, MT, Univ. of Arizona, Tucson, AZ, USGS, MTCWRU, Univ. of Montana, Missoula, MT; james.mouton@umontana.edu

Age-specific mortality and avian life history evolution: a role for hormone-mediated maternal effects?

Life history theory predicts that age-specific mortality favors traits that optimize fitness by balancing investment between growth, reproduction and survival. For example, in songbirds, species with low adult mortality probability tend to have behavioral traits that favor their own survival over the care of offspring when faced with a predator. Physiological studies within species suggest that levels of maternal hormones in egg yolk provided to developing embryos may influence related behavioral traits in adults. Hormones can influence a variety of traits simultaneously, and selection on these hormonal pathways may allow rapid correlated change in important life history traits underlying adaptive strategies. Indeed, comparative studies have shown that yolk androgen concentrations are correlated with nest predation rates and explain growth and developmental rates across species. While offspring mortality is important, the effect of adult mortality on the evolution yolk hormone concentrations remains poorly understood. We examined the relationship between yolk testosterone and corticosterone concentrations, adult mortality probabilities, and behavioral responses to experimental predator presentations across sympatric songbird species, while controlling for nest predation rates. Understanding these relationships promises to shed light on the physiological mechanisms that underlie life history variation and the role of maternal effects in adaptive evolution.

7-1 MULLER, M S*; VYSSOTSKI, A; YAMAMOTO, M; YODA, K; Nagoya Univ., Univ. of Zurich/ETH Zurich, Nagaoka Univ. of Technology; martina.muller9@gmail.com

Individual differences in autonomic nervous activity during and after stress: implications for the study of personality

The study of individual differences in behaviour that persist over time and across contexts, or personality, has become a new paradigm for behavioural research and has been applied to a wide range of animal species. Yet the physiological underpinnings of personality remain poorly understood. As most personality tests measure reactions to novel stimuli and other potential stressors, personality differences may be linked to individual differences in the physiological stress response. Until now, there is only weak evidence for a link between personality and the hormone-mediated stress response (i.e. increased corticosterone in the blood), which may be because behaviour is usually measured in short tests lasting 1-2 minutes, and before corticosterone increases in the blood. An additional stress response occurs in the autonomic nervous system (ANS) immediately during stress, and before hormones increase in circulation. ANS activity during stress may therefore show a stronger correlation with behaviour from short-term tests. Heart rate (HR) and HR variability (HRV) provide a non-invasive measure of the balance between the activity of the two branches of the ANS: the parasympathetic nervous system (PNS), which promotes self-maintenance and restoration, and the sympathetic nervous system (SNS), which prepares an animal to survive danger. We attached ECG loggers to streaked shearwaters (*Calonectris leucomelas*) and from HR and HRV, quantified their PNS and SNS activity during and after handling stress. We also measured behaviour in various standardised tests. We repeatedly tested both ANS activity and behaviour in the same individuals over the course of two breeding seasons. We evaluate the evidence for individual differences in stress sensitivity of the ANS and discuss the implications for the study of personality.

97-11 MULLER, UK*; SCHWANER, MJ; BERG, O; California State University Fresno, Wageningen University; umuller@csufresno.edu

It's all about being brief - how minute suction feeders beat creeping flow

Suction feeding is the most common feeding mode in adult and larval fish. Yet our current understanding of its fluid mechanics shows that there is a lower size limit to suction feeders because suction is not effective in the creeping-flow regime. The smallest known suction feeders are members of the carnivorous plant genus *Utricularia* (bladderwort), which feed on zooplankton using underwater suction traps that are roughly 1 mm in size. We hypothesize that small suction feeders can escape the creeping-flow regime by completing their feeding strikes before viscous flow is fully developed. To test our hypothesis, we recorded the flow patterns generated by suction events at frame rates of up to 50,000 per second, and characterized the flow inside and outside the traps. We found that the fluid is accelerated at rates in excess of 45,000 m/s² and reaches peak speed in excess of 4 m/s, ensuring that the flow is inviscid. We conclude that the short duration of the feeding strike (less than 1 millisecond) creates an effective inward jet. The flow is well described by inviscid flow models, showing that flow speed is limited only by the pressure inside the trap, and that the initial acceleration is determined by pressure and channel length of the trap.

124-2 MUNOZ, MM*; LANGHAM, GM; BRANDLEY, MC; WILLIAMS, SE; MORITZ, CM; The Australian National University, National Audubon Society, University of Sydney, James Cook University; martha.munoz@gmail.com

Behavior influences physiological divergence along thermal clines in a group of tropical Australian skinks

There is pressing urgency to understand how tropical ectotherms can behaviorally and physiologically respond to climate warming. Here we test whether basking behavior influences physiological trait divergence across dramatic climatic gradients in several species of lygosomine rainforest skinks from the Wet Tropics of northeastern Queensland, Australia. Using both phylogenetic and conventional analyses, we demonstrate that physiological traits exhibit contrasting divergence patterns. Whereas montane lizards were more cool tolerant than those from lower elevation in all taxa, basking species (*Carlia* and *Lampropholis*) were substantially more heat tolerant than the shade skinks (*Gnypetoscincus* and *Saproscincus*). Heat tolerance, however, remained otherwise static across steep thermal gradients. The optimal sprinting temperature and performance breadth were both inversely correlated with environmental temperature: We suggest that as environmental temperatures approach lethal limits, basking species and shade-dwellers alike reduce surface activity patterns, leading to tighter specialization to cooler environmental temperatures. These findings demonstrate that some physiological traits shift concomitantly, whereas others shift (or remain inert) independently. This modularity in physiological evolution implies that responses to climate change can manifest in multiple independent directions, although it is unlikely that heat tolerance, the trait of most immediate importance to rising temperatures, can exhibit substantial shifts.

S9-2 MURDOCK, C.C.*; THOMAS, M.B.; University of Georgia, Pennsylvania State University; cmurdock@uga.edu

Estimating vector-borne disease transmission in a thermally variable environment

Several studies suggest the potential for climate change to increase malaria incidence in cooler, marginal transmission environments. However, the effect of increasing temperature in warmer regions where conditions currently support endemic transmission has received less attention. We investigate how increases in temperature from optimal conditions (27°C to 30°C and 33°C) interact with realistic diurnal temperature ranges (DTR: ±0°C, 3°C, and 4.5°C) to affect the ability of key vector species from Africa and Asia (*Anopheles gambiae* and *An. stephensi*) to transmit the human malaria parasite, *Plasmodium falciparum*. The effects of increasing temperature and DTR on parasite prevalence, parasite intensity, and mosquito mortality decreased overall vectorial capacity for both mosquito species. Increases of 3°C from 27°C reduced vectorial capacity by 51-89% depending on species and DTR, with increases in DTR alone potentially halving transmission. At 33°C, transmission potential was further reduced for *An. stephensi* and blocked completely in *An. gambiae*. These results suggest that small shifts in temperature could play a substantial role in malaria transmission dynamics, yet few empirical or modeling studies consider such effects. They further suggest that rather than increase risk, current and future warming could reduce transmission potential in areas with the highest disease burden.

34-1 MURONE, JM; DEMARCHI, JD; VENESKY, MD*; Allegheny College; mvenesky@allegheny.edu

Exposure to corticosterone affects host resistance, but not tolerance, to an emerging fungal pathogen

Corticosterone ("CORT") is the primary vertebrate stress hormone. When secreted at high levels, CORT is generally thought to be immunosuppressive. Despite the known association between stress physiology and disease resistance in domesticated organisms, it is unclear whether these associations are ecologically and evolutionary relevant in wildlife species. We explored these patterns using a 3x3 fully crossed laboratory experiment in which we exposed American toads (*Anaxyrus* [= *Bufo*] *americanus*) to CORT and the pathogenic chytrid fungus *Batrachochytrium dendrobatidis* ("Bd"). We assessed Bd infection levels and tested how CORT and Bd affected toad resistance, tolerance, and mortality. Exposure to CORT and Bd each increased toad mortality, but these two factors did not interact to affect mortality. Toads that were exposed to high levels of CORT had lower Bd abundance than toads exposed to ethanol controls or low CORT, a pattern opposite that of most studies on domesticated animals. Exposure to high levels of Bd reduced toad tolerance to infection; however, exposure to CORT (and the interaction between CORT dose and Bd dose) was non-significant. We demonstrated that host physiological condition can affect disease outcomes by enhancing toad resistance to infection. However, exposure to CORT also increased mortality and did not affect tolerance to infection. Collectively, these results show that physiological stressors can alter a host's response to pathogens, but that the outcome might not be straightforward. Future studies that inhibit CORT secretion are needed to better our understanding of the relationship between stress physiology and disease resistance and tolerance in wild vertebrates.

52-5 MUSCEDERE, M.L.*; WAXMAN, H.; BAO, Y.; PLUIMER, B.; TRANIELLO, J.F.A.; Hendrix College, Boston University; mmuscudere@gmail.com

Resilience in a miniature nervous system: olfactory impairment minimally affects task performance in ant workers

Task performance in social insects is governed by the interplay between ecological and social factors that influence task demand and regulated by neurobiological mechanisms. Workers of the ant *Pheidole dentata* develop their pluripotent and flexible task repertoire over the first few weeks of adult life in concert with a suite of physiological, neuroanatomical, and neurochemical changes. Our current research probes the limits of nervous system miniaturization and behavioral flexibility in *P. dentata* workers by impairing olfaction, their primary sensory modality, through ablation of one antenna. Using age-matched worker cohorts and multiple behavioral and neurobiological assays, we demonstrate remarkable resilience following reduction in the size of an already miniaturized nervous system. Unilateral ablation results in a 25% reduction in the volume of the primary olfactory input region of the brain, but increased expression of synaptic vesicle proteins in ipsilateral higher-order areas, potentially reflecting compensation in olfactory circuits. Worker task performance is largely preserved after our experimental injury: only pheromone trail-following is impaired, and preliminary evidence suggests that workers that sustain injuries earlier in life may regain some trail-following ability. Injured ants leave the nest sooner, engage in riskier behaviors such as foraging and aggressive interactions, and have increased levels of biogenic amine neuromodulators in their brains relative to same-aged, non-injured nestmates. Our results suggest that despite their minute brains, ants can compensate for significant sensory deficits and continue to effectively contribute to colony labor needs.

122-1 NAIR, A.M.*; NGUYEN, C.N; MCHENRY, M.J.; Univ. of California, Irvine; arjunnair0513@yahoo.com

Larval fish evade predators with a fast start in three dimensions

Larval fish evade predators with the 'fast start' escape response. We recently learned that this response can be with executed with three-dimensional trajectories. However, it is unclear whether the 3D motion is used to evade predators. Therefore, we measured the 3D kinematics of larval zebrafish (*Danio rerio*) as they were preyed upon by adults of the same species. The larvae did execute 3D fast starts and the elevation angle of these maneuvers was greatest for escapes initiated in close proximity, where the lateral line system is capable of detecting the bow wave of the predator. Fast starts beyond this range were presumably initiated in response to visual stimuli and were significantly lower in elevation. These results suggest that the fast start in larval fish is more three-dimensional when triggered by a combination of lateral line and visual stimuli. These results have implication for both the survival strategy of fishes and the neurophysiological control of the fast start.

129-2 MUTH, F.; PAPA, D.R.; LEONARD, A.S.*; University of Nevada, Reno, University of Arizona; anneleonard@unr.edu
The dynamics of bee learning with nutritionally complex floral rewards

Plants attract pollinators with visually complex displays and reward them with nutritionally complex resources. Ever since Karl von Frisch's Nobel Prize-winning work in the early 1900s, study of how bees learn these floral stimuli has emerged as an important model system for the study of learning, memory and foraging. However, nearly every study of bee cognition to date has used a sole reward, nectar, which serves as bees' main source of carbohydrates. However, bees also collect pollen from plants as their only source of protein. Surprisingly, little is known regarding whether bees can learn about flowers based on pollen rewards, and how this might interact with their ability to learn nectar associations. As plants may reward bees with nectar, pollen, or both resources, bees' relative ability to learn and remember floral features has implications for both their own foraging efficiency as well as conspecific pollen transfer for the plant. In a series of lab-based color learning experiments using artificial flowers, we show for the first time that bumblebees (*Bombus impatiens*) can learn to associate multiple visual cues with a pure pollen reward, and that these associations are remembered long-term. We found that bees can 'cope' with learning about these two reward types simultaneously when collecting each from different flowers, but that the presence of both nectar and pollen on a flower impaired a bee's ability to learn the pollen-color association. These results have implications for understanding the functional ecology of floral rewards and raise more general questions about how animals learn when multiple rewards are available—a common but underexplored feature of foraging in natural environments.

7-6 NASH, AE*; MACKESSY, SP; MCGLAUGHLIN, M;
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Social Network Structure in the Spiny Tailed Iguana, *Ctenosaura similis*: Preliminary Results and Next Steps

Understanding social organization in cryptically social animals is crucial for questions in behavioral ecology. Association with conspecifics may be based on characteristics including sex, personality, refugia location, and genetic relatedness. Cohorts may influence mate choice, foraging, predator avoidance, and disease transmission. I evaluate the effect of genetic relatedness and personality on the social structure of a group of Spiny-Tailed Iguanas, *Ctenosaura similis*, at Palo Verde National Park, Costa Rica. Lizard physical proximity interactions were recorded via focal sampling to build the association network of this group of animals. Network matrices were constructed of pairwise relatedness between iguanas. I use multiple regression quadratic assignment procedures (MRQAP) to model the influence of genetic relatedness on the structure of association networks. Analyses show no effect of kinship on organization patterns, which, while not uncommon in reptiles, is inconsistent with many socio-ecological models. Personalities or behavioral syndromes in *Ctenosaura similis* were determined running field assays of personality (flight initiation distance, novel object, and open-field testing). I present preliminary results from these assays. I also outline how the Encounternet wireless system will be used to gather future network data for these studies. This is the first large-scale study to look at behavioral type and social network structure in an egg laying, neotropical lizard. Because other *Ctenosaura* species are listed on the IUCN "Red List" as Near Threatened to Critically Endangered, analysis about this "proxy species" can provide a model for understanding what social structure characteristics may support a self-perpetuating population of endangered iguanas.

79-1 NATESAN, D*; SAXENA, N; EKEBERG, Ö; SANE, S P; National Centre for Biological Sciences, Bangalore, NCBS, Bangalore, KTH, Stockholm; dinesh@ncbs.res.in

Airflow mediated antennal positioning in flying hawkmoths

During flight, most insects hold their antennae at fixed positions relative to their head. This position depends on information from multiple sensory cues including optic flow and airflow. How does the antennal motor system combine inputs from such disparate sensory modalities to compute antennal position? We addressed this question using computational tools and experiments. From computational models we proposed that the antennal system comprises of two circuits: i) a purely mechanosensory one (Böhm's bristles mediated) that maintains antennal position (set point) ii) a multisensory one that computes antennal set point from multiple sensory cues. The models also predict the circuits to be autonomous but coordinated. We tested the predictions in the oleander hawkmoth, *Daphnis nerii*. Moths, bees and other flying insects respond to increasing airflow by moving their antennae forward. We show that the mechanosensory Johnston's organ (JO) at the base of the antenna senses airflow and sends information to the antennal motor system. In the absence of JO inputs, moths move and maintain position of antennae, but do not respond to increasing airflow by moving antennae forward. Thus, JO feeds into the multisensory circuit that computes antennal position. These data show that computation and maintenance of antennal position are mutually independent, as predicted by our models. Collectively, we show that the antennal system breaks down the task of dynamically responding to multiple modalities into: i) computation ii) maintenance of set point. We argue that this circuitry allows antennae to respond quickly to perturbations while retaining the ability to use slower modalities to determine position. This type of architecture is therefore robust and likely to be the generic architecture for most appendages.

119-3 NEAL, A.E.*; MOORE, P.A.; Bowling Green State University, BGSU; nealale@bgsu.edu

Static versus dynamic exposure assays: How are crayfish impacted by realistic exposure paradigms

Animals living within aquatic habitats regularly encounter chemical pollution as a result of anthropogenic activities. Typically, the toxicity of chemical pollutant or toxins is determined by the median lethal concentration (LC₅₀). However, LC₅₀'s do not provide an accurate representation of exposure to a pollutant within natural systems. In their native habitats, animals experience exposure as a fluctuating concentration as a result of turbulent mixing. Edwards and Moore (2014) showed that more turbulent environments produce exposures with a high degree of fluctuation in frequency, duration, and intensity. In order to more effectively evaluate the effects of pollutants, we created a more ecologically relevant exposure paradigm, utilizing both natural flow and substrate within a small mesocosm. A commonly used pharmaceutical, naproxen, was used as the toxin and female *Orconectes virilis* crayfish as the target organism to investigate changes in fighting behavior as a result of dynamic exposure. Flow-through streams with a substrate mixture of gravel and sand were constructed for dynamic exposure trials, while aquarium tanks were used for static exposures. Crayfish underwent either a static or a dynamic exposure to naproxen in 23 hour long trials. Following exposure, the target crayfish and an unexposed size matched opponent underwent a 15 minute fight trial. These fight trials were recorded and later analyzed using a standard ethogram. Results indicate that exposure to sub-lethal concentrations of naproxen, in both static and flowing conditions, significantly alters aggressive behavior. Results also indicate a significant difference in behavior as a result of different exposure paradigms.

43-2 NAVON, D*; ALBERTSON, RC; Univ. of Mass. Amherst; dnavon@cns.umass.edu

Assessing the genetic and developmental basis of morphological variation in the African cichlid radiation

Neoteleosts exhibit a stunning array of diversity in morphology and behavior that often matches their preferred feeding mode. For instance, benthic fish that remove food from the substrate tend to differ in consistent and predictable ways from pelagic fish that hunt mobile prey in the water column. Many fish lineages vary along this axis comprised of ecological, behavioral, and morphological variables. Much of the literature focuses on the differences between benthic and pelagic head and trophic structures; however, significant changes also occur to body shape and fin morphology. These differences likely evolve in response to distinct locomotive demands which are associated with various foraging tactics. Here we focus on natural variation in the development of fin morphology among several species of African cichlids, including the close ecological competitors *Labeotropheus fuelleborni* (LF) and *Tropheops* sp. redcheek (TRC). We next describe variation within an F2 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. We show that the genotype-phenotype map for fin and body shape is distinct from that for head/jaw shape, which suggests that these traits coevolve due to common selective pressures, not pleiotropy. We also present a notable candidate gene, *wnt7aa*, which may underlie variation in the number of bony fin rays that support the pectoral fin. We describe variation in the expression of *wnt7aa* across species, and use small molecules to modulate Wnt expression during fin development. Our work seeks to better understand the fundamental interplay between genetics, development, and morphology during this textbook adaptive radiation.

23-3 NEDVED, B.T.*; BATZEL, G.; HADFIELD, M.G.; University of Hawaii at Manoa; nedved@hawaii.edu

Molecular analysis of tube cement of the biofouling tubeworm *Hydroides elegans*

The serpulid polychaete *Hydroides elegans* is a common member of the warm-water marine fouling community. Its calcified tubes can form a layer several centimeters thick on submerged surfaces. The secretion of this tube begins early in metamorphosis and continues throughout the life of the worm. A strong cement is co-secreted with the tube, and both the tube and the cement are produced by a ventrally-positioned pair of "shell glands" located in the first thoracic segment. Little is known about either the composition of this cement or of the genes that encode it. In an attempt to better understand these cements, we used RNA-sequencing to assemble and annotate transcriptomes from both the first (containing putative cement glands) and second thoracic segments (lacking cement glands) of adult worms. We further determined the pool of transcripts that were differentially expressed in the first segment. No marine-invertebrate cement homologs were found in this transcript pool. Because the gene products for the cements are secreted and may be novel, we assembled a group of transcripts that were upregulated in the first segment, did not align with any proteins in NCBI databases, and contained a signaling peptide sequence. We then used whole-mount *in situ* hybridizations to determine where the 25 most highly expressed transcripts are expressed in competent larvae and in juvenile worms (24h post-induction). Initial results show that some of these transcripts are uniquely expressed in and around the shell glands in both larvae and juvenile worms, and may be components of the tube cement. Assembling a full set of transcripts compromising the cements of *H. elegans* promises to reveal a novel glue that is secreted and can set in seawater.

59-1 NEEMAN, N; SPOTILA, JR; O'CONNOR, MP*; Drexel Univ; mike.oconnor@drexel.edu

A physiologically-based model of sea turtle remigration intervals

The inaccessibility of sea turtles to census during pelagic foraging and substantial cyclic variation in yearly nesting numbers (cohorting) complicate efforts to understand turtle population sizes and dynamics and efforts to conserve turtles. We formulated a relatively simple, physiologically based, stochastic model of sea turtle remigration intervals (intervals between nesting bouts) as influenced by conditions on the foraging grounds - particularly temperatures. Simulations suggest that cohorts (cyclic variation in numbers of turtles) were likely to develop under a variety of conditions, but could be enhanced by cyclic variation in foraging conditions (temperature). Cohorts once developed, however, were not stable and tended to diffuse over 3-10 years, unless reinforced by continued cyclic variation in foraging conditions. Temperatures on the foraging ground affected the diffusion of cohorts in our simulations, with relatively low temperatures resulting in faster dissolution of cohorts. Single year temperature pulses could synchronize nesting, inducing cyclic variation in nesting. This suggests that sea turtle nesting dynamics are a complex mix of induced cohorts that tend to diffuse away but can be reinforced by cyclic variation in conditions on the foraging ground. These cyclic variations will tend to be superimposed on longer term dynamics of the sea turtle population itself.

95-2 NEWCOMB, LA*; JEFFERDS, I; STRENGE, R; FRIEDMAN, CS; CARRINGTON, E; University of Washington, Penn Cove Shellfish; newcombl@uw.edu

Congener mussel species show opposite responses to elevated temperature

One predicted biological consequence of rising temperatures due to global climate change are shifts in species' ranges and latitudinal distributions. Cold-adapted species may suffer range contractions, while warm-adapted species may experience range expansions. Washington State mussel growers farm the warm-adapted *Mytilus galloprovincialis* and cold-adapted *M. trossulus*. The persistence of these congener species on aquaculture lines is closely tied to their attachment strength. It is not known how warming waters might affect attachment of these species. We compared attachment strength of *Mytilus trossulus* and *M. galloprovincialis* exposed to temperatures ranging from 10 to 25°C. We found these species are equally strong at temperatures between 10 and 18°C. Above 18°C, they showed opposite responses to rising temperature: *M. trossulus* attachment weakened by 89% while *M. galloprovincialis* attachment increased by 62%. As water temperatures vary seasonally in Washington's coastal bays, we predict attachment strength of *M. trossulus* will peak in the cooler winter months while that of *M. galloprovincialis* will peak in the warmer summer months. We tested these predictions by measuring attachment strength monthly on mussels growing in suspension culture in Penn Cove (*M. trossulus*), Quilcene Bay and Totten Inlet (*M. galloprovincialis*). Our field observations reflect the findings of our lab studies: seasonally weak attachment strength in *M. trossulus* coincided with periods of high temperature. *Mytilus galloprovincialis* attachment did not vary seasonally, and thus showed no correlation with temperature. Warming oceans could increase the competitive advantage of *M. galloprovincialis* in more northern latitudes, with detrimental effects on native *M. trossulus* populations.

51-5 NEVITT, Gaby*; HOOVER, Brian; EDWARDS, Scott; Univ. of California, Davis, Harvard University; ganevitt@ucdavis.edu

The neuroecology of avian chemical signaling: Exploring potential molecular markers of self / non-self recognition in a seabird model

Chemical ecology of birds is a new and exciting area of research, and we have been exploring molecular signals contributing to odor profile and mate choice focusing on genes of the Major Histocompatibility Complex (MHC). The relationship between MHC, personal odor and mate choice has been the subject of heated controversy in natural populations, in part, due to the requirement for sufficiently large sample sizes to avoid Type I errors. To test whether MHC Class IIB plays a role in scent-based mate choice decisions, we have conducted a large-scale, multi-year study of Leach's storm-petrels (*Oceanodroma leucorhoa*). We genotyped partial genomic fragments of two MHC Class IIB gene duplicates (Ocle-DAB1 and Ocle-DAB2) in nearly 1500 birds to characterize the MHC variability in a natural population and test for evidence of MHC-based disassortative mating. We used randomization tests to compare observed and bootstrapped medians of 4 MHC similarity metrics (pairwise heterozygosity differences, band-sharing coefficients, mean amino-acid substitutions, maximum amino acid substitutions) in 327 established pairs and found no significant evidence of disassortative mating (HZ: $p=0.47$; band-sharing: $p=0.32$; mean AA: $p=0.27$; maximum AA: $p=0.35$). This sample size is unprecedented in any MHC study investigating disassortative mating in a wild population. We further show that test subjects can discriminate personal odors of conspecifics when MHC class IIB genotype is held constant ($n=24$, $p<0.01$, binomial test), suggesting that factors other than MHC class IIB contribute to personal odor discrimination in this species. These results provide one of the most definitive characterizations to date of the role (or lack thereof) of MHC Class IIB in individual odor discrimination and mate choice in a natural population.

90-2 NEWTON, KC*; KAJIURA, SM; Florida Atlantic University; knewton5@fau.edu

The yellow stingray, *Urobatis jamaicensis*, has a magnetic sense but can it use the geomagnetic field to derive a sense of location

The strength and inclination angle of the geomagnetic field vary predictably with latitude and magnetically sensitive animals can use these cues to derive a sense of location during migrations. Our previous work has demonstrated that the yellow stingray, *Urobatis jamaicensis*, can detect magnetic fields from permanent magnets. However, it is unknown if elasmobranchs can detect changes in the strength or inclination angle of a magnetic field. Naïve stingrays were placed into two treatment groups and their initial response to magnetic stimuli served as a control. Magnetic stimuli were 2.5X the range of values that this species would encounter across its distribution. Individual stingrays were trained to shuttle across an experimental tank when the magnetic field strength (+45 uT) or the inclination angle (+75°) surrounding the tank was altered by two orthogonal Merritt four-coil electromagnets. Once the rays learned the task the rays were then exposed to stimuli from the other treatment group to determine if the rays could discriminate between the two magnetic stimuli.

107-1 NG, P.Q.*; SPRINGTHORPE, D; FULL, R.J.; University of California, Berkeley; qwnpng@gmail.com

Mobile manipulation: Ghost crab climbing using pincer-like claws

We typically consider arthropod pincer-like appendages or chelae as structures to manipulate objects such as food, predators, competitors and barriers to movement. We discovered a behavior in the ghost crab, *Ocypode quadrata*, where crabs required chelae to manipulate their body over tall, vertical obstacles. Ghost crabs hurdled narrow, vertical walls up to 16 cm high, approximately 8x hip height and greater than their sideways leg span, using both their legs and chelae. To explain this exceptional hurdling behavior, we presented ghost crabs with obstacles ranging from 2 -16 cm high. At low heights, crabs simply raised their hip height and stepped over the obstacle. For obstacles greater than 6cm, however, ghost crabs adopted a different strategy where chelae became critical to the crabs' capability. We tested the ability of crabs to manipulate their body using their chelae by immobilizing the chelae and then challenging crabs to hurdle a 10 cm obstacle. Immobilization reduced the success rate to zero compared to unconstrained controls which all scaled the hurdle. Quasi-static models of mobile manipulation during the hurdling behavior suggest that chelae are critical because they provide the torque necessary to manipulate the animals' body over the complex, three dimensional terrain they encounter on the upper beach and in the supratidal zone. Ghost crab hurdling using pincer-like claws provides biological inspiration for the design of legged robots where graspers could not only be used to move objects, but manipulate the body itself for enhanced mobility.

18-7 NIELSEN, M.E.*; LEVIN, E.; DAVIDOWITZ, G.; PAPAJ, D.R.; University of Arizona; nelsenm@email.arizona.edu

Color alters thermoregulatory behavior in *Battus philenor* caterpillars by changing the behavior's cue

When an organism has multiple plastic traits, they can alter each other's expression. This could occur, however, either because one trait changes the cues received from the environment that the other responds to or because it changes the reaction norm the other trait uses to respond to those cues. *Battus philenor* caterpillars we have previously established that a thermoregulatory color change reduces the use of thermoregulatory behavior, and we sought to test which of these mechanisms cause this effect. Our original demonstration that black caterpillars seek thermal refuges at lower environmental temperatures than red ones involved a field experiment with live caterpillars. In subsequent lab experiments, we have shown that this effect remains if intense light is used to heat the caterpillars; however, if this light is removed and caterpillars are heated by primarily by conduction, color no longer affects the refuge-seeking behavior. Additionally, color has no effect on the sensitivity of the caterpillar's metabolism to temperature, a potential mechanism which would likely alter the thermoregulatory behavior's reaction norm. As such, we find that the effect of color on thermoregulatory behavior is due to how it changes the cues which trigger color change (i.e., body temperature), rather than the reaction norm that responds to those cues. Cue-based interactions like this one are likely to be common in thermoregulation, and they also present a novel, within-generation consequence for any alterations an organism makes to its environment (i.e. niche construction). In other circumstances, both mechanisms presented here remain possible and need to be considered more broadly across additional species and ecological contexts.

99-5 NIEBERGALL, AK*; DOUGHERTY, LF; CALDWELL, RL; Univ. of California, Berkeley; alex.niebergall@berkeley.edu
Analysis of Sulfur Presence in Tissue of *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 lip has a dense collection of silica nanospheres, which are highly scattering, and the other side of the mantle tissue is absorbent. Experiments were conducted to determine the behavioral function of the flashing. One hypothesized fitness value is aposematic signaling; the idea that the photic display is meant to deter predators. This hypothesis relies on two fundamental pieces of evidence: that the clams react to the presence of potential predators and that their tissue is noxious or toxic to predators when consumed. To test the behavioral component of aposematism, the clams were presented with stimuli of a looming predator. 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 the stimuli. To determine the palatability of the tissue, scanning electron microscopy (SEM) with energy dispersive x-ray spectroscopy (EDS) was performed on prepared tissue samples. The presence of sulfur was identified in mantle and tentacle tissue. Volatile sulfur compounds have been known to act as chemical defense mechanisms in nature, including guava plants, snails and algae. To test for sulfuric excretions, electrospray ionization mass spectrometry (ESI-MS) was performed with rinse water from clams that were calm (not in the presence of a predator) and disturbed (attacked by the mantis shrimp, *Odontodactylus scyllarus*, until shell breakage occurred). Unique peaks were identified in the ESI-MS of the disturbed rinse that did not exist in the calm clam rinse, and analyses are ongoing.

56-5 NISHIGUCHI, MK*; JONES, C; YILDIZ, F; New Mexico State University, University of California, Santa Cruz; nish@nmsu.edu

Experimental evolution of pathogenic biofilms: How predator-prey interactions influence virulence in *Vibrio cholerae*

Understanding the combined effects of both environmental and host selection on the evolution of microbes to a specific host species has been difficult and confounding due to the various mechanisms that are responsible for a successful association. Phenotypic *in vitro* studies using experimental evolution and strain specific genomic approaches have been useful in deciphering which particular components are key to ensuring a successful symbiosis, yet the order in which specific adaptations to benefit both host and symbiont occur has been questionable. We set out to examine how environmental/biotic stresses lead to the adaptation and therefore selection of highly specific *Vibrio cholerae* biofilms that are more resistant to abiotic stresses. By experimentally evolving both wild-type and mutated strains of pathogenic *V. cholerae*, we assessed whether grazing by various protozoan predators promoted the evolution of less competitive and/or effective strains to more dominant isolates. We also measured whether the same grazing pressures have pleiotropic effects upon other aspects of biofilm production (attachment, polysaccharide production). By comparing both early and late biofilms with two different types of grazers (*Rhynchomonas nasuta* and *Acanthamoeba castellanii*), we were able to determine whether predator-prey interactions outside the host caused increased biofilm production (and possibly virulence) in this human pathogenic bacterium.

SI-6 NIVEN, J.E.; NIVEN, Jeremy; University of Sussex, Falmer, Brighton, UK; J.E.Niven@sussex.ac.uk
Voltage-gated potassium channels improve the energy efficiency of signalling in fly photoreceptors
 Nervous systems, neurons and neural circuits are under selective pressure to produce behaviour adapted to an animal's environment but are also subject to energy costs. These costs are dominated by electrical signals because of the need to maintain ionic concentration gradients in neurons. Consequently, voltage-gated conductances that permit ion flow across the neural membrane are well placed to adjust ion flux and influence the energy consumption of signal processing, though their precise role is unclear. Fly R1-6 photoreceptors have been a key system for studying the trade-offs between cost and performance in single neurons; a Law of Diminishing Returns relates performance to cost so that improving performance requires ever larger increases in cost. The photoreceptors of different fly species contain different sets of voltage-gated conductances with different biophysical properties that are related to their visual ecology. Blowfly photoreceptors contain two voltage-gated K⁺ conductances, a fast and a slow delayed rectifier (DR). By modelling these photoreceptors, we show that the DRs reduce photoreceptor resistance and produce negative feedback that reduces membrane impedance below a specific frequency determined by activation kinetics. The negative feedback from DRs decreases gain and increases bandwidth. In doing so, the DRs do not incur the energy cost of decreasing the resistance of a passive RC membrane. In doing so, they save energy and improve energy efficiency. The DRs create a low bandwidth, low cost regime at low light intensities, and a high bandwidth, high cost regime at high light intensities, enabling blowfly photoreceptors to match energy investment in bandwidth to signal quality. Thus, voltage-gated K⁺ conductances permit differential energy investment, improving energy efficiency with widespread implications for neuronal function and evolution.

28-7 NOREN, D.P.*; HOLT, M.M.; DUNKIN, R.C.; WILLIAMS, T.M.; NOAA NMFS Northwest Fisheries Science Center, Univ. of California, Santa Cruz, Univ. of California, Santa Cruz; dawn.noren@noaa.gov
Echolocation is Cheap for One Vertebrate: Dolphins Conserve Oxygen while Producing High-Intensity Clicks at Depth
 Echolocation has evolved in bats, cave dwelling birds, some shrew, and Odontocetes (toothed whales, dolphins, and porpoises). The production of echolocation signals is linked to respiratory cycles in both bats and birds, usually at a high energetic cost. Unlike their terrestrial counterparts, the conservation of oxygen is paramount for Odontocetes that echolocate while holding their breath underwater. To determine whether echolocation under water is also associated with a large energetic cost in dolphins, we used flow-through respirometry to measure the metabolic cost of click production at depth in trained male bottlenose dolphins (n=2). As expected, metabolic rates (MR) decreased upon submergence during control (silent) and click production trials, concomitant with reduced respiration rate and metabolic adjustments associated with the dive response. The reduction in MR during submergence was less when dolphins produced clicks, compared to when they were silent. On average, MR during submerged clicking was 1.1 X MR during submerged silence. MR increased linearly with increasing cumulative energy flux density (cEFD) of all clicks produced during bouts; however, most MRs measured during click production were within the range measured for silent dolphins. Thus, the energetic cost of click production in submerged bottlenose dolphins is negligible. Unlike bats, dolphins produce echolocation signals independent of respiratory cycles via a complex nasal structure that recirculates air while breath-hold diving. This minimizes oxygen consumption while clicking, and consequently, dolphins echolocate at a low energetic cost.

47-4 NOEL, A.*; IMGRUND, J.; ZHONG, X.; SAHA, R.; HU, D.L.; Georgia Institute of Technology; alexis.noel@gatech.edu
Fluid mechanics of taste
 Saliva plays a key role in maintaining oral health as well as aiding in digestion, speech and sensation. Lack of saliva, also known as dry mouth syndrome, increases risk of tooth decay and alters sense of taste; nearly 10% of the general population suffer from this syndrome. In this experimental study, we investigate the spreading of fluids on wet and dry tongues. We have found that fluids flow faster on a flooded tongue than a dried tongue. By using fluorescent particles, we are able to see the flow of fluids into the taste receptors embedded in the tongue. The role of papillae height and spacing is also analyzed across a variety of animal species.

25-2 NOVARRO, A.J.*; BELY, A.E.; University of Maryland, College Park; Anovarro1@gmail.com
Why don't lungless salamanders follow Bergmann's rule?
 While Bergmann's Rule (i.e., organisms are larger in cooler climates) applies to many organisms, it is not ubiquitous among ectotherms. Notably, Bergmann's Rule does not apply to lungless terrestrial salamanders (genus *Plethodon*). *Plethodon* salamanders prefer cool microhabitats, but are physiologically and behaviorally limited by moisture and competition. As such, we were interested in whether moisture and competition outweigh the effects of temperature on body size. To determine the effects of abiotic (i.e., temperature and moisture) and biotic (i.e., intra- and inter-competition) variables on average adult body size, we performed repeated surveys of *Plethodon* species along an elevation gradient on Salt Pond Mountain, Virginia. We continuously recorded temperature and moisture and measured the body size of the most abundant species, *Plethodon cinereus*. Although competition for food and space is intense among *Plethodon* salamanders, moisture limits virtually all activity. Thus, we predict that moisture will be the greatest determinant of adult body size in *Plethodon cinereus*. By identifying the drivers of adult body size in natural populations, our results will contribute to ecogeography theory and the global understanding of species' responses to climate change.

131-1 NUNEZ, CMV*; ADELMAN, JS; SMITH, J; GESQUIERE, LR; RUBENSTEIN, DI; Iowa State University, Princeton University, Duke University, Princeton University; nunezcmv@iastate.edu
Linking social behavior and stress physiology in feral mares (*Equus caballus*): Group transfers elevate fecal cortisol levels

Feral horses (*Equus caballus*) have a complex social structure, the stability of which is important to their overall health. Behavioral and demographic research has shown that decreases in group (or band) stability reduce female fitness, but the potential effects on the physiological stress response have not been demonstrated. To fully understand how band stability affects group-member fitness, we need to understand both behavioral and physiological consequences of decreases to that stability. We studied group transfer behavior in feral mares (an activity that induces instability, including both male and female aggression) on Shackleford Banks, NC. We found that mares in the midst of transferring groups exhibit increased fecal cortisol levels. In addition, mares making more group transfers show higher levels of cortisol two weeks post-behavior. These results offer insights into how social instability is integrated into an animal's physiological phenotype. In addition, our results have important implications for feral horse management. On Shackleford Banks, mares contracepted with porcine zona pellucida (PZP) make approximately 10 times as many group transfers as do untreated mares. Such animals may therefore be at higher risk of chronic stress. These results support the growing consensus that links between behavior and physiological stress must be taken into account when managing for healthy, functional populations.

28-6 O'MARA, M.T.*; VOIGT, C.C.; TER MAAT, A; POLLOCK, H.S.; BURNES, G.P.; DESANTIS, L.M.; DECHMANN, D.K.N.; Dept. of Migration and Immuno-ecology, Max Planck Inst. for Ornithology; Dept. of Biology, Univ. of Konstanz; Smithsonian Tropical Research Inst., Leibniz Inst. for Zoo and Wildlife Research, Dept. of Behavioural Neurobiology, Max Planck Inst. for Ornithology, Program in Ecology, Evolution and Conservation Biology, Univ. of Illinois Urbana-Champaign, Dept. of Biology, Trent Univ.; tomara@orn.mpg.de

Rapid Metabolic Rates and Physiological Counter-Strategies in Tent-Making Bats

The balance between energy intake, distribution and expenditure drives many aspects of animal ecology and evolution. However, the relationship between the energetic cost of life and how it is maintained within an ecological context is not well understood for most animals. We take a multi-pronged approach including instantaneous energetic expenditure (heart rate), metabolic incorporation rates (carbon dioxide isotopes of breath), and energy mobilization (cortisol) to investigate how tent-making bats (*Uroderma bilobatum*) maintain a high-energy lifestyle fueled primarily by fig juice. *Uroderma* undergo cyclical depressions in heart rate at rest to less than 200 beats per minute (bpm) that counters heart rates of over 900 bpm during flight. They use some of the fastest metabolic incorporation rates measured in vertebrates to support this explosive metabolic shift between rest and flight and elevate circulating cortisol values to 10-15 times basal values when stressed, which indicates rapid mobilization of glucose reserves as bats transition from rest to active states. These data suggest that *Uroderma* suppress energetic expenditure at multiple physiological levels when at rest, but rapidly mobilize resources to fuel activity and their specialization on a widely distributed, but temporally unpredictable fruit resource.

80-2 O'BRIEN, H.D.*; FAITH, J.T.; JENKINS, K.; PEPPE, D.J.; TRYON, C.A.; Ohio University, U. Queensland, SUNY Albany, Baylor, Harvard; haley.d.obrien@gmail.com
How to grow a trumpet: Ontogeny elucidates hollow nasal crest evolution in dinosaurs and mammals

Fully ossified, hollow nasal crests occur rarely in vertebrates, & even less often interact directly with the airway. Hadrosaur dinosaurs are the best known example of such craniofacial morphology. Until a mass death assemblage of the alcelaphine bovid *Rusingoryx atopocranium* was unearthed from Kenyan Pleistocene deposits, osseous nasal crests were unknown outside of Archosauria. Adult *Rusingoryx* reveal anatomical & functional analogs with lambeosaurine hadrosaurs, suggesting deep homoplasy between these distantly related groups. An understanding of how this bizarre morphology evolves & why it is so rare remains incomplete when only adults are considered. The presence of juveniles in the *Rusingoryx* assemblage presents a unique opportunity to examine evolution of nasal crest ontogeny, in which crest development strengthens bovid-hadrosaur parallels. In this case, analogous cranial elements are rearranged in a surprisingly similar sequence. In both taxa, elevation of the incipient crest is accomplished by a dorsal expansion of the (pre)frontal bones. The caudal border of the crest migrates from anterior to posterior relative to the orbit with strong caudal flexion of the frontal bones. Outgroup comparisons uncover similar shifts in both external & internal cranial morphology, including dorsal rotation of the nasal passages prior to crest inflation. Although hadrosaurs & bovids have each achieved osseous nasal crests from non-homologous cranial architecture, the ontogenetic & evolutionary antecedents to crest formation are largely similar. This suggests that, in order for terrestrial vertebrates to evolve hollow circumnarial domes, a suite of coordinated and highly specific developmental-evolutionary shifts must occur, perhaps in response to a limited set of environmental factors.

101-2 O'ROURKE, C.*; RENN, S.C.P.; O'ROURKE, Cynthi; Reed College; kickseine@gmail.com

Regulation of Trade-Off Behaviors in a Mouthbrooding Cichlid Fish

Trade-offs between fundamental life history traits strongly influence fitness, and yet the molecular mechanisms underlying trade-off behaviors - for example decreases in somatic maintenance that allow for increases in reproductive output - are rarely explicitly studied. Here we investigate both feeding and parental care behaviors and molecular regulatory pathways in *Astatotilapia burtoni*, a cichlid fish that undergoes extended voluntary periods of starvation and wasting while mouth-brooding offspring. We investigate activity levels of neuropeptides implicated in feeding and parental-care regulatory circuits in the cichlid brain through immunohistochemical staining, and track gene expression patterns in select regions of the hypothalamus and pituitary as well as in key peripheral tissues such as the midgut and liver through RNA-seq. We furthermore assess feeding motivation through operant conditioning assays, and plasma levels of key behavior-regulating hormones through ELISAs. The results of our on-going work implicate differential regulation of both appetite and metabolic pathways between brooders and fasted non-brooding subjects, as well as hormonal changes correlating with degree of parental care investment. Each of these levels of investigation both informs and is informed by the output of the other levels, allowing us to pursue a model of appetite and parental care co-regulation of greater depth than would be possible through the independent investigation of these trade-off behaviors at individual systemic levels.

S4-4 OAKLEY, TH*; RAMIREZ, MD; Univ. of California, Santa Barbara; oakley@lifesci.ucsb.edu

Opsins without eyes - precursors or derivatives?

A common conception of eye evolution is the "Gradual-Morphological (GM) model", which posits that eyes originated as a simple light sensitive patch that gradually elaborated into eyes through natural selection. Surprisingly, the prediction of GM model that simple photoreception is ancestral is rarely (if ever) tested with phylogenetic comparative methods. Furthermore, focus on the GM model draws attention away from the possibility that simple light sensors could be not precursors, but rather sometimes derived from components of complex eyes. Although data are incomplete, I will review instances of simple light sensors in modern animals whose genetic components may be descended from ancestral precursors of eyes. I will also review instances of simple light sensors in extant groups whose genetic components in contrast may be descended from more complex eyes. With additional data, these cases of 'opsins without eyes' could show that extraocular light sensitivity is very common in animals and may illustrate the starting point (precursor) or alternatively a derivative of the end point of the traditional GM model of eye evolution.

45-2 OLBERDING, J.P.*; DEBAN, S.M.; University of South Florida, Tampa; jpolberding@mail.usf.edu

Temperature dependence of muscle work is determined by load

The temperature dependence of muscle work has implications for whole-organism performance in behaviors involving muscle-powered movements in variable-temperature environments. Behaviors using elastic energy-storage mechanisms are thermally robust, but this relies on the ability of muscle to do the same work at any temperature. We investigated the effects of temperature on the work done by isolated plantaris muscles from Cuban tree frogs (*Osteopilus septentrionalis*) while also varying the load against which the muscles were contracting. Stimulating muscle contraction through the sciatic nerve, we calculated work done on a lever ergometer by simultaneously measuring the force exerted by the muscle and the displacement of the lever. Experiments were conducted at five different temperatures (9 - 25 °C) under six different loads for each muscle. Effects of temperature on muscle work depended on the load the muscle was moving. Muscle work on larger loads was more sensitive to temperature changes than muscle work done on smaller loads. For high loads, muscle work at the lowest temperature was only 25% of the work done at high temperatures. For low loads, however, muscle work saw no reduction from high to low temperatures. This pattern may be due to the temperature dependence of muscle force output, which decreases at lower temperatures. At larger loads muscle force is a more important determinant of work than is displacement. These results suggest that performance is affected by temperature when muscles move large loads, but behaviors using muscles to move relatively small loads are robust to changes in temperature. Muscles associated with elastic structures in energy-storage mechanisms may be expected to operate at lower loads and thus maintain performance in variable-temperature environments.

S3-9 OKAMURA, Beth; Natural History Museum, London, UK; b.okamura@nhm.ac.uk

Covert infections, host tolerance and environmental change

Many parasite life histories incorporate a cryptic stage when parasites persist as covert (asymptomatic) infections when parasites are hidden in immunologically privileged sites or otherwise tolerated (e.g. latent periods of malaria and tuberculosis). Horizontal transmission occurs when cues trigger a transformation from cryptic to infectious stages, resulting in overt infection and disease. Covert infections are a common parasite strategy with improved detection methods demonstrating cryptic stages in a range of animal hosts and parasites, yet their significance is little explored. How might environmental change influence covert infection dynamics? This question is addressed by focusing on a colonial host (freshwater bryozoan)-endoparasite (myxozoan) system to examine how environmental and host conditions interact to influence infection dynamics and, in turn, cause an emerging fish disease. Our research reveals host condition-dependent cycling between covert and overt infections. When hosts are growing vigorously (warm temperatures/abundant food) virulent overt infections temporarily castrate bryozoans, producing stages infectious to fish and disease outbreaks. Stressful host conditions cause regression to avirulent cryptic stages. The parasite also exploits host clonal replication, undergoing 'vertical transmission' to asexual dispersive propagules. Such environmentally-conditioned persistence strategies are linked with high infection prevalences over space and time and facilitate parasite dispersal, establish disease reservoirs and trigger disease emergence. As environmental change (increasing temperatures and productivity) frequently drives parasite proliferation, disease outbreaks and spread mediated by covert/overt infection dynamics in permissive hosts may become increasingly common.

80-3 OLSEN, AM*; WESTNEAT, MW; Univ. of Chicago, IL; aolsen@uchicago.edu

Two levers and a linkage: patterns of morphological and functional diversity in the upper beak, lower beak and cranial linkages of birds

The beaks of birds display remarkable morphological, functional and mechanical diversity. However, behind the upper and lower beak of most birds are eight to nine additional mobile bones arranged in parallel sets of four- and five-bar linkages, forming a coupled mechanical system consisting of two levers and a linkage. These linkage bones enable rotation of the upper beak and serve as attachment sites for muscles that adduct the lower beak. While the geometry of these linkage bones likely has implications for beak function, little is known about how these geometries vary across birds and whether particular geometries correspond to particular beak shapes. In this study, we use recently published methods for collecting 3D shape data and predicting linkage kinematics to compare the morphology and leverages of the upper beak, lower beak and linkage bones from at least one representative of each bird order. We compute leverage of the upper and lower beak by measuring the effective mechanical advantage (EMA) for different outlever lengths along the tomium and inlever lengths at force input points. We compute leverage of the linkage bones by estimating kinematic transmission for force inputs to the quadrate, pterygoid and palatine. We then test whether mechanical changes in these components evolve congruently toward the same functional extreme or whether they evolve independently. We find that posterior head width and differences in the articulation of the jugal and palatine with the upper beak determine the major axis of variation in linkage morphology and that a single lever or linkage can yield widely varying leverage values, depending on the assumed sources of input and output force in the system. This work was funded by NSF grants DGE-1144082, DGE-0903637 and IOS-142549.

129-6 OLSON, C.R.*; YU, B.; OWEN, D.C.; RYABININ, A.E.; MELLO, C.V.; Oregon Health & Science University, Lewis & Clark College; olsonch@ohsu.edu

Alcohol effects on vocal learning and brain activation in zebra finches

Zebra finches are commonly used to study vocal learning, which provides the basis of human speech and language acquisition. Here we describe the effects of alcohol on song learning and activation of the vocal circuit. Male juveniles learn to sing during a critical period when they first establish a tutor song auditory memory, and then learn to produce that song over a prolonged period of sensorimotor practice. Juveniles were provided free access to 3.5% alcohol during the song learning period (from 45 - 125 days of age), while control siblings received only water. Singing was recorded weekly during alcohol-free conditions, until adulthood. To evaluate the effects of alcohol on song we measured song stereotypy and the similarity of songs compared to tutors in experimental and control groups. Alcohol increased stereotypy of undirected (plastic) song and this effect was detectable within 10 days after the initial alcohol exposure. The similarity of pupil song at maturity to tutor song was diminished in the alcohol group, suggesting that alcohol either impaired the recall or imitation of the tutor template. We also note alcohol increased horizontal song transmission, where finches were more apt to learn from other juveniles, to assess the mechanism that may underlie these behavioral changes, finches raised to 70d were given 6.5% alcohol or water and sacrificed after intense singing. *In-situ* hybridization revealed that alcohol decreased song-induced expression of ZENK (*egr-1*) in Area X, a basal ganglia nucleus crucial for song learning. We suggest that alcohol affects vocal development by inhibiting a brain circuit required for vocal motor plasticity, thus limiting the bird's ability to learn tutor song.

102-1 ORBACH, DN*; MARSHALL, CD; WÜRSIG, B; MESNICK, SL; Texas A&M University at Galveston, Southwest Fisheries Science Center, NOAA; orbachd@tamug.edu

Variation in Reproductive Tract Morphology of Female Common Bottlenose Dolphins (*Tursiops truncatus*)

Cetaceans exhibit unusual protrusions of the vaginal wall into the lumen. Inconsistent terminology and a lack of anatomical landmarks in the literature have hindered explorations of diversity and evaluations of functions of vaginal folds. Our objectives were to: 1) develop a standardized measurement protocol, 2) assess variation in morphometrics within the common bottlenose dolphin (*Tursiops truncatus*), and 3) determine if vaginal muscle contractions are under somatic (voluntary) control. A sampling protocol was developed to collect up to 15 measurements from the reproductive tracts of deceased females using calipers. Measurements were analyzed across age class, reproductive states, and geographic areas from the southeastern USA (n=18 specimens). Presence of striated muscle and variation in density of muscle banding were assessed using 90 histological samples (n=5 specimens) stained with a modified Masson's trichrome stain. Dolphins had one large vaginal fold. Few differences were detected in vaginal measurements between sexually mature and immature or between pregnant and non-pregnant mature females. Vaginal morphology attributes appear to be conserved within this species. The muscular layer of all vaginal tissue consisted of smooth muscle, consistent with other mammals. No differences were found in the density of smooth muscle banding between vaginal regions or age classes. Vaginal contractions appear to be under autonomic control. Our systematic protocol lays the foundation for evaluating evolutionary functions of vaginal folds (e.g. sexual selection, natural selection, phylogeny).

108-4 ONTHANK, K.L.; Walla Walla University; Kirt.Onthank@wallawalla.edu

Respiratory responses of octopuses to ocean acidification

Cephalopods are active, mobile predators that are physiological convergent with vertebrates, despite using molluscan physiological components. To achieve oxygen loading/unloading dynamics similar to vertebrate hemoglobins, cephalopod hemocyanins exhibit a pronounced Bohr effect. This could potentially lead to respiratory impairment under acidified environmental conditions, such as those predicted to occur over the coming century. I measured routine respiratory rate of ruby octopuses (*Octopus rubescens*) that I acutely and chronically (5 weeks) exposed to elevated CO₂ and measured critical oxygen pressure and ventilatory efficiency of octopuses chronically exposed to elevated CO₂. I found that, while neither acute nor chronic exposure to elevated CO₂ led to detectable changes in routine respiratory rate, critical oxygen pressure increased significantly when octopuses were chronically exposed to high CO₂, and ventilatory efficiency was moderately lower. These data suggest that ocean acidification may make octopuses more sensitive to hypoxic conditions. This is particularly concerning as shallow water low oxygen events are becoming increasingly common in coastal habitats.

55-10 ORR, T.J.*; BRENNAN, P.L.R.; Department of Biology, University of Massachusetts, Department of Biological Sciences, Mount Holyoke College; tjorr@cns.umass.edu

All features great and small - an exploration of male genital evolution in mammals

Mammalian penises are morphologically diverse, but most studies of mammalian intromittent organs have focused on the highly variable and taxonomically informative baculum (os penis) possessed by many - but not all - species. Meanwhile, soft tissue morphology of the glans penis has remained largely under-studied. This has led to two biases. First- certain clades with baculum bearing species (e.g. Carnivora, Rodentia, and Chiroptera) have been better studied relative to those that lack a baculum (e.g. Cetartiodactyla, Didelphidae, and Lagomorpha). Second- the diversity evident in soft tissue elaborations of the glans remains poorly described and un-quantified. To understand the evolution of genital morphologies as well as key structures that directly interact with female reproductive tract, we undertook a comparative study of male glans elaborations across all mammalian orders. Here we describe their astounding diversity including the grooves, domes, hooks, spines and notches seen in the glans of mammals great and small. We discuss this diversity with a focus on elaborations in the context of form and function. We will present the criteria that we used to classify these diverse structures, and then ask what factors can explain the presence or absence of glans elaborations. We discuss the potential role of mating system, risk of sperm competition as well as female reproductive physiologies and phylogenetic histories. We also investigate whether the presence or absence of the baculum influences the presence and type of glans elaborations present in mammals. Our findings highlight the importance of considering the functional structure of the penis as a whole, rather than focusing only on the baculum, and make it clear that glans elaborations have been under selection in mammals.

71-1 ORTEGA-JIMENEZ, VM*; DUDLEY, R; Univ. of California, Berkeley; *ornithopterus@gmail.com*

Ascending Flight with Folded Wings: Gliding Deceleration of Anna's Hummingbirds

Vertical flight is particularly challenging for birds, bats, and insects because of simultaneous and large increases in the costs to overcome gravity and drag, particularly at high speeds of ascent. We analyzed vertical flight performance for four male Anna's Hummingbirds (*Calypte anna*) ascending over a 2 meter distance. Birds flew using a horizontal stroke plane and a vertical body axis, reaching stroke amplitudes as high as 190°. Mass-specific aerodynamic power at maximal climbing speed was about 60 W/kg, a value similar to that obtained in earlier maximal load-lifting studies. Near the top of the flight trajectory, birds stopped flapping and folded their wings against the body to effect a smooth deceleration towards a feeder. The first derivative of the tau function (i.e., the visual distance to target divided by the instantaneous velocity), averaged 0.75, in accordance with previous studies of hummingbirds during horizontal deceleration towards flowers. We conclude that hummingbirds transiently reach maximal aerodynamic performance during vertical ascent, but can then precisely decelerate, without flapping, using visual cues to effect a controlled braking within 170 ms.

73-1 OTTO, A.W.; ELIAS, D.O.; HATTON, R.L.*; Oregon State Univ., Univ. of California, Berkeley; *Ross.Hatton@oregonstate.edu*

Physical and Computational Models of Spider Web Vibrations

Web-building spiders tend to have poor eyesight and rely on web vibrations for situational awareness. Web-borne vibrations are used to determine the location of prey, predators, and potential mates. The influence of web geometry and composition on web vibrations is important for understanding spider's behavior and ecology. Studies in web vibrations have experimentally measured the frequency response of web geometries by removing threads from existing webs. The full influence of web structure and tension distribution on vibration transmission; however, has not been addressed in prior work. Furthermore, little attention has been given to developing dynamic models for web vibrations. We have constructed artificial webs and computer models to better understand the effect of web structure on vibration transmission. An instrumented test stand has been built for artificial web construction, control of web tension, and vibration analysis. Artificial webs of 1.2 m in diameter were made of different types parachute cord to mimic the different stiffnesses of silk that spiders use in constructing their webs. Accelerometers placed radially around the hub of the artificial web (at the feet of the "spider") were used to measure vibration response. A receptance-coupling approach was used to model vibrations in the web as networks of strings. We are presenting our initial results on model correlation, prey detection, and implications of basic changes in web geometry on vibration transmission.

113-6 OUFIERO, C.E.*; NGUYEN, T.; SRAGNER, A.; ELLIS, A.; Towson University; *coufiero@towson.edu*

The mantis strikes again: patterns of variation in the kinematics of a praying mantis feeding strike.

Praying mantises, which are often ambush and cryptic predators, rely on the rapid movements of three segments (coxa, femur and tibia) of an exaggerated foreleg to capture prey. The predatory strike of a praying mantis has been characterized into two stages, the approach, which positions the mantis to strike; and the sweep, the actual strike. Previous research has characterized the general movements of the foreleg, suggesting that the sweep and some of the movements of the foreleg are stereotypical and that strike speed increases with prey distance. However, the amount of variation in the kinematics of the individual segments, including their relative angles and velocities, has not been well examined. In this study we further describe the kinematics of the exaggerated forelegs of the praying mantis strike and examine the patterns of variation in relation to the prey position. We analyzed 58 feeding strikes from 8 ghost praying mantises (*Phyllocrania paradoxa*) within instar 6 (juveniles) filmed at 1000 Hz. We addressed several questions: 1) is the variation in the approach time different than the sweep time, 2) is there a relationship between predator-prey position and foreleg velocity and 3) are kinematics of the foreleg segments consistent? We found: 1) more variation in the approach time than the sweep time, 2) only femur velocity is related to predator prey angle, and 3) mantises modulate their strikes by adjusting the percent of their arms versus their body used in the strike and by changing the angle of the coxa. Our results suggest that while certain aspects of the strike are stereotypical, such as sweep time and some joint angles, other traits, such as approach time and percent of body and arms used during the strike are modulated based on prey position.

S6-2 OUYANG, Jenny Q; University of Nevada, Reno; *j.ouyang@nioo.knaw.nl*

Endocrine variation as a mediator of life-history evolution: the relationship between hormones and fitness in a fluctuating environment

Hormones fulfil a dual role in integrating changes that occur in the external with those of the internal environment to promote appropriate behavioral responses. While the role of hormones in mediating behavior has been studied in a variety of taxa, many questions on the evolution of such physiological systems remain unanswered. For example, one major question is: to what extent is hormonal variation among individuals due to genetic contributions, i.e., is a hormonal phenotype heritable and evolves through selection, or is it primarily the result of current environmental conditions? Diverse approaches, such as using selection lines, natural variation, and phenotypic engineering, can elucidate hormone, behavior, and fitness relationships. In our free-living population of great tits, *Parus major*, corticosterone levels are related to food availability and influence reproductive decisions. Moreover, experimentally elevated corticosterone levels before breeding increased parental effort. Therefore, it appears that corticosterone levels are regulated prior to breeding to mediate reproductive effort and regulated during breeding by parental workload. Highly plastic endocrine traits play a central role in allowing organisms to respond rapidly to environmental change; yet, not all individuals display the same degree of plasticity in these traits. I find significant individual variation in corticosterone levels in response to repeated food restriction, but the degree of plasticity is not related to oxidative costs. These results from exploring the causal and natural variation of hormone-behavior-fitness trait relationships are promising. Once we uncouple behavior and hormone cascades in relation to fitness measures, we can begin to uncover how the endocrine control system constrain and facilitate response to natural selection.

S2-4 O'BRIEN, K.M.*; CROCKETT, E.L.; GROVE, T.J.; LEWIS, J.M.; OLDHAM, C.A.; University of Alaska, Fairbanks, Ohio University, Valdosta State University, Georgia Southern University; kmobrien@alaska.edu

Is the lack of oxygen-binding proteins in Antarctic fishes advantageous in the extreme cold waters of the Southern Ocean? The interrelationship between oxygen-binding proteins and oxidative stress

The loss of expression of the oxygen-binding protein hemoglobin (Hb) in Antarctic icefishes (suborder Notothenioidei, family Channichthyidae) is considered by most to be a neutral mutation, persisting in icefishes inhabiting the icy-cold and oxygen-rich waters of the Southern Ocean where competition is minimal. The lack of expression of the intracellular oxygen-binding protein myoglobin (Mb) in cardiac muscle is more of a conundrum. Mutations leading to the loss of Mb occurred at four points during the radiation of the icefish family and by three distinct molecular mechanisms, suggesting weak selective pressure maintaining the Mb gene. Both Hb and Mb are iron-centered proteins that can promote the formation of reactive oxygen species and elevate oxidative stress. Moreover, the potential for oxidative damage may be particularly high in notothenioids, due to their high capacities for oxidative metabolism, membranes rich in polyunsaturated fatty acids, and oxygen-rich environment. We investigated whether the loss of Hb and Mb may be advantageous to icefishes because it reduces oxidative stress, thereby reducing rates of protein turnover and resulting in an energetic costs savings. Despite having higher levels of oxidized and ubiquitinated proteins, red-blooded and red-hearted notothenioids do not synthesize or degrade proteins at a faster rate than icefishes, and energy expenditures on protein synthesis are equivalent between the two groups. These data support the idea that the losses of Hb and Mb are adaptations. Research supported by NSF (OPP 1341663).

117-5 PADIAN, K.*; CUNNINGHAM, J. R.; LANGSTON, W. A.; University of California, Berkeley, Cunningham Engineering Associates, Collierville, TN, (deceased 2013) formerly University of Texas, Austin; kpadian@berkeley.edu

How the largest known flying animal, the pterosaur *Quetzalcoatlus*, walked on land

The giant pterosaur *Quetzalcoatlus northropi* (QN) lived at the very end of the Cretaceous Period, about 67 million years ago, in Texas. It was named on the basis of a few incomplete post-cranial bones that suggested a wingspan of 11-13 m; a morph about half this size is known from numerous bones and partial skeletons. In the air, like most large aerial animals, it mainly soared, but it could flap to some degree. On the ground, like all pterodactyls, QN walked quadrupedally, but this was mainly because its metacarpals were so long that the manus could not avoid touching the ground. Pterosaurs were originally bipedal, like their ancestors. Manipulation of QN's forelimb and hindlimb bones confirms that in a quadrupedal pose the humerus had limited rotation (about 25°) and the forearm and metacarpus could be slightly elevated and depressed at the elbow, but the forelimb had no significant retractive power. All joints of the hindlimb are hinges except the hip, a ball-and-socket offset by a neck oriented dorsally, medially, and posteriorly. The hindlimb thus had an erect stance and parasagittal gait, as in other ornithomirans. Pterodactyls such as QN lifted their limbs unusually, because overstepping was not possible: the lift cycle was LM - LP - RM - RP, where M is manus and P is pes; however, the sequence of emplacement would have been LP - LM - RP - RM. The full step cycle was: LM lift - LP lift - LP place - LM place - RM lift - RP lift - RP place - RM place. Although technically quadrupedal, QN showed its bipedal heritage when it walked on land.

17-9 PACE, D.A.*; RENDLEMAN, A.J.; RODRIGUEZ, J.; FIGUEROA, P.; DELEON, A.; CHANG, E.; California State University, Long Beach; douglas.pace@csulb.edu

Determining the metabolic growth efficiency in larvae of the sand dollar, *Dendraster excentricus*, fed at different food conditions.

Larvae of the sand dollar, *Dendraster excentricus*, have been used extensively to understand morphological responses to variation in environmental conditions. The goal of this study was to assess the physiological responses in growth and development of larvae reared at different algal concentrations. Larvae were fed 1,000 (low-fed) and 10,000 (high fed) algal cells ml⁻¹ (*Rhodomonas sp.*) and rates of feeding, metabolism and growth were monitored. We hypothesized that high-fed larvae would not only grow faster than low-fed larvae, but would also have a higher metabolic growth efficiency. At 21 days of age, cumulative energy used for metabolism was 3.5 and 20 mJ for low- and high-fed larvae. Cumulative protein growth at day 21 was 35 and 813 ng protein ind⁻¹. Total energy invested in growth was calculated as 2.2 and 51.6 mJ. Energy acquired through algal feeding, was 9.2 and 82.8 mJ. The gross metabolic growth efficiency (energy utilized for metabolism and growth standardized to energy acquired) was 62% and 86% for low- and high-fed larvae. Efficiency of protein growth was 19% and 46% for low- and high-fed larvae. Relative to changes in growth, differences in developmental rates were much more modest. By day 21 low-fed larvae were at the 6-arm stage and high-fed larvae were at the 8-arm stage. While these results support our hypothesis, they also highlight alternate strategies for growth and development available to larval forms. Exploitation of these alternate pathways likely plays a significant role in linking larval recruitment success to environmental conditions.

23-1 PADILLA, DK*; MCCANN, MJ; Stony Brook University, Rutgers University; Dianna.Padilla@stonybrook.edu

Effects of a patchy food environment across life history stages

Many animals experience periods of feast or famine, which can have major consequences for growth, survival, and reproductive fitness. For animals with complex life histories, the question remains whether a major ontogenetic transition, such as metamorphosis, removes the legacy of early diet variability, or if early stressors persist into later stages. This study examined the effect of constant versus variable food availability and average food concentration during the larval stage on the performance of the marine gastropod *Crepidula fornicata* before and after metamorphosis. There was no detectable effect of variable food availability on larval growth, energy stores, survival, and metamorphic competence, or juvenile growth rate and survival. Instead, the average amount of food available during the larval period had the greatest impact on larval size and metamorphic competence. Surprisingly, there were no impacts of larval diet on growth or survival during the juvenile stage. Differences that originated during the larval stage were removed post-metamorphosis. These results suggest that some organisms may be resilient to variations in food availability and that not all early life experiences produce legacy effects. Heterogeneous environments, including variable food availability, should favor flexibility in the timing of ontogenetic transitions that allow individuals to be robust in later life stages.

104-3 PADILLA-GAMINO, J.L.*; GAITAN-ESPITIA, J.D.; KELLY, M.; HOFMANN, G.; CALIFORNIA STATE UNIVERSITY DOMINGUEZH HILLS, UNIVERSIDAD AUSTRAL DE CHILE, LOUISIANA STATE UNIVERSITY, UNIV. OF CALIFORNIA, SANTA BARBARA; jpgamino@csudh.edu

Physiological plasticity and local adaptation to ocean acidification in the calcareous algae *Corallina vancouveriensis*: An ontogenetic and geographic approach

Ocean acidification has been found to affect the physiology and growth of coralline algae, which play significant functional roles in marine ecosystems worldwide. Currently there are no studies that examine the potential for local adaptation to different pCO₂ conditions in this important group. In order to examine the physiological plasticity between life stages and signatures of local adaptation, we used common garden experiments to investigate how adults and spores of *Corallina vancouveriensis* from populations naturally exposed to different carbonate chemistry due to upwelling events responded to different pCO₂ levels. Our results show that spore growth for both populations was not affected by pCO₂ conditions, however adults from different sites showed distinct responses in acclimation capacity, photosynthetic performance and growth rates when exposed to higher pCO₂. Growth rates of *C. vancouveriensis* decreased under high pCO₂; however algae from the northern site showed a smaller change in size than algae from the southern site suggesting higher acclimation potential and/or local adaptation in the northern population. All adult populations showed higher respiratory rates and a significant reduction of pigment content (chlorophyll and phycobilins) after being exposed to high pCO₂ levels for 30 days. Our results indicate that different life stages of *C. vancouveriensis* have different tolerances of high pCO₂; spores showed less sensitivity to changes in the carbonate chemistry whereas adults were more sensitive. Adults from the site with more carbonate chemistry variation showed both higher tolerance and greater acclimation potential.

97-12 PAIG-TRAN, E.W.M.*; BARRIOS, A.; FERRY, L.A.; C.S.U. Fullerton, Arizona State University; empaig-tran@fullerton.edu

Skeletal anomalies in the mesopelagic oarfish, *Regalecus russelii*

Hyperostosis, extra bone growth, has evolved independently in at least 22 families of fishes most of which are tropical or subtropical marine species. While the presence of hyperostosis is well documented in fishes, the mechanism driving the development of the extra bone growth is unclear. We documented hyperostosis along the dorsal pterygiophores in Oarfish, *Regalecus russelii*. This is the second lampriform fish with hyperostosis and the first case documented in a truly mesopelagic, temperate zoned fish. In oarfish, the majority of the dorsal pterygiophores are highly unmineralized, acellular bones that shift to stiffened, cellular, hyperostotic growths near the distal edge. Oarfish lack a swim bladder so they must continuously beat their bi-directional dorsal fin to maintain position within the water column and while engaged in locomotory behavior. It is therefore not surprising that these fishes have areas of localized, hyperostotic skeletal elements along the dorsal pterygiophores that, presumably, function as a stiffened lever system to support fin undulation. We noted that hyperostification was not present in all fish examined and was only documented in fishes with total lengths greater than 3 m.

13-1 PAGE, J.W.*; WALKER, S.M.; University of Oxford, United Kingdom; jonathan.page@zoo.ox.ac.uk

Reassessing the Gear Change Mechanism in Dipteran Flight

Flies are able to quickly change direction during flight and these manoeuvres require concurrently rapid changes in wing kinematics. However, due to its anatomy, the indirect flight musculature cannot produce sufficiently asymmetrical wing movements by itself. Instead, other mechanisms must be used; one example being the gear change mechanism. This involves a mechanical interaction between two cuticular structures: the radial stop (RS), found proximally on the underside of the wing's radial vein, and the pleural wing process (PWP) which protrudes laterally from the ventral part of the wing hinge. The RS can interact with the PWP during the downstroke in several ways: bypassing it entirely, locking into one of the dorsal grooves of the PWP, or hooking behind it, each altering wing movement. The shapes of the PWP and RS also differ across species, potentially varying the effects on the wing kinematics. It has previously been noted in hoverflies that the alula (a small, proximal part of the wing) changes between a flipped and flat state relative to the rest of the wing at the same time as wing kinematic changes, and so it has been hypothesised that it is an indirect indicator of the state of RS-PWP interaction. We have examined the RS-PWP interaction through recording high-speed macro videos of tethered *Calliphora vicina* (amongst other species) with simultaneous recordings of the three-dimensional wing kinematics. Our data quantifies the effects of these interactions on wing kinematics and the result of the differing structural shapes amongst species. Our results also show greater variety in RS-PWP interactions than previously thought, and evaluate the utility of the alula as an indicator of the gear change mechanism.

S2-10 PAIGHT, C.; MUÑOZ-GÓMEZ, S. A.; SAFFO, M. B.; SLAMOVITS, C.; LANE, C. E.*; University of Rhode Island, Dalhousie University; clane@uri.edu

Life inside a tunicate: did high concentrations metabolites facilitate an apicomplexan lifestyle transition?

Despite their photosynthetic roots, apicomplexans are highly successful parasites, infecting every major metazoan lineage. They are primarily intracellular parasites that form tissue cysts or target blood cells, however, species in the genus *Nephromyces* are endosymbionts, inhabiting all members of the tunicate family Molgulidae. Specifically, *Nephromyces* inhabits the renal sac, an organ unique to the Molgulidae. The renal sac contains high levels of urate, but its function is currently unknown. Adding to the complexity of this biological system are the bacterial endosymbionts within *Nephromyces* species, which introduce additional metabolic capacity. We have performed preliminary sequencing of the *Nephromyces* genome to determine the metabolic pathways that enabled *Nephromyces* to become an endosymbiont. The metabolic capabilities of both *Nephromyces* and its bacterial endosymbiont will be discussed with a focus on purine and carbon metabolism.

121-4 PAITZ, RT*; BOWDEN, RM; Illinois State University; rpaitz@ilstu.edu

Maternal steroid and environmental chemical exposure: What is an embryo to do?

It is well established that embryos are particularly sensitive to alterations of their phenotype when exposed to chemicals during development (i.e. "fragile fetus"). These chemicals can be endogenous substances such as steroids produced by mothers or exogenous substances such as industrial chemicals present in the environment. Relative to what we know about how adult vertebrates modulate their exposure to steroids and environmental chemicals, we know remarkably little about how vertebrate embryos modulate exposure to these substances, despite their increased sensitivity. We have recently demonstrated that embryos are capable of modulating their exposure to maternal estradiol via steroid metabolism in the red-eared slider (*Trachemys scripta*). Importantly, this modulation can be inhibited by a common environmental chemical, bisphenol-A (BPA), which results in elevated estradiol within the egg during development. In this study, we examined the fate of BPA itself during embryonic development and found that BPA is also rapidly metabolized in red-eared slider eggs. Pairing these data with the previous findings that BPA inhibits estradiol metabolism, we are able to demonstrate that environmental chemicals can still elicit biological effects despite being rapidly metabolized. These findings highlight the dynamic nature of embryonic exposure to chemicals where an important effect of exogenous chemicals may simply be to alter exposure to endogenous chemicals. Going forward, it is critical that we understand how chemical exposure is realized by the embryo in order to predict how organisms may respond to changes in chemical exposure, and urge caution against viewing embryos as passive recipients of chemical signals during development.

15-8 PARKER FISCHER, C.E.*; ROMERO, L.M.; Tufts University; clare.parker@tufts.edu

Easing the transition to captivity: use of alpha- or beta-blockers to reduce the chronic stress of capture.

Animals introduced to captivity are subjected to a multitude of stressors, including confinement, altered diet, and human presence and contact. Not surprisingly, captivity is a potent and reliable means of inducing chronic stress in wild animals. Physiological changes due to captivity include increased baseline heart rate, reduced or absent startle response, and altered baseline or stress-induced glucocorticoid levels. Some of these changes may be due to a high degree sympathetic nervous activation caused by high levels of epinephrine and norepinephrine, which also decrease heart rate variability. The use of alpha- or beta-blockers may be a tool to reduce the negative effects of chronic stress and help animals adjust more quickly to captivity. These drugs temporarily block the receptors for epinephrine or norepinephrine, and are frequently prescribed for anxiety in humans. We tested the effects of a short course of an alpha-blocker (phentolamine) and a beta-blocker (propranolol) during the first week of chronic stress in house sparrows (*Passer domesticus*). We hypothesized that after one week of captivity, compared to control birds, propranolol or phentolamine treatment would have (1) a lower baseline heart rate, (2) less sympathetic activity (i.e. higher heart rate variability), and (3) reduced change in glucocorticoid release. We found that propranolol blocked the increase in baseline glucocorticoids evident in saline-treated animals. Phentolamine, on the other hand, caused a decrease in nighttime heart rate variability, indicating increased nighttime sympathetic nervous activity. We conclude that at least propranolol appears to ameliorate the transition to captive conditions.

126-5 PANDORI, L.L.M.*; SORTE, C.J.B; Univ. of California, Irvine; lmcquinn@uci.edu

Ontogenetic Variation in Microhabitats and Environmental Conditions of Intertidal Invertebrates

Predicting responses to climate change requires an understanding of how microhabitats and associated abiotic conditions differ across species' lifetimes. We addressed the question: how do microhabitats and thermal conditions differ across life stages of two marine invertebrates, the mussel *Mytilus californianus* and the barnacle *Chthamalus fissus*, inhabiting the rocky intertidal at Crystal Cove State Park, CA? To determine the distribution of ages of the study species across microhabitats, we quantified individuals of different ages (using size as a proxy) every 0.2 m in tide height along N=5 transects. To assess age-specific variation in thermal conditions, we used *in vivo* thermistor measurements from 3 (high, mid, and low) tide heights within the species' distributions to compare time series of body temperatures for juveniles and adults. Tide height distributions and temperatures differed by age for *M. californianus* but differences among age classes were not as pronounced for *C. fissus*, for which multiple ages shared more similar microhabitats. Thus, we found that ontogenetic variation in microhabitats and environmental conditions was species specific, a finding that has implications for attempts to predict future responses to climate change.

69-5 PARRIN, AP*; HARMATA, KL; SAMOVA, EL; YAEGER, MA; BLACKSTONE, NW; Northern Illinois University; apparrin@gmail.com

Like lemmings off a cliff?: Unraveling Symbiodinium migration in octocorals via canonical and non-canonical bleaching pathways

Octocorals remain one of the understudied groups of cnidarians. In addition to cell death or exiting the colony, colonial octocorals unlike anemones provide a third option for perturbed symbionts (*Symbiodinium* spp.) migrating deeper into the colony. Cell death pathways typically initiate with the disruption of photosynthesis, shifting photosystem redox state in the direction of reduction and the formation of reactive oxygen species (ROS), which in turn trigger programmed cell death in symbiont and host cells ("canonical" bleaching pathway). Disrupting photosynthesis, however, has other consequences; specifically, a decrease in photosynthesis increases the available CO₂ as bicarbonate (HCO₃⁻). This can then activate ciliary action and symbiont migration via the soluble adenylyl cyclase (sAC)/cyclic adenosine monophosphate (cAMP) "non-canonical" pathway. Migrating symbionts may exit the colony or move deeper into the coenenchyme. The former contributes to bleaching, while the latter can result in symbiont retention and recovery and thus determines colony fate. In this context, several species of octocorals, *Phenganax parrini*, *Sarcothelia* sp., and *Symposium* sp., have been adapted for microscopic experimentation. The effects of these pathways can be examined by thermal stress in the presence and absence of light. If light energy is present and photochemistry is blocked downstream of photosystem I and II, water may split but the resulting electrons will usually form ROS, leading to cell death. In the dark, photochemistry is abolished, and no light energy is available to provide electrons for ROS formation. Results from light/dark comparisons and experiments with exogenous HCO₃⁻ support the existence of non-canonical pathways.

116-4 PARTHASARATHY, K.*; WILLIS, M.A.; Case Western Reserve University; pxk272@case.edu

Effect of luminance on the visual responses of the hawkmoth *Manduca sexta*.

The hawkmoth, *Manduca sexta* is nocturnal and executes rapid controlled maneuvers in dim light conditions. It is known that moth's compound eyes improve the gain by integrating light spatio-temporally. Though this adaptation improves the brightness of the visual scene it is likely to impose a limit on detectable spatial and temporal frequencies. Despite these limitations *M. sexta* is known for its flight maneuverability, including hovering, which relies on visual input for control. Our study is aimed at characterizing the flight performance envelope of *M. sexta* in low light conditions. The experimental design utilizes wide-field motion induced optomotor response as a read out of moth's ability to perceive visual cues at low light levels. Tethered moths were tested with a horizontally oscillating sinusoidal grating at the following luminance (cd/m²) levels: 70, 10, 1, 0.1, 0.01, 0.001 & 0.0001. We used a range of spatial, temporal and contrast values for the gratings. The optomotor response (i.e., head turning, wing stroke asymmetries, etc.) was recorded using an overhead camera for offline analysis. The contrast sensitivity and visual acuity decreased as a function of decreasing luminance levels. *M. sexta* responded to spatial frequencies between 0.08 to 0.3 cycles/degree and temporal frequencies between 3 to 5 Hz. Our results are in agreement with previous study on wide-field motion tuning of lobula neurons. These experiments, KP, and MAW were supported by AFOSR grant FA9550-12-0237.

124-3 PEARSON, PR*; WARNER, DA; Auburn University; prp0005@auburn.edu

Do seasonal changes in developmental temperature have season-specific fitness consequences in a lizard?

Rapidly changing environmental conditions can reduce the fitness value of a phenotype. Phenotypic plasticity can solve this problem by enabling individuals to quickly develop phenotypes that are suited to their immediate environment. Seasonal shifts in environmental conditions are particularly important because they provide predictable cues to which organisms can respond in adaptive ways. For example, seasonal changes in temperature can induce phenotypes at different times of the year that have season-specific fitness benefits. Reptilian embryos are especially sensitive to their developmental environment. Our previous study has shown that temperature during different times of the season can affect phenotypes and performance. In this study, we assessed whether the timing of oviposition is adaptively matched to the thermal environment that embryos experience at a given time of the reproductive season. We used the brown anole lizard (*Anolis sagrei*), which has an extended reproductive season (April-October), to address this question. Eggs were collected from two temporally-separated breeding colonies (April and July) and exposed to two incubation treatments that mimicked the natural fluctuations in nest site temperatures during early and late periods of the reproductive season. Hatchlings were measured, and their locomotor performance was assessed in the lab. They were then released on a small island to quantify growth, movement, and survival. Preliminary data suggests that eggs exposed to early-season temperatures have relatively low survival and longer incubation periods than those experiencing late-season temperatures. Further evaluation of the interactive effects of the timing of oviposition and season-specific incubation temperature will provide critical insights into how embryos might be adapted to season-specific developmental environments.

5-3 PARZER, H.F.*; POLLY, P.D.; MOCZEK, A.P.; Fairleigh Dickinson University, Madison, NJ, Indiana University, Bloomington, NJ; hparzer@fdu.edu

The evolution of relative trait size and shape: insights from the genitalia of dung beetles

Insects show little genital variation within species, yet exhibit extraordinary diversity among species. One solution to this paradox suggests that even though intraspecific variation in relative size might be small and limit the effectiveness of selection, variation in shape alone might be sufficient to enable rapid divergence. This hypothesis predicts that intraspecific variation for genital shape should be higher when compared to genital size and that genital shape should evolve at a higher rate than genital size. We tested this hypothesis in male dung beetles by comparing intra- and interspecific variation in shape and size of genitalia and by calculating their evolutionary rates. For comparison we estimated the same parameters for the head and tibia. We found significant intraspecific variation in genital shape in all species examined, whereas only one species also exhibited significant size variation. Furthermore, genital shape evolved at higher rates than genital size. While shape also evolved relatively faster than size in head and tibia, genitalia had the highest rate of shape evolution of the three. We discuss the functional constraints that may bias the developmental evolution of size and shape of genitalia and other morphological traits.

111-3 PEREZ, J.H.*; KRAUSE, J.S.; CHMURA, H.E.; BOWMAN, S.; MCGUIGAN, M.; ASMUS, A.L.; MEDDLE, S.L.; HUNT, K.E.; GOUGH, L.; BOELMAN, N.T.; WINGFIELD, J.C.; UC Davis, Univ. of Alaska, Fairbanks, Univ. of Texas, Austin, Univ. of Edinburgh, New England Aquarium, Towson University, Columbia University; jhperez@ucdavis.edu

Growing up in the Arctic: Nestling growth rates in two species of passerine.

The growth of nestlings to fledging is an energetically demanding period for songbirds that requires the balancing of several major tradeoffs. Parents must balance investment decisions of feeding and brooding with self-maintenance activities. The rapid rate of development and growth of altricial nestlings is highly susceptible to variation in environmental conditions and parental investment as they have a limited capacity to manage their own energetic requirements. Highly variable environments with short breeding seasons, such as the Arctic, magnify these tradeoffs. Arctic nesting passerines provide a good model system in which to explore variation within and between species in growth rates with regards to environmental conditions. Here we present our findings on the inter-annual and inter-species variation in nestling mass gain for two species of arctic nesting passerines: Gambel's white-crowned sparrows (*Zonotrichia leucophrys gambelii*) and Lapland longspurs (*Calcarius lapponicus*) from 2013 and 2014 breeding seasons on the North Slope of Alaska. Comparisons of environmental variables between years suggest that conditions were more challenging in 2014 as compared to 2013, as birds experienced lower temperatures and increased precipitation during the nestling period. In addition, arthropod biomass was also reduced in shrub tundra in 2014 as compared to 2013. These more challenging abiotic and biotic conditions in 2014 resulted in a reduced rate of nestling mass gain in both species. We suggest that this effect may have been mediated by changes in parental investment patterns in response to sub-optimal environmental conditions as birds were forced to reallocate time budgets for brooding and foraging thus negatively impacting growth rates.

19-5 PERLMAN, B.M.*; ASHLEY-ROSS, M.A.; Wake Forest University; perlbm0@wfu.edu

Effects of captivity on terrestrial performance of mangrove rivulus (*Kryptolebias marmoratus*)

Mangrove rivulus (*Kryptolebias marmoratus*) is a self-fertilizing hermaphroditic fish, giving rise to progeny that are isogenic clones of the parent generation. Found in mangrove swamps from central Florida, USA, to southern Brazil, these amphibious fish make occasional bouts onto land using the tail-flip to locomote when out of the water. Most often housed in the lab in small containers without the ability to access non-aquatic environments, we predicted that individuals from different populations, both genetically distinct and geographically distant, would decline in jumping performance when in captive conditions. We collected specimens in the field from three genetically different populations in the Florida Keys, USA (n = 5 individuals per population), and three populations from Lighthouse Reef Atoll, Belize (n = 12 individuals per population). All Florida individuals underwent an exercise assay once per month for a 13 month period. Six individuals from each Belize population underwent exercise assays for all 13 months, with the remaining individuals acting as a control, undergoing the exercise assay for only the first and final months to determine the effects of periodic exercise vs. no exercise on jumping performance. Individuals were placed in a shallow, empty wading pool covered with wetted bench liner paper with a camera (60 fps) suspended above the arena to record all behaviors. Fish were able to voluntarily move for two minutes, immediately followed by 30 seconds of being chased in the arena to elicit maximum jumping performance. Latency to first movement and jump performance changed through time for both geographically distant and genetically distinct populations, suggesting that captivity and genetic differences interact to produce changes in jumping performance.

25-5 PEROTTI, EA*; D'ANDREA, AF; GALLEHER, S; STRICKLAND, SA; MOFFETT, C; Oregon Dept. of Fish & Wildlife; elizabeth.a.perotti@state.or.us

Is the subtidal "spawning stock hypothesis" supported? Testing a management principle for bay clams

Subtidal habitats are often assumed to harbor large bay clam populations that serve as spawning stock for intertidal populations subject to harvest. This hypothesis is rarely tested, but is used as a management principle by natural resource agencies. The Shellfish and Estuarine Habitat Assessment of Coastal Oregon project of the Oregon Department of Fish and Wildlife conducted extensive surveys of bay clam populations in subtidal and intertidal habitats of four Oregon estuaries that differ in size, geomorphology, and extent of commercial and recreational harvest. Using a stratified-random design (tide flat x tide height), bay clam population and habitat data were collected for the main intertidal flats and subtidal channels for several fisheries targeted bay clams: butter clams (*Saxidomus gigantea*), cockles (*Clinocardium nuttallii*), gaper clams (*Tresus capax*), littleneck clams (*Leukoma staminea*), and purple varnish clams (*Nuttallia obscurata*). Density and biomass estimates were used for an indirect test of the spawning stock hypothesis. Support for the spawning stock hypothesis was mixed. Subtidal cockles were significantly more abundant than in intertidal habitats in several estuaries. Other clam species were rare or less abundant in subtidal habitats. Bay clams are managed as a unit in Oregon and these results indicate that management may need to be estuary-specific and species-specific, especially for clams that are harvested commercially.

29-6 PEROTTI, EA*; D'ANDREA, TF; MOFFETT, C; STRICKLAND, SA; Oregon Dept. of Fish & Wildlife; elizabeth.a.perotti@state.or.us

Clam I am: predicting bay clam distribution using a multiplicative habitat modeling approach

Shellfish utilize estuarine habitats, which are heterogeneous and can differ greatly from bay to bay, during many stages of their life history. These habitats are becoming increasingly more important for the management of shellfisheries, especially in the face of climate change, ocean acidification, and development. The Shellfish and Estuarine Assessment of Coastal Oregon project of the Oregon Department of Fish and Wildlife conducted extensive surveys of bay clam populations and estuarine habitats in three Oregon estuaries: Netarts Bay, Tillamook Bay, and Yaquina Bay. These estuaries have active bay clam fisheries, but differ in size, geomorphology, and distribution of abiotic and biotic features. This analysis evaluates clam-habitat associations and generates quantitative models of clam distribution for four recreationally and commercially targeted bay clams: butter clams (*Saxidomus gigantea*); cockles (*Clinocardium nuttallii*); gaper clams (*Tresus capax/nuttallii*); and littleneck clams (*Leukoma staminea* and *Venerupis philippinarum*). We used nonparametric multiplicative regression (NPMR) to predict the distribution of bay clams. The best fitting models identified specific variables that predicted clam density and biomass within and among estuaries. Results indicate that assessment efforts and management decisions may need to be estuary-specific rather than coast-wide for some clam species. Bay clams are managed as a unit in Oregon and these results will inform decisions pertaining to harvest, critical habitats, aquaculture, land development, and resilience to climate change and ocean acidification.

54-7 PETERS, JM*; GRAVISH, N; MAHADEVAN, L; COMBES, SA; Harvard University, Univ. of California, Davis; jcbptrs@gmail.com

Collective nest ventilation by honey bees: Global flow patterns arise from local fanning responses

Many social insects that live in large, congested colonies (e.g., some ants and termites) build elaborate physical structures that facilitate passive airflow through the nest. This airflow allows for colony-level gas exchange with the environment and prevents buildup of heat and carbon dioxide within the nest. However, honey bees build their nests in pre-existing cavities, often with single openings, which precludes passive airflow as a reliable mechanism of ventilation. Instead, groups of honey bee workers actively drive air currents through the nest by fanning their wings at the nest entrance. Individual fanning bees can only sense local information and they only make a meager contribution to hive-scale airflow, yet fanning bees collectively structure stable, unidirectional airflow through the nest, with air entering and exiting at different locations within a single opening. We measured air speed, temperature and the density of fanning bees at 14 locations along the entrances of four bee hives, over the course of three days. Our data suggest that asymmetric distributions of fanning bees along the nest entrance allows for continuous inflow and outflow through a single opening. We share our empirical observations and present a mathematical model describing how groups of honey bees organize their ventilation effort by following simple, individual control rules.

83-8 PETERSEN, A.M.*; GRAY, E.M.; BUCK, C.L.; VON HIPPEL, F.; CRESKO, W.A.; POSTLETHWAIT, J.H.; Oregon State University Cascades, University of Oregon, Northern Arizona University, University of Alaska, Anchorage; ann.petersen@osucascades.edu

Developmental patterns of thyroid growth and function in divergent populations of threespine stickleback

Thyroid hormone activity is of particular importance to anadromous fishes that face osmotic and metabolic challenges while migrating long distances prior to spawning and immediately after hatching. Differences in adult hypothalamic-pituitary-thyroid (HPT) axis function have been postulated to be adaptive traits in divergent population of stickleback, yet little is known about how genetic background versus developmental environment affects thyroid morphology and function. We investigated morphological and functional development in genetically divergent populations from anadromous (RS) and fresh water (BL) habitats. We raised fish for eight generations under identical environmental conditions. Fish from each population were sacrificed at time intervals from 8 to 100 days postfertilization (dpf), and we examined histological sections for thyroid morphology, circulating thyroid hormone levels, thyroglobulin production, and expression of genes important to thyroid cell function (SLC5A5 and SLC5A8). Morphologically, anadromous fish had more follicles and follicular epithelial cells than freshwater fish. Freshwater fish had larger follicular epithelial cells, however, and higher circulating thyroid hormone levels at 100dpf. Our gene expression data suggest that anadromous fish express genes more important to early metabolism and activity, while freshwater fish express genes of mineralization and craniofacial mineralization earlier and more broadly. Adult fitness in the face of pollutants or environmental perturbations that disrupt thyroid function may therefore be affected by developmental environment, as well as genetic background of a given population.

100-5 PFEIFFENBERGER, JA*; HSIEH, ST; Temple University; jpfeiffe@temple.edu

Feed-forward control strategies enable sideways-running animals to overcome locomotor perturbations

The more quickly an animal runs, the less time it has to adjust to and recover from sudden perturbations. A combination of neural feedback, feed-forward control, reflexes, and distributed mechanical feedback, are known to be important recovery strategies for humans, guinea fowl, and cockroaches. Some investigators have postulated that increased leg number naturally leads to greater locomotor robustness against perturbations. While this seems to be largely supported for multi-legged, forward moving animals, it is unknown whether this also applies to sideways moving animals. The Atlantic ghost crab (*Ocypode quadrata*) is a high-speed, sideways runner. The goal of this study was to determine how these crabs respond to an unexpected slip perturbation. We hypothesized that these crabs would maintain constant locomotor kinematics and limb phasing, similar to that observed in cockroaches, in spite of an applied slip perturbation. Thirty running ghost crabs were filmed at 500 fps, capturing one dorsal and two lateral views. Crabs were randomly assigned to one of two treatments: (I) a control treatment, in which crabs ran unperturbed along a sand trackway; and (II) a slip treatment, in which crabs encountered a low-traction surface in the middle of the trackway. Analyses show that ghost crabs' limbs slipped up to 80% carapace width on the low-traction surface. Surprisingly, in spite of such long-distance slips, ghost crabs exhibited few signs of instability. Limb kinematics (e.g., stride frequency and duty factor) and phasing parameters in perturbed trials were statistically similar to those observed during control trials ($P > 0.05$, mixed-model ANCOVAs), suggesting feed-forward control. As a result, we conclude that sideways running, multi-legged systems likely use similar strategies as forward running systems to maintain locomotor stability when perturbed.

81-7 PFALLER, J.B.*; PAYTON, A.C.; MCDANIEL, S.F.; BJORN DAL, K.A.; Univ. of Florida, Gainesville; jpfaller@ufl.edu

Hitchhiking the High Seas: Global Genomics of Rafting Crabs

Crabs of the family Grapsidae are common and conspicuous inhabitants of rocky shorelines and mangrove forests across the tropical and subtropical oceans. However, one lineage - three species in the genus *Planes* - occupies the open ocean, where crabs recruit to floating debris or pelagic animals and spend the rest of their lives rafting at the surface of the ocean. Among living substrata, *Planes* crabs are frequently found associated with oceanic-stage sea turtles. Currently, there are three described species of *Planes*: *Planes minutus* (N. Atlantic and Mediterranean), *Planes major* (worldwide, except N. Atlantic), and *Planes marinus* (worldwide, except N. Atlantic). While *P. marinus* is morphologically distinct, *P. minutus* and *P. major* show very subtle morphological differences. Genetic differentiation among *Planes* species and widely distributed *Planes* populations has never been evaluated. In this study, we performed restriction-site associated DNA-sequencing (RAD-seq) based population genomic analyses to (1) test the validity of current species designations and (2) quantify genetic connectivity of globally distributed populations. First, we found that *P. marinus* is distinct from *P. minutus* and *P. major*, but is not genetically distinct from *Pachygrapsus laevimanus*, an intertidal species. Second, we found that *P. minutus* and *P. major* are not genetically distinct and, collectively, form four intermixing populations around the world. Results of this study are not only important for understanding the ecology and evolution of *Planes* crabs, but also for understanding the process of speciation and population differentiation in a marine invertebrate with both planktonic and rafting dispersal.

56-1 PHILLIPS, G*; HUDSON, D; CHAPARRO-GUITERREZ, J; ROCHA, M; Georgia State University, Atlanta Metropolitan State College, Universidad de Antioquia, Universidad Nacional de Colombia Instituto de Ciencias Naturales sede Bogota; gillianlynphillips@gmail.com

Presence of Paragonimus species within the secondary crustacean hosts in Bogota, Colombia

Paragonimus spp. are parasites that infect many populations worldwide. It is predicted that infection rates within Asia reach ten to fifteen percent of the total population. Three largest areas of possible infection are Asia, Central and South America as well as Africa where the combined population at risk is estimated to be 293 million people. Ingestion of raw or undercooked crustaceans are the source of infection to mammals. The crustaceans *Neostrengeria macropa* and *Procambarus clarkii* in Bogotá, Colombia were collected from local markets, pet stores and waterways. Dissection for presence of parasites is imperative to estimate the prevalence of crustacean infection by lung flukes. The preliminary findings show, pending laboratory confirmation, that the native crab species, *N. macropa*, has a prevalence of 17.2% infection. Invasive crayfish species, *P. clarkii* has a prevalence of 36.4% from both captive and field capture samples. While the prevalence estimated within this study is lower than compared to previous research in other cities of Colombia, there may be a number of factors that contribute to the difference in prevalence including: collecting season, overall low rainfall, temperature, altitude and the El Niño Southern Oscillation.

S9-6 PINCEBOURDE, S.*; SAUDREAU, M.; CAILLON, R.; EZANIC, A.; Institut de Recherche sur la Biologie de l'Insecte, INRA, Université Blaise Pascal; sylvain.pincebourde@univ-tours.fr
The thermal heterogeneity at leaf, canopy and biogeographical scales: consequences for leaf dwelling insects

Environmental heterogeneity drives the response of organisms to global changes and climate fluctuations. Habitats with the highest microclimatic diversity are more likely to continue to provide favorable microclimates despite regional warming. This heterogeneity is, however, not known for most microhabitats. We measured and modeled the heterogeneity of the apple leaf microclimate at several key spatial scales: the leaf surface, the canopy and the geographical gradient. A single leaf surface shows a high thermal variance when it is exposed to solar radiation. Temperature ranges of up to 10°C over single leaf surfaces were frequent. A biophysical model stressed out the key role of the leaf microtopography. This thermal variance at leaf scale was comparable to that measured at the scale of a single apple canopy. The heterogeneity at canopy scale is explained mainly by the various orientation angles of the leaves. Finally, we followed apple trees along a 750km temperate latitudinal gradient. The leaf temperature differences found between the two extremes of the gradient were of similar amplitude than the thermal variance at the within-leaf and within-canopy scales. Therefore, there is potentially as much thermal heterogeneity within a single leaf surface than along a biogeographical gradient. This result is crucial for leaf dwelling arthropods that thermoregulate: climate variations may be buffered by moving over few centimeters, like if they moved over hundreds kilometers. Biophysical models should be developed to quantify this heterogeneity at scales relevant to organisms, to be further included in global change ecology frameworks.

S2-5 PODRABSKY, J.E.; Portland State University; jpod@pdx.edu
The effects of oxygen deprivation on the development of a vertebrate extremophile

Hypoxia is typically a potent inhibitor of vertebrate development and even brief exposures can lead to abnormal development or death. Embryos of the annual killifish *Austrofundulus limnaeus* can develop normally across the entire spectrum of oxygen availability. As oxygen partial pressures are reduced, the rate of development is reduced until levels reach near anoxic, at which point development is arrested and embryos enter into a state of reversible quiescence. The level of hypoxia required to arrest development is extremely low during early development and increases during late development. In fact, the rate of early development through somitogenesis appears to be independent of oxygen partial pressure. As embryos develop, they transition from oxyconformers into oxyregulators at about the onset of organogenesis. Further, the critical partial pressure of oxygen required to alter metabolic rate decreases as embryos develop. It appears that a unique set of mitochondrial traits and the ability to accumulate gamma-aminobutyric acid are critical for supporting survival and normal development under extreme oxygen limitation in this species.

61-3 PINSHOW, B*; ADAMS, A.M.; TURNER, J.S.; Ben-Gurion University of the Negev, Texas A&M University, State Univ. of New York, Syracuse; pinshow@bgu.ac.il
Scorpion Burrow Morphology Attenuates Ventilation by Trapping Eddies

We examined the structural features of the burrows of three species of scorpion, *Scorpio maurus palmatus*, *Opisthophthalmus wahlbergii*, and *O. setifrons*, to test the idea that burrow structure is an extension of the organism's physiology and regulates temperature and moisture levels. Specifically, we predicted that scorpion burrows are built to minimize convective ventilation of the burrow air space. In a desert environment, this may maintain high relative humidity in the burrow, thereby reducing the scorpion's evaporative water loss. We cast natural burrows with molten aluminum and used a 3D scanner to quantify the burrows' linear measurements, angles, and volumes. We found that burrows of all three species had several structural features in common, in particular, a horizontal platform just below the entrance and near the surface. Burrow of all three species have at least two bends, ending in an enlarged terminal chamber. Mean total burrow depth for *S. m. palmatus* in the Negev Desert, Israel was 17.3 ± 4.2 cm, 27.1 ± 5.8 cm for *O. wahlbergii* in the Kalahari Desert in Namibia, and 19.5 ± 3.1 cm for *O. setifrons* on the Central Plateau in Namibia. At these depths, burrows reach an adequately stable temperature that provides refuge from extreme ground-surface temperatures. The similarity among burrows of the three different species and their common design features imply their importance for regulating the physical environment of their scorpion inhabitants the burrows, and that they are part of scorpions' "extended physiology" (*sensu* Turner 2000). Turner, J. S. 2000. The extended organism; The physiology of animal-built structures. - Harvard University Press.

S9-1 POERTNER, Hans-O.; Alfred-Wegener-Institute; hans.poertner@awi.de

Impacts of climate variability and change on marine animals: physiological underpinnings and evolutionary consequences.

Understanding thermal ranges and limitations of organisms becomes important in light of climate change and observed effects on ecosystems as reported by the IPCC (Pörtner et al., IPCC 2014). This understanding also supports efforts to project climate-induced shifts in the distribution and productivity of marine species. For animals, the integrative concept of oxygen and capacity limited thermal tolerance (OCLTT) has successfully characterized the earliest thermal limits to performance and the consequences of such limits at ecosystem level. Steady state temperature dependent performance profiles trace the thermal window and indicate a key role for aerobic metabolism and energy budget in shaping the temperature dependence of steady state performances, from growth to exercise and reproduction. Recent modeling illustrates how routine energy demand characterizes the limits of the realized niche. Evolutionary adaptation is presently unable to keep animals in place; they rather follow the moving isotherms. Assessments across climate zones require consideration of how OCLTT principles were modulated on evolutionary timescales, e.g. in the tropics, in subpolar areas characterized by temperature variability and in permanently cold polar waters. Earlier work has proposed how these relationships have shaped the functional characteristics of survivors in mass extinction events during earth history (Pörtner et al., 2005, J. Geophys. Res., 110, C09S10) and contributed to the evolution of endothermy in mammals and birds (Pörtner, 2004, Physiol. Biochem. Zool. 77, 959-981, Clarke and Pörtner, 2010, Biol. Rev. 85, 703-727). It will be discussed how the knowledge of physiological principles can play a role in reducing uncertainty about projected impacts of climate variability and change.

13-5 POLET, D.T.*; FLYNN, M.R.; SPERLING, F.A.H.; University of Calgary, University of Alberta; dtpolet@ucalgary.ca
A mathematical model to capture complex microstructure orientation on insect wings

Microstructures on insect wings can promote directional drop shedding, and the local orientation of these structures is expected to facilitate drop removal. However, microstructures may exhibit very different orientations at different locations on the wing. Using the march fly *Penthetria heteroptera*, we propose that local orientation of small hairs (microtrichia) reflects a balance of three nonexclusive strategies: (1) preventing water from becoming stuck in interveinous grooves (microtrichia point upslope), (2) shedding water off the wing as readily as possible (microtrichia point towards the nearest edge), and, (3) shedding water away from the body (microtrichia point distally). We present evidence for all three and show that local microtrichial orientation is seldom determined by any one factor. We develop a mathematical model that employs factor-specific weighting values determined via optimization. Our predictions are tested against the orientation of microtrichia randomly sampled from a *P. heteroptera* specimen. Using the best-fit weighting parameters, the model displays a median residual of 20°; no residual is greater than 46°. The model also reproduces qualitative aspects of microtrichial orientation, such as bifurcation midway between veins and convergence toward peaks. This strong correspondence between modelled and observed orientation supports the role of microtrichia as directional antiwetting devices and highlights the importance of considering both function and wing geometry to explain the organization of natural microstructure arrays.

76-3 POLLOCK, H.S.*; BRAWN, J.D.; CHEVIRON, Z.A.; Univ. of Illinois, Urbana-Champaign, Univ. of Montana;
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Seasonal variation in avian thermal tolerances across latitude: are temperate-zone birds more flexible?

Phenotypic flexibility, or the ability to make reversible phenotypic adjustments to variation in environmental conditions, is essential for organisms to cope with environmental change. An emerging framework for understanding variation in phenotypic flexibility is the Climate Variability Hypothesis (CVH), which predicts that flexibility should increase with climatic variability. For example, thermal tolerances of both ectotherms and endotherms increase with latitude (a proxy for climatic variability), which has been interpreted as support for the CVH. However, whether a) thermal tolerance is a flexible trait that can be adjusted to changing environmental conditions, and b) flexibility in thermal tolerance increases with climatic variability as predicted by the CVH, remains unclear. We used flow-through respirometry to measure seasonal variation in breadth of the thermoneutral zone (TNZ; a proxy for thermal tolerance) in a suite of temperate-zone and tropical bird species to determine whether avian thermal tolerance is a flexible trait that varies seasonally and whether temperate-zone birds exhibit greater seasonal flexibility in thermal tolerance than their tropical counterparts. We found that TNZs of tropical species were relatively invariable across seasons (wet vs. dry), whereas TNZs of temperate-zone species were flexible and increased with increasing climatic variability (i.e. winter-acclimated individuals had significantly broader TNZs than summer-acclimated conspecifics), supporting the CVH. Avian thermal tolerance is thus a flexible trait and the magnitude of flexibility varies across latitude, suggesting that tropical birds may have reduced ability to cope with environmental change compared to temperate-zone counterparts.

83-5 POLLOCK, NB*; DRAZENOVIC, M; FEIGIN, SE; JOHN-ALDER, HB; Rutgers Univ., New Brunswick;
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Dihydrotestosterone inhibits growth in a female-larger lizard (*Sceloporus undulatus*): implications for the development of sexual size dimorphism

Sexual size dimorphism (SSD) is widespread, and both male- and female-biased SSD occurs even within species lineages. Recent evidence indicates that testosterone (T) is a bipotential regulator of sex-specific growth rates contributing to the development of SSD in lizards, where T has opposite effects on growth in male- versus female-larger species. However, mechanisms behind these effects are not known. We previously reported that T inhibits growth in *Sceloporus undulatus* (Eastern Fence Lizard), in which females grow faster to become larger adults than males. Here, we test whether the growth-inhibitory effect of T can be replicated by dihydrotestosterone (DHT), which would suggest T acts via androgen receptors and not via aromatization of T to estradiol. We conducted laboratory experiments on yearling *S. undulatus* captured in their first full activity season at about ten months of age. We implanted Silastic tubules containing 150 microgram DHT into intact females and into intact and castrated males. Growth rates were measured for 40 days. We quantified dorsal and ventral colorations to corroborate treatment efficacies. Dihydrotestosterone inhibited growth in both females and males and caused the expression of male-typical coloration in females and castrated males. Feeding rate and body condition were unaffected by DHT, indicating that differences in growth rates were independent of energy balance. The present results suggest 1) that growth inhibition by T, which contributes to the development of SSD, is mediated by androgen receptors, and 2) that the T-regulatory network, including functional androgen receptors, is present in both sexes.

127-5 PORRO, LB*; COLLINGS, AJ; CHADWICK, KP; RICHARDS, CT; Royal Veterinary College, Hatfield, UK;
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Limb kinematics and inverse dynamic modelling of jumping in the red-legged running frog (*Kassina maculata*)

Although the skeletal morphology of anurans is adapted for jumping, frogs engage in a range of locomotor behaviours. *Kassina maculata*, thought to be specialized for walking and running compared to other frog taxa, nonetheless retains the capability to jump. High-speed video cameras and skin markers were used to capture three-dimensional movements of the right hind limb during jumping while ground reaction forces (GRF) were simultaneously recorded. Proximal joints were extended before distal joints during jumping, consistent with results reported in other frog species. Peak GRF ranged from 1.2 to 4.3 times body weight (similar to values recorded in jumping species), with the highest GRFs associated with both strong vertical and horizontal jumps. Peak vertical force exceeded and occurred before peak horizontal force in most trials. Thus, there does not appear to be a performance trade-off between jumping and walking in *K. maculata*. *K. maculata* exhibited a wide range of jump angles (from 1 to 50 degrees from the horizontal), with more vertical jumps apparently achieved by the animal tilting its body to a higher angle about the pelvic-femoral joint prior to take off. This motion has implications for the function and moment arms of major leg muscles, which will be investigated for all hind limb joints using inverse dynamic modelling.

73-2 PORTER, M/M; Clemson University; mmporte@clemson.edu
Biology for mechanical engineers: A new method for teaching biomimetics and bioinspired design

Lessons learned from nature inspire engineers to develop new technologies for many real-world applications. This requires engineers to study biological systems, often in collaboration with biologists, to better understand the complexity of natural systems and their functions. This is often easier said than done. The high variability among biological systems (which never grow exactly alike) and limited access (many organisms are protected or difficult to obtain) can make studying the mechanics of biological systems a tedious and sometimes impossible task. However, new technologies, like 3D-printing, allow researchers to mimic biological designs, and even build comparative hypothetical models of designs not found in nature. Using these techniques, engineers have begun to test biological hypotheses in the lab and develop new design paradigms to describe biology within the realm of engineering principles. In a new course at Clemson University, titled Biomimetics and Bioinspired Design, natural design paradigms in biological materials, structures, and organisms are described in the context of mechanical engineering topics, ranging from statics and dynamics to materials science and fluid mechanics. In this talk, I will outline the design paradigms taught in the course and describe how, as mechanical engineers, students respond to a diverse range of topics in biology and transfer their knowledge between disciplines.

S11-7 POWELL, D*; KNIBB, W; ELIZUR, A; University of the Sunshine Coast; dpowell1@usc.edu.au

Transcriptomic analysis of hepatopancreas tissue from families of farmed banana shrimp (*Fenneropenaeus merguensis*) that exhibit differing levels of hepatopancreatic parvo-like virus resistance.

Viral pathogens pose a serious threat to the cultured shrimp industry. Hepatopancreatic parvo-like virus (HPV) is a shrimp parvovirus that has been reported to be widely distributed in a variety of wild and cultured penaeid shrimp species throughout the world. The occurrence of HPV infection was examined in a population of commercially produced banana shrimp (*F. merguensis*) in North Queensland, Australia. Large differences (up to 3 orders of magnitude) were observed in HPV copy numbers between families bred and grown together. Heritability for HPV copy number was estimated to be moderate to large (0.40 ± 0.13). To further investigate the genetic mechanisms of resistance to HPV, hepatopancreas tissue sampled from 4 animals from 6 families, 3 exhibiting high viral load and 3 exhibiting lower viral load (n=24), was subjected to RNA-Seq, *de-novo* transcriptome assembly and subsequent gene expression analysis. These data revealed over 400 transcripts that were differentially expressed between the high and low families and uncovered a rich set of genes involved in immune system related functions. Over 80 of these transcript sequences exhibited homology with genes associated with invertebrate innate immune responses to known bacterial and viral pathogens. Comparative analysis of gene sequences among family groups revealed a number of interesting single nucleotide variations. This research has provided some insight into our understanding of the mechanisms involved in the resilience of this shrimp species to a naturally occurring viral pathogen.

S4-2 PORTER, M.L.; University of Hawai'i at Manoa; mlporter@hawaii.edu

Beyond the eye: extraocular opsin evolution

Opsin proteins are essential molecules in animal photodetection. Together with a vitamin-A derived chromophore, opsins form the photosensitive pigments used in all known animal visual systems. More recently, opsins have been found expressed in a multitude of non-visual tissues, including skin / chromatophores, nervous systems, bioluminescent structures, and muscles. Based on the ever-increasing volume of sequence data, opsins may be even more prevalent in non-visual photodetection systems than those used in the process of image formation. To better understand the evolution of opsins in general, opsins in non-visual photodetection, and opsins used for image detection, I have mapped known extraocular and visual system opsins within opsin and taxonomic diversity. Many of the currently described opsin sequences are extraocular, with opsins used in visual systems arising at least once in every major opsin clade. Additionally, many sequences that have been characterized from genomes and large-scale tissue transcriptomes may represent even more diversity of extraocular photoreception than currently understood.

97-6 POWELL, J.W.B.*; DUFFIELD, D.A.; KAUFMAN, J.J.; WELLS, R.S.; MCFEE, W.E.; Portland State University, CyberLogic, Inc., Chicago Zoological Society/Sarasota Dolphin Research Program, National Ocean Service; james.powell@pdx.edu
Technological advancements to foster clinical assessment of bone density in live, free-ranging bottlenose dolphins, *Tursiops truncatus*
 To circumvent limitations in traditional radiographic bone density assessment, a custom quantitative ultrasound device and protocols were developed for assessment of live bottlenose dolphins resulting in a novel diagnostic tool for measuring the effects of environmental contaminants on mineralized tissue. Traditional methods for bone density measurement utilize radiographic (x-ray) scanners that have limited potential in open-water field settings due to the inherent limitations of access, regulation and the radiographic nature of the technology. Alternatively, quantitative ultrasound is an ideal diagnostic tool as it is portable, non-invasive, and does not expose patients or technicians to radiation. In laboratory measurements on disarticulated flippers collected during strandings, a strong correlation was established between bone mineral density (BMD) as measured with x-ray and quantitative ultrasound ($r=0.93$). A primary target skeletal site in the radius of the dolphin pectoral flipper was comprehensively defined. 389 radii from 280 bottlenose dolphins were analyzed using dual-energy x-ray absorptiometry (DXA). The BMD distribution pattern throughout the radius was characterized and a single region of interest (ROI) was selected that had a high correlation to the density of the overall bone ($r=0.98$). Successful clinical trials were conducted to ultrasonically assess BMD in live, free-ranging dolphins during capture-release health assessments. Development of this technology enables assessment of dolphin bone tissue to become part of the armamentarium of researchers and veterinarians and should additionally broaden the understanding of dolphin and overall ecosystem health.

120-3 POWERS, D.R.*; SCHROEDER, R.J.; CANEPA, J.R.; LANGLAND, K.M.; ELTING, R.L.; WETHINGTON, S.M.; GRAHAM, C.H.; CORMIER, T.; George Fox Univ., Newberg, OR, HMN, Patagonia, AZ, Stony Brook Univ., Stony Brook, NY, Woods Hole Res. Ctr., Falmouth, MA; dpowers@georgefox.edu
Influence of Habitat Structure on Hummingbird Response to Climate Change

Hummingbirds are ecologically important because they are pollinators for many nectar-producing plants. Climate change threatens the link between hummingbirds and plants in many ecosystems because of the sensitivity of both hummingbirds and plants to higher environmental temperatures. How hummingbirds physiologically respond to higher temperature is virtually unknown. We present data for broad-billed hummingbirds (3.2g; *Cyananthus latirostris*) from a cooler, protected habitat (HC) compared to an exposed, warmer habitat (SC) to illustrate how high temperature impacts daily energy expenditure (DEE) and energy-budget management. In both habitats DEE in June, when peak temperature was 45-50°C, was 28% lower than in July when monsoons routinely reduced peak temperatures to <40°C. The reduced DEE is due primarily to reduced thermoregulatory costs. DEE was always 15-20% higher at SC where temperature was 5°C warmer for much of the day. In both habitats birds appeared to behaviorally regulate plumage surface temperature when temperatures were within 3°C of body temperature to avoid absorbing heat. Nighttime temperature was 10°C warmer at SC where birds spent 66% less time in torpor and had 20% higher nighttime energy costs. However, nighttime energy costs accounted for only 25% of the higher DEE at SC. The remaining difference in DEE could be due to behavioral changes related to structural differences between sites. Our data suggest that higher temperatures related to climate change will not push broad-billed hummingbirds beyond their physiological tolerance as long as their habitat structure remains intact.

2-1 PRATT, BG*; DICKERSON, BH; SANDERS, E; HARRIS, M; DANIEL, TL; Univ. Washington, Cal. Inst. Technol., UC San Diego; danielt@uw.edu
Encoding properties of moth wing mechanosensors are similar to haltere neurons.

Insects collect and process information from their environment using a host of sensory modalities to maintain control during flight. While vision is necessary for flight, the precision, sensitivity, and rapid processing speeds of mechanoreceptors relative to vision make that modality a critical component, particularly in response to perturbations. Furthermore, previous anatomical and behavioral evidence confirms that the wings of the hawkmoth *Manduca sexta* could inform the animal of its body dynamics, much like halteres do for dipteran flies. But, the features of mechanosensory stimuli, their timing, and the precision with which those stimuli are encoded by wing mechanoreceptors remain relatively unexplored. Using multi-site extracellular electrophysiology along with white-noise mechanical stimulation, spike sorting algorithms, and methods from computational neuroscience we characterized the encoding properties of wing mechanoreceptors in the hawkmoth. We focused on two key aspects of encoding: the average stimulus feature (the spike triggered average: STA) and the non-linear decision function (NDF). The STA is derived from the ensemble of stimuli that yield spikes in any one sensory neuron. The latter is a measure of the probability of spiking given any arbitrary stimulus. We measured the STA and NDF for 32 identified neurons from 16 moths. We found (1) nearly all STAs show a very rapid response with their peaks occurring less than 5 ms prior to a spike (2) the shape of the STA varies in manner consistent with those identified for haltere neurons and (3) the NDF shows that mechanoreceptors are extremely selective for the temporal pattern of the stimulus. These results are similar to those found for halteres in Diptera. Unlike halteres, however, wings serve the dual roles of sensing and actuation.

25-4 POWERS, S.D.*; POWERS, D.R.; MASON, R.T.; FRIESEN, C.R.; George Fox Univ., Newberg, OR, Oregon State Univ., Corvallis, OR, Univ. of Sydney, Sydney, Australia; seandpowers@gmail.com
Is Cold Body Temperature a Reproductive Cue in Red-Sided Garter Snakes?

Pheromones produced by female red-sided garter snakes (*Thamnophis sirtalis parietalis*) are the primary reproductive cue for courting males. Some males (she-males) also produce this pheromone and are actively courted by other males, but the functional significance of this is unknown. Body temperature (T_b) has been a suggested secondary cue for reproductive state because newly emerged virgin females are cold when they leave the den. Clarifying role T_b plays in female attraction will improve our understanding of the competitive scramble mating system exhibited by red-sided garter snakes. In this study, we tested whether or not female and she-male attractiveness to courting male snakes changes with T_b . We collected virgin (VF) and non-virgin (NVF) female, and she-male (SM) and unattractive male (UM) snakes in Manitoba, Canada. All females, SM, and UM were cooled to ~8°C and individually placed in courtship arenas with 50 courting males. During courtship trials we recorded changes in T_s over time using infrared thermography and noted whether or not snakes were courted over a range of T_s . All VFs (n=8) and SMs (n=10) were courted whereas all NVFs (n=9) and UMs (n=10) were not courted. T_s of females (VF & NVF) and males (SM & UM) rapidly increased and stabilized at ~30°C within 10 minutes, and male courtship remained constant over all measured T_s . Warming rates did not differ between VF and NVF ($F=0.04$, $P=0.84$) or between SM and UM ($F=0.71$, $P=0.40$). Cold T_s could serve as an initial indicator that a female is virgin, but since T_s rises quickly would at best be a short-term cue. Intense courtship at warm T_s suggests that female pheromones are the primary determiner of female and she-male attractiveness.

44-7 PRESNELL, J.S.*; VANDEPAS, L.E.; DAVIDSON, P.L.; SWALLA, B.J.; AMEMIYA, C.T.; BROWNE, W.E.; Univ. of Miami, FL, Univ. of Washington, WA, Friday Harbor Laboratories, WA, Benaroya Research Institute, WA; j.presnell@miami.edu
Evolution of gut patterning: insights from the ctenophores Mnemiopsis leidyi and Pleurobrachia bachei

The early branching metazoan phylum, Ctenophora, represents an important group for understanding how coordinated developmental patterning of discrete germ layers evolved into higher-order organ systems in the early metazoans. In this study we investigated gut patterning in the ctenophores *Mnemiopsis* and *Pleurobrachia* through a combination of morphological observations and gene expression analysis. The animal gut is typically composed of ectodermal (mouth and anus) and endodermal (midgut) derivatives. The endoderm is thought to be the oldest germ layer among metazoans, and many of the genes expressed during endoderm patterning predate multicellularity. The ectoderm is thought to have originated as an additional germ layer after the endoderm. Among bilaterian animals, genes that regulate endoderm and ectoderm development are well conserved, and these animals share similar structural and morphological gut traits. For example, most bilaterians have a unidirectional alimentary canal with two openings. However, few studies have examined gut patterning at the molecular or morphological level in basally branching metazoan lineages, with most having been done in cnidarian species. It has been previously shown that during gastrulation in ctenophores, endodermal precursors are internalized in the embryo and eventually give rise to the midgut analog (the endodermal canal system), whereas ectodermal precursors have been shown to give rise to a majority of the stomodeum (mouth) and pharynx. We describe the morphological and functional organization of the ctenophore gut system as well as gene expression patterns of conserved endodermal and ectodermal markers. Our findings highlight an elaborately organized gut with an unexpected degree of differentiation.

10-7 PRICE, SA*; CHIONO, AJ; HOPKINS, SSB; Univ. of California, Davis, Univ of Oregon; saprice@ucdavis.edu

Does hypercarnivory constrain carnassial evolution?

The repeated evolution of hypercarnivorous lineages that specialize on vertebrate prey within Carnivora is generally characterized as a history of increasing evolutionary and functional constraints on the morphology of the skull and limbs. One functional system that is consistently modified in hypercarnivorous lineages are the carnassial teeth, which are elongated to form highly efficient shearing blades. The increasing specialization of carnassial teeth in hypercarnivores is expected to constrain carnassial diversity and lower rates of morphological evolution. To test this prediction across extant Carnivora as well as between the very different feliform and caniform suborders we compared morphospace occupation and phylogenetic rates of morphological evolution between hypercarnivorous lineages and all other carnivorans. Tooth morphology (upper P4 & lower M1) was captured by placing four homologous landmarks on the main cones and conulids of the occluding surfaces. Surprisingly we found very different evolutionary patterns between the upper and lower sub-units of the carnassial system. The upper carnassial evolves as predicted: hypercarnivores have lower rates of morphological evolution in P4 and feliform and caniform hypercarnivores cluster in a constrained region of morphospace. In contrast the morphospace of M1 reveals the sub-orders have achieved elongation through different means and the rates of morphological evolution within hypercarnivorous lineages are significantly higher than those within general feliforms or caniforms. We speculate that the faster rates within the lower carnassial of hypercarnivores may reflect a release of constraint on the crushing function of the M1.

34-6 PUSCH, E.A.*; BENTZ, A.B.; BECKER, D.J.; NAVARA, K.J.; University of Georgia; epperfectchoice@gmail.com

Does personality type correspond to physiological differences in immune function and measures of stress?

Studies suggest that, in animals, personality type is correlated with the degree of stress responsiveness. For example, white laying hens are reactive, flighty, and exhibit large hormonal and behavioral responses to stress while brown laying hens are proactive, exploratory, and exhibit low hormonal and behavioral responses to stress. The objective of this study was to determine if personality type also corresponds to differences in immune responses and to test additional measures of stress as well. To test the responses of the hens to stress, we provided feed according to an unpredictable schedule for 14 days, and measured corticosterone levels, heat shock protein expression, H:L ratios, and tonic immobility responses. We predicted that white hens would show greater stress reactions to the stress treatment. Plasma corticosterone levels were significantly greater after 7 days of treatment ($p < 0.001$), but did not differ significantly between strains. H/L ratios, on the other hand, were significantly elevated by day 14 of treatment ($p < 0.04$), and raised significantly more in white hens than brown ($p = 0.03$). After the stress protocol was completed, we then challenged hens immunologically. Immune function was assessed by comparing the febrile responses to lipopolysaccharide (LPS) injection and measuring two consecutive inflammatory responses to injection with phytohemagglutinin (PHA). Because white hens are exposed to more corticosterone in response to stressful stimuli, we predicted that brown hens would show greater immune responses than white hens. Swelling of the toe web in response to PHA injection was significantly greater in white hens than brown after both challenge events ($p = 0.0003$ and 0.008). Finally, LPS injection resulted in a significant increase in temperature at 6 and 12 hours post injection ($p = 0.0001$ and $p = 0.02$) in both strains but there was no difference between strains. Our results suggest that white hens are more reactive not only behaviorally and hormonally, but also immunologically.

99-4 PRUETT, J.A.*; HEWS, D.K.; PRUETT, Jake; Indiana State University; jpruett1@sycamores.indstate.edu

The scent of danger: Male *Sceloporus undulatus* lizards exhibit different responses to chemical cues from snakes that pose different levels of predation risk

Animals use information about risks associated with different predators to potentially minimize costs associated with engaging in anti-predator behavior. Chemical cues can provide information about the level of risk posed by potential predators, and predator scent alone can induce anti-predator behavior in many vertebrates. Previous studies have produced conflicting results regarding whether lizards use chemical cues produced by snakes to assess predation risk, but many studies consider only a subset of the potential responses to snake scents. We tested whether male *Sceloporus undulatus* (eastern fence lizards) discriminate among chemical cues of snakes that pose different levels of predation risk. We recorded behavior (chemosensing, motion displays, movement and head turns) of free-ranging males following presentations of chemical cues of high-risk predatory snakes (*Pantherophis spiloides*, eastern rat snake; *Nerodia sipedon*, northern watersnake), a low-risk snake (*Storeria dekayi*, Dekay's brown snake) or clean pieces of paper (stimulus control). Overall activity was higher for males exposed to scents of high-risk predatory snakes relative to activity of males exposed to scent of the low-risk snake or control. Male *S. undulatus* performed more chemosensory behaviors and head turns following exposure to chemical cues of high-risk snakes relative to cues of the low-risk snake or control. Our results indicate that *S. undulatus* males distinguish between chemical cues of high- and low-risk snakes and underscore the importance of considering multiple responses in studies of anti-predator behavior.

109-1 PUTNAM, HM*; DAVIDSON, J; GATES, RD; University of Hawaii Manoa; hputnam@hawaii.edu

Ocean acidification influences DNA methylation and phenotypic plasticity in environmentally susceptible corals

Climate change challenges organismal fitness by creating a mismatch between phenotypes based on historic conditions and the new environment. Rapid compensatory response to environmental change, or adaptive phenotypic plasticity generated by epigenetic mechanisms (e.g., DNA methylation) can provide a temporal buffer for evolution through natural selection, and may therefore be especially crucial for sessile marine organisms, such as reef-building corals. We tested the potential for scleractinian corals to exhibit phenotypic plasticity and altered DNA methylation in response to ocean acidification (OA). Clonal fragments of the environmentally susceptible coral *Pocillopora damicornis* and environmentally resistant *Montipora capitata* were exposed to ambient pH (7.9-7.65) and low pH (7.6-7.35) conditions in common garden tanks at ambient temperature (26.6°C) for ~6 weeks. Response was assessed by growth as a proxy for fitness, 1H-NMR profiling or physiological phenotype, and host DNA methylation as a measure of epigenetic change. *M. capitata* responded weakly to OA, with no difference in growth, minimal separation of metabolite profiles, and no change in DNA methylation between treatments. Conversely, *P. damicornis* exhibited a significant decline in growth (30%) at low pH, stronger separation in metabolite profiles between the two treatments, and a higher DNA methylation (~2x) at low pH than ambient. Our results suggest some corals have a more sensitive environmental trigger for real-time epigenetic reprogramming and provide evidence of a mechanism whereby intra-generational and trans-generational acclimatization and soft inheritance may occur, which has significant implications for future reef persistence.

113-4 RADE, C.M. *; SANFORD, C.P. ; HERNANDEZ, L.P.; The George Washington University, Hofstra University; cristinarade@gmail.com

Prey-specific muscle activation patterns of the cypriniform palatal organ

The cypriniform palatal organ is a dorsal tongue-like muscular mass that spans the buccal roof and is bilaterally connected to the branchial elements. It has most often been associated with benthic sorting behaviors. Previous research on common carp and goldfish has shown that this taste bud-studded structure produces localized protrusions that selectively sort organic matter from inorganic matter during bottom feeding behaviors. Its possible role in other feeding modes has been largely overlooked as it has been presumed that the palatal organ's only function is in sorting during benthic prey capture events. Using electromyography to examine palatal organ activity in the common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*), muscle activation patterns demonstrate that the palatal organ is active during prey capture events, during prey processing events, and may even play a role in respiration under stressful conditions. Furthermore, the palatal organ of both species shows behavioral flexibility when fed different prey types that provide different functional challenges. These data suggest that the palatal organ is a multi-functional structure with a much wider range of functional repertoires than previously thought. While sorting during benthic sorting behaviors may have been the primitive function of the palatal organ, it has likely been secondarily adapted for increasing dietary breadth during the course of cypriniform evolution.

119-8 RADZIO, TA*; O'CONNOR, MP; Drexel University, Drexel University ; tomradzio@hotmail.com

Behavior and Short-term Survival of Captive-reared Yearling Gopher Tortoises Following Hard Release

Captive-reared animals may lack critical traits required for success in the wild. This can impede research or conservation efforts in which animals must be raised in captivity and subsequently released responsibly back into nature. We collected hatchling gopher tortoises from natural nests in southwest Georgia and raised them in the laboratory for physiology experiments that required having animals in controlled environments for prolonged periods. Upon completing the lab work, we outfitted 30, one-year-old individuals with radio transmitters and hard-released them in late summer at their nest sites to determine post-release behavior and survivorship. Most yearlings constructed burrows soon after release, and, like wild tortoises, released tortoises disproportionately placed burrows under deadwood. Video cameras located at tortoise burrows indicated normal activity patterns. Tortoises slept in burrows at night, emerged during warm daylight hours, basked extensively at burrow entrances, and limited time spent foraging away from the safety of burrow areas. Importantly, simulated predator approaches revealed that released tortoises showed normal antipredator responses by reliably hiding inside their burrows in response to potential threats. Released yearling tortoises exhibited survivorship similar to that of wild yearlings, 63-77% survived until the following spring. All known mortalities were due to predators. Despite having been raised inside plastic boxes and having daily contact with laboratory personnel for the first year of their life, captive-reared yearling tortoises retained critical traits necessary for success in the wild. These findings indicate that young gopher tortoises used in lab studies or captive-reared in efforts to augment wild populations may be successfully hard-released back into nature.

82-6 RADER, J.A.*; HEDRICK, T.L.; University of North Carolina at Chapel Hill; jrader@live.unc.edu

Behavioral compensation for decreased air density in turkey vultures

The breadth of environmental conditions that species tolerate and exploit may, in large part, determine their geographic extent. Intuitively, species that can tolerate only a narrow set of environmental variables are expected to have smaller geographic distributions than species that thrive in more diverse conditions. Exploring how some species compensate for environmental challenges, and what prevents others from reacting similarly, may shed light on what determines their range. Turkey vultures (*Cathartes aura*) span a broad geographic range in North, Central and South America exposing them to a range of environmental conditions including elevations from sea level to >3000 meters. Because air density decreases with increased elevation, flight at high elevation presents a challenge for animals. Compensation for life in lower density air will manifest either in wing morphology, flight speed or increased power input. While some high elevation fliers have been shown to have larger wings, relative to their lowland relatives, and thus decreased wing loading (body mass/wing area), there has been less focus on whether and how fliers respond behaviorally. We used 3-dimensional videography to track the flights of turkey vultures at two elevations (~120 m and 2200 m) to look for evidence that high elevation vultures tend to fly faster than low elevation conspecifics. We predicted that the high elevation birds would have a 12% faster airspeed, on average, relative to low elevation birds, assuming that they are geometrically similar. Preliminary data analysis indicates that high elevation vultures fly approximately 7% faster, suggesting partial behavioral compensation for the elevational gradient. Our study exemplifies how field studies can illuminate the relationship between biomechanical performance and ecology.

20-2 RAMSAY, JB*; WILGA, CD; Univ. of Rhode Island; jasonramsay@uri.edu

Stable and dynamic gears: Morphological effects on mechanical output of the jaw adductors in sharks

The muscles of the adductor mandibulae complex (AMC) in sharks are complexly subdivided and diverse in architecture. A possible benefit of the subdivisions is observed when manipulating the jaws in fresh specimens. As the jaws are moved closed, the angles of the muscle divisions reconfigure, and may affect the force output to the jaws during feeding. Here we investigate the anatomy and mechanics of the AMC divisions during jaw closure in sharks that employ suction and bite feeding mechanisms. The goal of the study is to determine if the reconfiguration of the muscle divisions result in a mechanical benefit related to feeding mechanism. Mechanical models of the AMC in suction and bite feeders show that the AMC is capable of transferring a stable level of force to the jaw tips from 0 to 100 percent jaw closure using two disparate methods, which appear to have evolved with the constraints associated with the different feeding mechanisms. In suction feeders, stable force transfer is a consequence of a reduced gape, which does not significantly alter the insertion angles of the posterior-more adductors, and large processes on the upper jaw that restrict posterior excursion of the anterior-more adductors. These muscles occlude much of the lateral gape, are geared low-to-high and have moment arms that do not change with jaw closure. In bite feeders, stable force transfer is accomplished by changes in the insertion angle of the adductors, some switch from large to small moment arms during jaw closure, while others switch from small to large. As the jaws close, total force transfer to the jaws remains the same as divisions increase and decrease force transfer capabilities. These muscle divisions also allow for a wide gape without a reduction of bite force that is useful in capturing and processing large prey.

57-5 RANKIN, JW*; VELO-ANTÓN, G; NICIEZA, AG; HUTCHINSON, JR; The Royal Veterinary College, UK, University of Porto, Portugal, University of Oviedo, Spain, They Royal Veterinary College, UK; jrankin@rvc.ac.uk
Ontogenetic changes in locomotor mechanics and performance in fire salamanders

Salamanders undergo a highly derived developmental cycle that requires a transition from an aquatic to a land environment, accomplished by considerable musculoskeletal and locomotor changes. Indeed, their movement capability appears to be limited to gaits up to a moderate speed, lumbering trot. Previous studies show strong metamorphic and locomotor changes linked to the transition from swimming to walking in taxa with aquatic larvae (*Ambystoma*). However, locomotor performance shifts in more terrestrial, direct-developing salamanders such as Spanish populations of the fire salamander (*Salamandra salamandra*) have not been characterized. In this study, we aimed to determine: 1) the changes in (fully viviparous) fire salamander morphology through ontogeny and 2) how these changes relate to changes in locomotor mechanics. We hypothesized that, like *Ambystoma*, there would be an ontogenetic transition in locomotor performance that occurs early in ontogeny and is linked to changes in limb and/or body morphology. To test our hypothesis, anthropomorphic data (e.g., body and limb length) were collected from 164 salamanders of varying age (weight range: 0.13-21.91g). High speed video data were collected using 3 GoPro cameras during five gait trials per individual. Gait variables were calculated from ~1300 strides and used to construct linear mixed effects models for statistical analysis. Mass was found to significantly influence maximum speed ($p=0.02$) and stride frequency ($p<0.001$), with smaller (i.e., younger) salamanders exhibiting higher stride frequencies and salamanders of intermediate size exhibiting the fastest speeds. These results also have bearing on early tetrapod motion as salamanders are the commonly used postural model.

82-1 RAVI, S*; NODA, R; KONOW, N; BIEWENER, A; COMBES, S; LIU, H; Chiba University/RMIT University, Hong Kong University of Science and Technology, Brown University, Harvard University, Chiba University; sridhar.ravi@rmit.edu.au
Dynamics of roll control in hummingbirds

Airflow conditions close to the Earth's surface are often complex, posing challenges to flight stability and control of volant taxa. Maintaining flight while being subjected to aerial disturbances would require efficient sensorimotor system capable of sensing disturbances and effectuating control maneuvers. Hummingbirds are ideal organisms for studying the influence of aerodynamic perturbations on flight, as they forage in a variety of aerial conditions and are powerful flyers. In this study we measured muscle activation of upstroke and downstroke muscles and performed computational fluid dynamics analysis to identify the flight control strategies implemented by hummingbirds when flying in a longitudinal vortex that induced strong roll perturbations. It was noted that the birds maintained significantly asymmetry wing kinematics of either wings. The birds could maintain significantly different bilateral wing kinematics with only small variation in the timing of each muscle. Additionally, the kinematics of each wing remained consistent over many strokes, suggesting that the birds made fixed systematic modifications to their kinematics when subjected to the "steady" aerodynamic roll perturbation. Computational analysis revealed that the birds produced the necessary torque to maintain flight in the vortex, mainly through the bilateral asymmetry in wing angle of attack. Our results highlights the exceptional flight prowess of hummingbirds and their capacity to devise control strategies even in unfamiliar and unique aerial conditions.

7-3 RAPIN, K*; MOORE, P; Bowling Green State University; rapink@bgsu.edu

Comparison of individual personality in laboratory and field settings: How personality affects fitness consequences of individuals

The origin and function of behavioral traits or personalities (called syndromes) is an increasing field of study in biology. What is lacking from this extensive field of research is a connection between the behavioral syndromes as measured in the laboratory to the behavioral and evolutionary consequences of these syndromes within natural field settings. To assess the importance that personalities may play in an organism's natural setting, individual crayfish were run through five separate and distinct behavioral assays in a lab setting to determine their behavioral syndrome across a broad spectrum of behavioral situations. Once animals had completed the random sequence of assays, they were placed in a natural stream and videotaped for twenty-four hours. The outcomes of each laboratory assay were used to place individual crayfish on a spectrum of boldness and shyness within the population that was tested. This spectrum was then used to compare the behavioral responses from the field set up and what was observed in the lab setting. Laboratory results show a broad spectrum of behaviors along the bold-shy spectrum and that animals that were bold within one assay typically were bold for other assays. In field tests, bold and shy animals exhibited different behavioral responses to threats of predation, competition with other species of crayfish as well as other ecological interactions.

82-3 READ, T.J.G.*; SEGRE, P.S.; MIDDLETON, K.M.; ALTSHULER, D.L.; University of British Columbia, Vancouver, University of Missouri; read@zoology.ubc.ca

Hummingbirds control turning velocity with body orientation and turning radius with asymmetrical wingbeat kinematics

Turning in flight requires reorientation of force, which birds, bats, and insects accomplish either by shifting body position and total force in concert or by using left-right asymmetries in wingbeat kinematics. Although both mechanisms have been observed in multiple species, it is currently unknown how each is used to control changes in trajectory. We addressed this problem by studying hummingbirds tracking a revolving feeder. Comparing hovering and turning flight revealed that hummingbirds banked both their stroke plane and body into turns, supporting a body-dependent mechanism. However, several body-independent wingbeat asymmetries were present during turning, including a higher and flatter outer wing-tip path and a lower more deviated inner wing-tip path. We next varied the radius and velocity of the revolving feeder. Body and wing banking were significantly associated with changes in translational velocity, and four asymmetries in wingbeat kinematic variables were significantly associated with changes in turn radius. No kinematic variables were associated with both velocity and radius. These results indicate that hummingbirds use both body-dependent and body-independent mechanisms to reorient forces, and that these mechanisms can be used to control separate aspects of the same maneuver.

73-6 READER, LL*; ZOU, H; SCHMIDT, AJ; HSU, E; GOMEZ, AD; University of Utah, Johns Hopkins University; L.Reader@utah.edu

A composite beam approach for finite element simulations of feathers: a case study in simply supported bending

The mechanical responses of biological superstructures, including feathers, span multiple hierarchically organized scales; but despite their potential role in quantifying structure and function, the experimental and computational methods for modeling mechanics rarely support multiscale analysis. At the same time, numerical modeling via basic beam theory is insufficient to capture the geometric complexity of feather shafts (largely responsible for increased bending resistance), and finite element analysis (FEA) remains time and labor intensive. We introduce a new approach for model simplification: geometrical complexities are captured via computer tomography (CT) and automatically mapped as variations of stiffness within a simpler geometry. Because both the original and simpler mapped geometry have equivalent flexural stiffness, it is possible to obtain identical responses given the same set of loading characteristics. We detail the experimental validation of the proposed methodology (with a numerical verification against traditional FEA), and explore its application to feathers of different internal geometries and multi-unit configurations. The results indicate that the simplified equivalent shape can accurately predict bending deflection in a cantilevered feather shaft, while improving model construction and computational efficiency compared to traditional FEA.

123-3 REEDY, A.M.*; EVANS, W.J.; COX, R.M.; University of Virginia; amr3mb@virginia.edu

Does sexual conflict hinder life-history evolution? A comparative test with lizards

Species with high annual reproductive effort tend to have low annual survival, whereas those with low reproductive effort have high survival. However, most lineages exhibit considerable interspecific variation about the axis that defines this life-history tradeoff, with some exhibiting relatively higher (and others relatively lower) survival than predicted by their level of reproductive effort. Though often treated as error variance, one alternative possibility is that this residual variance is actually the signal of unresolved genomic conflict over divergent life-history strategies in males and females. To indirectly test the role that sex-specific selection in males may play in constraining life-history evolution in females, we used comparative phylogenetic analysis of life-history data from 58 lizard species, and considered the degree of sexual size dimorphism as a proxy for the extent of intralocus sexual conflict. In accordance with the basic predictions of life-history theory, we found a negative relationship between female reproductive effort and survival. Additionally species with larger body size had higher annual survival rates. When controlling for reproductive effort and body size, we found no evidence for intralocus sexual conflict as a constraint on the evolution of female life-history.

54-1 REDDON, A.R.; McGill University; adam.reddon@mcgill.ca
Submissive behaviour reduces the costs of conflict and facilitates group living: A case study in a highly social cichlid fish

Submissive behaviour serves to signal acquiescence to a dominant individual, thereby avoiding further conflict. Despite its important role in agonistic interactions, submissive behaviour has received scant research attention compared to the vast literature on aggression. In the current paper, I highlight the importance of submissive signals. In particular, I emphasize the value of submissive behaviour in reducing the costs of aggression for both winners and losers during agonistic interactions, thereby mitigating the costs of social conflict. I argue that submission has a place of particular importance in the behavioural repertoire of gregarious species, which must regularly interact with conspecifics. Frequent interactions have the potential to lead to recurring conflict, which could obviate the benefits of group living. Furthermore, social species must settle disputes while remaining in the same spatial area, thereby restricting the ability for the loser to flee, which may further incentivize the use of submissive behaviour. As a result, submissive signals are likely a key building block of animal sociality. I discuss the relationship between submission and sociality using recent experimental data collected on the cooperatively breeding cichlid fish, *Neolamprologus pulcher*.

63-6 REID, R.M.L.*; FROELICH, J.M.; BIGA, P.R.; University of Alabama at Birmingham; rreid01@uab.edu

Novel Insights into Myogenic Precursor Cell Phenotypes using Comparative in vitro Analyses.

Zebrafish (*Danio rerio*) and giant danio (*Devario aequipinnatus*) represent comparative growth models, providing valuable data for the understanding of adult growth potential. These species exhibit two muscle growth paradigms, determinate (zebrafish) and indeterminate (giant danio), allowing for an in-depth investigation into the pathways that regulate muscle growth. Recent studies have shown that myogenic precursor cells (MPCs, adult muscle cells) from these two species exhibit differential biomarkers and proliferation capacities. The present study utilized a primary myogenic cell culture system to test the hypothesis that MPCs exhibit specific phenotypes that are responsible for muscle growth potential in adult organisms. To test this, MPCs from each species were isolated and cultured under the same conditions. Proliferating myoblasts were treated with several molecules to assess growth hormone, transforming growth factor, insulin and insulin-like growth factor pathways for 4 days. The cellular phenotype was measured by analyzing cell proliferation, cell differentiation, and gene expression changes between growth paradigms. Giant danio MPCs exhibit greater proliferative capacity, *in vitro*, compared to zebrafish MPCs. Consistent with the proliferative data, zebrafish cells express higher levels of the myogenic lineage commitment marker *myf5*. Also, the expression of Pax-3 and -7 genes are differentially regulated between the growth paradigms and growth factor treatments, which likely modulates pathways responsible for establishing growth trajectories. These data suggest that giant danio and zebrafish can serve as excellent model organisms for studies investigating how myogenic precursor cell phenotypes likely can contribute to organismal growth potential.

103-5 REN, JING*; KONSTANTINOV, A. S.; WANG, X. S.; RUAN, Y. Y.; YANG, X. L.; CHEN, RUI; HU, DAVID; GE, SIQIN; Institute of Zoology Chinese Academy of Sciences, Beijing China, Smithsonian Institution, Washington, School of Mechanical Engineering and Biology, Georgia Institute of Technology, Atlanta; renjing@ioz.ac.cn

Camouflage Feeding: Leaf Bite Patterns Are Proportional to Beetle Body Size

Life on a leaf can be dangerous. The distinctive body shape and color of flea beetles make them easily spotted by birds and other predators. In this study, we show that flea beetles bite leaves in particular patterns to camouflage themselves. We measure the hole dimensions of 29 flea beetle individuals (15 species) from South America. Beetles across two orders of magnitude in body mass bite holes that are one-fifth of their body surface area. Why is hole size so consistent? We perform time-lapse photography of feeding and micro-CT scanning of the gut. We find that hole size is constrained by two physiological factors, the mobility of the neck and the size of the foregut, which is of the same volume as that of the leaf hole. We hypothesize that these organs co-evolved in beetles to facilitate camouflage feeding.

512-8 RENN, SCP*; O'ROURKE, C; RENN, Susan; Reed College; renns@reed.edu

Integrating Metabolic Regulation and Maternal Care in an African Cichlid fish.

Maternal care is an essential adaptive social behavior for many species, yet the underlying neural mechanisms have largely been addressed in mammalian systems. A new mother's brain undergoes a fundamental transformation that shapes maternal behavior. We capitalize on the well-studied neural circuit plasticity for mammalian maternal behavior, "the maternal brain", to study maternal mouth-brooding in the cichlid fish *Astatotilapia burtoni*. In this independently-evolved instance of robust care, the neural circuits regulating maternal behavior must interact intimately with the feeding circuits to allow voluntary starvation despite significant loss of body mass. Maternal mouth-brooding offers an extreme example of parent-offspring conflict in a tractable system for careful mechanistic studies. Using two different *A. burtoni* fish stocks, each showing a different level of maternal care, we have identified gene expression changes associated with the transition from mouth-brooding to overt maternal care. By aligning our gene regulation results with homologous anatomical networks we can determine the extent to which the cichlid maternal brain corresponds to that of mammals implying deep homology across vertebrates.

132-3 REN, Y*; LIU, G; DONG, H; FISH, F; University of Virginia, West Chester University; haibo.dong@virginia.edu

Effect of Fluke Flexibility on Flow Modulation in Orca's Steady Swimming

The flexibility of the flukes has been found crucial in cetaceans' propulsion. Previous research (Fish et al., 2005) has shown both the chordwise and spanwise flexibility could increase thrust generation in swimming dolphins. In this work, we examined the effect of fluke flexibility on the hydrodynamic performance and flow modulation in a freely swimming orca, which has demonstrated substantial spanwise bending in the oscillatory cycle. Using a combined experimental and computational approach, we first quantified the dynamic cambering and bending of the fluke in a complete oscillatory cycle during the steady swimming. It's found that the fluke presented larger spanwise bending during the upstroke, and smaller chordwise cambering during the downstroke. This resulted in an effective flow modulation and thus enhanced the fluke's propulsive performance. Further 3D vortex dynamics analyses have shown the key propulsion mechanism in orcas. Findings from this work are fundamental to understand key kinematic features of cetacean propulsors, and for quantifying the hydrodynamic force production that naturally occurs in cetaceans' steady swimming. (This work is supported by ONR MURI N00014-14-1-0533 and AFOSR FA9550-12-1-0071)

21-5 RETALLACK, G.J.; University of Oregon; gregr@uoregon.edu
The Silurian problematic fossil *Rutgersella* as another post-Ediacaran vendobiont

Rutgersella is a problematic fossil from the early Silurian (Llandovery) Shawangunk Formation of New Jersey, at first interpreted as a jellyfish comparable with Ediacaran fossils such as *Dickinsonia*. Three proposed species of *Rutgersella* from the same locality are here regarded as growth or reproductive variants of a single species, *R. truexi*. Sedimentary structures, associated trace fossils and petrographic examination now shows that they were sessile organisms of intertidal mudflats. These fossils have been dismissed as pyrite suns, but thin sections show that they were weakly pyritized, organic structures, with a quilted hollow internal structure, similar to Seilacher's constructional and taxonomic concept of Vendobionta. As for Cambrian *Swartpuntia*, and Devonian *Protonympha*, *Rutgersella* may be a post-Ediacaran vendobiont. The biological affinities of *Rutgersella* are problematic, but are compared with coenocytic green algae, cellular slime moulds, puffball-like fungal fruiting bodies, and foliose lichens.

123-1 REYES, M.*; BAKER, J.; Clark University;
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Juvenile compensatory growth impacts adult size and life-history traits within the threespine stickleback (*Gasterosteus aculeatus*) model system.

Organisms across the animal kingdom exhibit compensatory growth (CG), a form of phenotypic plasticity exhibited as faster than normal growth following a period of low nutrient levels. However, certain long-term impacts of CG, such as those on reproductive output remain poorly understood. We assessed reproductive costs of CG by exposing juvenile threespine stickleback (*Gasterosteus aculeatus*) to maintenance diet rations (*ad libitum* diet cut in half) across three different periods early in life, at one month (DPR1), two months (DPR2) and three months (DPR3) of age. Following one-month nutrient deprivation periods, the fish were returned to *ad libitum* diet levels and we enumerated the impact on female body weight and reproductive output (clutch and egg size) within the first spawning season, at one year of age. We hypothesized that DPR1 juveniles, due to their younger age, would show reduced body sizes and reproductive output upon reaching adulthood, in comparison to fish exposed to low nutrients at three and four months of age. Recent CG studies suggest potential trade-offs between maternal growth investment and offspring size as a response to undernourishment. Our results suggest that three-month old fish (DPR3) exposed to low nutrients, then returned to *ad libitum* diet levels, attained higher female body weights at one year of age, in contrast to the other dietary groups. Our work also suggest little variation in clutch size adjusted to female body weight among the dietary groups, however, fish from DPR2 and DPR3 groups yielded larger egg sizes in proportion to clutch size.

S2-11 REYSENBACH, A.L.*; DAVIS, R.; Portland State University;
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Comparative metagenomics of deep-sea hydrothermal vent microbial communities

Deep-sea hydrothermal vents are recognized as important biogeochemical environments that support unique ecosystems rich in microbial diversity. As the high temperature hydrothermal fluid mixes with the cold, oxygenated seawater, minerals precipitate to form vent deposits. These porous deposits are quickly colonized by a diversity of Archaea and Bacteria that harness the abundant geochemical energy available in the hydrothermal fluids. High throughput 16S rRNA gene amplicon sequencing has shown that the microbial diversity associated with these deposits is strongly influenced by the mode of hydrothermal fluid mixing and geochemistry of the fluids. In order to explore the functional diversity in these communities, three metagenomes were compared from two different vent fields along the Eastern Lau Spreading Center in the southwestern Pacific. The metagenomic phylogenetic diversity shared the 16S rRNA amplicon patterns, and provided insights into differences between key potential carbon fixation, nitrogen assimilation, hydrogen oxidation and sulfur oxidation/reduction metabolisms. Furthermore, the metagenomes provided hints of the physical environmental differences within the sulfide deposits that most likely helped drive the microbial community assembly.

107-5 REYNAGA, C.M.*; ASTLEY, H.C.; AZIZI, E.; Univ. of California, Irvine, Georgia Institute of Technology ;
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Morphological and kinematic constraints of quadrupedal walking in frogs

The general anuran body type, consisting of long hindlimbs, a short inflexible trunk, and short forelimbs is considered a specialization for jumping. However, some frogs primarily use a quadrupedal gait, characterized by limbs moving in diagonal pairs. It is unclear how the morphological specializations associated with jumping constrain the mechanics and kinematics of quadrupedal locomotion. In this study, we examined four frog species specialized for walking (*Kassina senegalensis*, *Melanophryniscus stelzneri*, *Phrynomantis bifasciatus*, *Phyllomedusa hypochondrialis*). We aimed to understand how the prominence of this novel quadrupedal gait correlates with a shift in limb morphology. We used 3D high-speed videography to examine whether limb kinematics, limb posture and body posture during walking function to compensate for differences in forelimb and hindlimb length. Our results suggest, frogs specialized for walking accommodate a quadrupedal gait with (1) an increase in relative forelimb length compared to the average anuran body plan and (2) by maintaining greater flexion in the hindlimb compared to the forelimb during walking. These features allow walking frogs to minimize body pitch and maintain a more symmetrical body posture during walking. The results of this study demonstrate how the evolution of novel gaits may lead to conflicts between diverse locomotor modes, and how potential constraints may be overcome through variation in limb morphology and kinematics.

100-4 RIBAK, G.*; DAFNI, E.; GERLING, D.; Tel Aviv Univ. ;
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Aerial stabilization in mm sized insects: take-off jumps in tobacco whiteflies, *Bemisia tabaci*

The take-off of *Bemisia tabaci* is executed by a powerful jump that launches the insect into the air while its wings are still in a resting position, i.e., pointing backwards along the sides of the body. We show that the take-off jump from a flat and uniform surface results in forward rotation of the body in the pitch plane. However, the insects manage to stop body rotation even before spreading their wings and flapping them. When the wings start to deploy, the rotation of the body reverses direction abruptly. We explored the mechanism behind this righting ability by modeling the dynamics (rigid body) of the aerial phase of the take-off jumps up to the point where the wings start to flap. We show that the contribution of aerodynamic force on the closed wings to stop and even reverse body rotation exceeds the contribution of the torque on the body by an order of magnitude. The distal half of the closed wings, which is located posterior to the body, contributes more than 80% of the aerodynamic torque. Once the wings deploy the torque responsible for righting increases but the predictability of the model is reduced suggesting that internal torques can also be at play at that phase. The righting response is extremely fast (<10 ms) underlining the effect of large surface area relative to body inertia in small creatures.

90-7 RICE, M.A.*; HOBBS, L.E.; WALLACE, K.J.; OPHIR, A.G.; Cornell University, University of Massachusetts Amherst; mr868@cornell.edu

Sex differences in spatial memory, hippocampal volume, and oxytocin receptor density in prairie voles *Microtus ochrogaster*.

Sex differences in brain and behavior are well documented in many species. Conventional thought is that sex differences are associated with polygamous males, which are better at spatial memory because sexual selective pressure has promoted mate searching in males. Monogamous species are not expected to differ in spatial ability, or the mechanisms associated with promoting spatial memory, presumably because the selective pressures on males and females is relatively equal. However, sex-specific selection is not identical in intensity and therefore should apply powerful influence over neural and behavioral phenotype in monogamous animals. We hypothesize that sex-specific cognitive demands are present in monogamous species. The effects of these demands should be observable in spatial learning performance and neural structures associated with spatial learning and memory. To this end, we analyzed spatial memory performance, hippocampal volume, and hippocampal oxytocin receptor (OTR) expression. The hippocampus is synonymous with spatial memory; our focus on OTR is rooted in its role for modulating memory and because it is well expressed in the hippocampus. To assess these parameters, we used a sexually monomorphic, socially monogamous rodent - the prairie vole (*Microtus ochrogaster*). Our results showed that males learn faster and perform better in a spatial memory test compared to females. Consistent with previous work, we found no sex difference in hippocampal volume. However, OTR expression in males was significantly lower than females. This is the first evidence implicating hippocampal OTR density in modulating spatial memory performance.

59-8 RIDDELL, EA*; ODOM, J; SEARS, MW; Clemson University; eriddel@clemson.edu

Improved measurements of skin resistance to water loss using first principles

The measurement of heat and water flux in amphibians has been problematic due to significant rates of cutaneous water loss. Physical surrogates, such as agar replicas of amphibians, have been used as a replacement for complex calculations to understand water loss physiology. Unfortunately, these physical surrogates likely do not measure the processes for which they were meant. Here, we present theoretical and empirical methods that improve estimating water loss traits in amphibians. Skin resistance (R_s) is the gold standard for water loss studies because it reflects the physiological mechanisms underlying water loss rates. To evaluate the efficacy of physical surrogates, we compared theoretical calculations to empirical methods for measuring R_s . Empirically, we measured water loss of agar models in five body sizes, two temperatures, and three vapor pressure deficits using a flow system capable of precisely controlling temperature and vapor pressure. We then calculated the same biophysical parameters under free and forced convection using dimensionless analysis. Upon applying these parameters to data collected from salamanders, empirical estimates underestimated R_s and even resulted in negative values of R_s . Contrary to previous research, our experiments revealed that agar replicas exhibit a temperature-dependent skin resistance. Underestimates of R_s are likely due to evaporative cooling which reduces of the water vapor density gradient. Based on our analyses, we recommend that agar replicas are an inadequate medium to characterize skin resistance to water loss. Instead, first principles provide better estimates of the biophysical parameters necessary to characterize water loss physiology.

16-3 RICHARDSON, C.S.*; FONTES, G.; MEWHERTER, J.; PONG, T.; SUCIU, N.; Northeastern University, Lesley University; c.richardson@neu.edu

The Impact on Metabolism and Immune function of the Immune Response of Bats to White Nose Syndrome

White-nose syndrome (WNS) has decimated populations of hibernating bats in the U.S. Among the bat species affected by WNS, *Eptesicus fuscus* (big brown bat) appear to be the least affected while *M. lucifugus* (little brown myotis) appear to be one of the most affected. Understanding the energetic cost of immune function in *M. lucifugus* and *E. fuscus* is important for understanding the immune response and recovery of bats to WNS. We examined basal metabolic rate (BMR), an important measure of energy expenditure, and bacterial killing ability of blood (BKA), an important measure of innate immune ability, in both species. WNS can damage a bat's wing, which can impact flight cost and energy use. Additionally, the extent of wing damage reflects the course of immune response and recovery to the *Pseudogymnoascus destructans* fungus, the cause of WNS. We hypothesized that wing damage would be positively correlated with BMR. After accounting for body mass, little brown myotis with moderate wing damage had a higher BMR than little brown myotis with both minimal and severe damage. Thus, wing damage due to WNS is energetically costly in little brown myotis. However, in little brown myotis, BMR was highest during the recovery phase to wing damage (when damage is moderate), but not during the phase of active exclusion of fungus from wing tissue (when damage is severe). We found BKA was positively correlated with the extent of wing damage in little brown myotis. Thus, complement protein activity is greatest during the active exclusion of fungus. Our initial analysis suggests that the impact of WNS on BMR and BKA is less in big brown bats than in little brown myotis.

77-5 RIEGER, N.S.*; MARLER, C.A.; University of Wisconsin-Madison; nrieger@wisc.edu

The role of ultrasonic vocalizations in social interactions of California mice

Recently, the role of ultrasonic vocalizations (USV) in rodent social behavior has become the source of greater investigation, including how complex social interactions effect USV call production. Here we explore the function of California mouse (*Peromyscus californicus*) USV calls during territorial defense. California mice produce a rich variety of both simple and complex USV calls. In this study we focus on three specific USV call types: Syllable vocalizations (SV), Barks and Phrase-sweeps. SVs contain up to 7 low-bandwidth syllables, a peak frequency of ~20 kHz and an inter-syllable interval up to 350 ms. Males were significantly more likely than females to produce SV calls and produced a greater number of SV calls when presented with an intruder prior to physical contact. Barks are short, intense calls which modulate frequency from 15-25 kHz with strong upper harmonics. These calls were produced by males and females equally, but only occurred during altercations with physical contact, indicating that they may be intrinsically tied to aggression. Phrase-sweeps are a previously undescribed call type, made up of a single, high bandwidth, complex cluster of simple calls with multiple inflection points across the call's duration. Males produced a greater number of these calls with longer average duration than females. These calls were produced more frequently when physical contact could not be made with an intruder. Associations among the different call types and aggressive behavior will be presented. These data indicate a higher level of complexity in vocal communication of *Peromyscus* mice than previously thought and provide a launching point for understanding how USV production in rodents is tied to complex social behavior and may be predictive of future behaviors used in territorial defense.

SI-8 RIFFELL, J.A.*; CLIFFORD, M.; LAHONDÈRE, C.; WOLFF, G.; Univ. Washington; jriffell@uw.edu

Neurecology and the olfactory basis of plant-pollinator interactions
Plant-pollinator interactions play profound roles in structuring ecological communities and populations. 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 the rest of the plant community, and how flower species are able to attract specific pollinators. Using a combination of field assays, chemical analytical methods, and neurophysiological experiments in the insect peripheral and central nervous system, we seek to determine how chemical communication systems mediate these interactions between plants and their pollinators. Our results suggest that, in many cases, evolutionary distant flower species have converged to emit similar bouquets to attract the same type of pollinator, whereas in other cases the flowers emit scents that mimic odors from other biologically important sources (eg. mates or hosts). In all examples, flower scents are represented by distinct neural representations in the insect antennal (olfactory) lobe suggesting that the scents activate conserved neural circuits to elicit behaviors mediating these mutualistic associations. However, the behavior and neural representation to these flower scents are sensitive to the background of volatiles in the environment. Together, these results provide new evidence that in insect pollinators, attraction to specific flowers is mediated by the precise integration of olfactory 'channels', and that alteration of the odor input transforms the network representations.

109-3 RITSON-WILLIAMS, R.*; GATES, R. D.; Hawaii Institute of Marine Biology; rrw33@hawaii.edu

Coral Bleaching in Hawai'i: A Window into Reefs of the Future
Coral bleaching is increasing in frequency and extent at reef locations around the world. The last documented coral bleaching in Hawai'i was 1996, but in both 2014 and 2015 corals throughout Hawai'i experienced extensive bleaching. On Oahu, field surveys in 2014 showed that reefs in Kaneohe Bay experienced 40-80% bleaching. In October 2014, 150 coral colonies were tagged and monitored for their health during and after the bleaching event. Only two colonies of *Montipora capitata* and one colony of *Pocillopora damicornis* died from bleaching. *Porites compressa* and *Pocillopora damicornis* appeared fully recovered by January 2015, but *Montipora capitata* had significantly slower recovery. Some corals never bleached during this event, suggesting adaptation or acclimation to thermal stress. This natural variation in thermal resistance can provide insight into the mechanisms that corals use to resist climate change. Using next generation sequencing techniques we are testing for genetic adaptation (RADseq) and physiological acclimation (RNAseq) by comparing healthy and bleached corals exposed to the same abiotic conditions. There is a pressing need to understand coral genetic and physiological mechanisms of thermal tolerance to better manage for reef resilience in the face of climate change.

49-5 RIGGS, C.L.*; PODRABSKY, J.E.; Portland State University; rclaire@pdx.edu

Small RNA gene expression and localization in anoxia tolerant annual killifish embryos

Embryos of the annual killifish *Austrofundulus limnaeus* can live without oxygen for a matter of hours, or over 100 days, depending on their developmental age. Studying the changes in their cellular response to anoxia, and comparing these across developmental stages reveals critical components of extreme vertebrate anoxia tolerance, which may hold clues to treatment and prevention of heart attack and stroke. Recently, small non-coding RNAs (such as microRNAs) have been found to play a role in metabolic depression and cellular response to hypoxia, by altering gene expression. In this study, we examined small RNA expression profiles of *A. limnaeus* embryos during anoxia and aerobic recovery, at four developmental stages. We identified highly differentially expressed small RNAs at each developmental stage in response to anoxia, as well as RNAs differentially expressed between developmental stages. Some sequences of interest matched ischemia-responsive small RNAs, previously described in anoxia-sensitive mammalian models. However, many of the sequences have yet to be described. These novel sequences may provide insight into the unmatched anoxia tolerance of *A. limnaeus* embryos. To begin to understand how these sequences function, we visualized them within the whole embryo, using *in situ* hybridization (ISH). ISH studies localized sequences to the developing brain and neural tissue, some of the most anoxia-sensitive tissues. The small RNA expression profiling and whole-embryo localization are the first studies of its kind in a highly anoxia tolerant vertebrate, and provide a foundation for further inquiry. Funding: NSF IOS-1354549, NSF DGE-1057604

101-5 RITTSCHOF, CC*; GROZINGER, CM; ROBINSON, GE; The University of Kentucky, The Pennsylvania State University, The University of Illinois; clare.rittschof@gmail.com

Social cues and diet restriction may act through similar mechanisms to affect aggression in honey bees (*Apis mellifera*)

Honey bees exposed to aggression-inducing social cues undergo a shift in brain energy metabolism that causes an enhanced response to future threats. The function of this metabolic shift is largely unknown. In a variety of organisms, diet restriction also leads to changes in brain energy metabolism that resemble those seen in the aggressive honey bee brain; thus we hypothesize that diet restriction and aggression-inducing social cues alter neural function using similar brain metabolic mechanisms. To begin to evaluate this possibility, we assessed whether diet restriction leads to increased aggression in honey bees. We found that long-term exposure to low-carbohydrate diets increased aggression. Short-term exposure to diet restriction had no effect on aggressive behavior, suggesting the effects of diet are distinct from acute changes in hunger state. We also measured general activity levels for diet restricted bees and found that, in contrast to the aggression results, activity increased predominantly in response to short-term diet restriction. Our results suggest that social cues and diet restriction may act through similar mechanisms to affect aggressive behavior. This result is particularly interesting in the honey bee, where we recently showed that larval bees exposed to high aggression social environments are more aggressive as adults; this social effect could be directly mediated by variation in larval diet. Though the specific neural functional outcomes of a shift in brain energy metabolism are unknown, molecular data from aggressive bee brains and diet-restricted brains in other species show evidence of increased neural plasticity. Thus the shift in metabolism could be central to changes in neural structure across social and non-social contexts.

88-8 RIVERA, C.*; ELIAS, D.O.; Univ. of California, Berkeley;
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Courtship Complexity in Habronattus Jumping Spiders

The range of signaling diversity found within the jumping spider genus, *Habronattus*, offers an excellent model system to study general principals in signal evolution, sexual selection, and speciation. Male *Habronattus* use multimodal courtship displays, composed of complex coordinated visual and acoustic elements. To explore the diversity in *Habronattus* courtship complexity, we focused on quantifying the acoustic elements in male displays in the *clypeatus* species group of *Habronattus* (*H. californicus*, *H. canyon city*, *H. cf. dossenus*, *H. clypeatus*, *H. dossenus*, *H. formosus*, and *H. forticulus*). We found differences among the overall composition of song elements, as well as overall courtship complexity. We then used a mathematical based nomenclature to transcribe display composition across species.

78-5 ROBERTS, S.P.*; MAHON, A.R.; HALANYCH, K.M.; Missouri University of Science and Technology, Central Michigan University, Auburn University; *stephen.roberts@mst.edu*

Biomechanics of locomotion in Antarctic sea spiders (Pycnogonida)

Eight-legged locomotion within chelicerates and other arthropod groups allows a diverse array of maneuvers (e.g. variable speeds; forwards, sideways and backwards walking; low turning radius turns) on uneven substrate. During straight path locomotion, an alternating tetrapod gait cycle (R1, R3, L2, L4 to L1, L3, R2, R4) is characteristic in terrestrial eight-legged species. However, far less is known about octopod locomotion in aquatic or marine arthropods which, like their terrestrial relatives, face highly uneven and variable substrates, but also live in a highly resistant fluid medium. While aboard the RV *Laurence M. Gould*, we investigated the walking kinematics of Antarctic sea spiders (Pycnogonida) in the genera *Pallenopsis*, *Colossendeis*, *Nymphon*, and *Austropallene* collected from the Southern Ocean near the Antarctic Peninsula. In all groups, absolute and relative walking speeds were comparatively slow, with absolute walking speed ranging from 0.05 to 0.2 cm/sec, and relative walking speed ranging from 0.07 to 0.11 body lengths/sec. While footfall patterns sometimes approximated an alternating tetrapod gait, the gait pattern was variable and often non-symmetrical, with leg pairs commonly transitioning from out of phase to in phase within the same individual. Extremely cold temperatures and low relative muscle mass likely contribute to the extremely slow walking speeds of sea spiders, while their variable gait patterns compared to those of terrestrial spiders suggest that aquatic and terrestrial habitats impose different selective pressures on central pattern generators controlling leg movements and walking.

22-3 RIVIE, A./T.*; MENON, J.; MARTUS, K.; William Paterson University of New Jersey; *riviea@wpunj.edu*

Plasma and tail regeneration in tadpoles Xenopus laevis. Do reactive oxygen species enhance the process?

In the last decade, advances in atmospheric pressure plasma technology have been utilized for several medical applications including tissue regeneration. Previously we have reported that application of plasma to amputated tail creates a favorable milieu for enhanced tail regeneration in tadpoles *Xenopus laevis*. Presently we carried out *in situ* staining for reactive oxygen species (ROS), immunohistochemistry as well as western blot analysis for superoxide dismutase (SOD) and catalase and histology of the regenerate following plasma exposure. Amputated tail region was immediately exposed to helium plasma for 40 seconds. We show an increased ROS production during first 24h and 5d post amputation at the wound site in plasma treated tadpoles. Immunohistochemistry for SOD revealed higher activity for SOD in wound epithelium and blastema at 24h and 5d post amputation in plasma treated tadpoles compared to control. Beneath the wound epithelium, there were groups of cells (possibly dedifferentiated?) which showed double immunostaining for both the enzymes being higher in experimental tadpoles. Blastema was more cellular with dendritic cells (probably immune cells) also revealed increased SOD expression in plasma treated tadpoles. These observations suggest requirement for resident immune cells and SOD in wound healing and regeneration as well as inflammation. Histologically, in plasma treated tadpoles, cells of wound and blastemic epithelium showed several characteristics of temporary cellular hypoxia. Increased ROS in plasma treated tadpoles, might be acting signaling molecules stimulating morphogenetic events of the regenerate and simultaneous increase in antioxidant defenses (SOD) help modifying the dynamics of wound healing and regeneration.

114-1 ROBERTS, K.T.*; WHEAT, C.W.; DAHLHOFF, E.P.; RANK, N.E.; Univ. of California, Berkeley, Stockholm University, Santa Clara University, Sonoma State University;
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Variation among metabolic enzymes along a thermal gradient in a montane ectotherm

Many montane organisms live in fragmented populations that are especially vulnerable to climate change. The ability of populations to persist depends on whether they possess genetic variation in their capacity to respond and adapt to altered environments. In the Sierra Nevada Mountains, the willow leaf beetle *Chrysomela aeneicollis* occurs at high elevations and experiences variable environmental temperatures, ranging from below freezing to above 30 °C in a 24 hour period. With increased availability of Next-Generation Sequencing, whole-genome approaches to non-model species are more accessible. Using Pool-seq, we examined how metabolic genes differ among three populations of willow beetles living along this latitudinal thermal gradient, as well as along an elevational (2800-3200m) gradient in the Bishop Creek Drainage. Across geographic clines, the enzyme locus phosphoglucose isomerase (*Pgi*), the FeS subunit of succinate dehydrogenase (*Sdhb*), lactate dehydrogenase (*Ldh*), and NADP dependent mitochondrial isocitrate dehydrogenase (*Idh2*) showed significantly higher genetic differentiation than 26 other examined loci. *Pgi* and *Idh2* show clinal genetic differentiation across latitude, while *Sdhb* and *Ldh* show clinal genetic differentiation across elevation. Clinal variation along geographic gradients suggests that temperature and hypoxia act as selective pressures on study populations and that local adaptation is happening between populations less than 1km apart.

98-5 ROBINSON, JM; Howard University College of Medicine;
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Differential microRNA Expression During Tissue Dissociation and Reaggregation in Demosponge Spongosorites

Demosponges share eight orthologous microRNAs (miRNAs), with none in common with Bilateria. While the biological functions of these demosponge miRNAs are unknown, bilaterian miRNAs function in the regulation of cellular processes including cell cycle, differentiation, and metabolism. Here, a newly developed qPCR assay to test for differential miRNA expression during dissociation and reaggregation in *Spongosorites*, gemmule hatching and development in *Ephydatia*. During *Spongosorites* dissociation and reaggregation, miRNA expression exhibits a global, statistically significant decrease in expression, with no recovery of miRNA expression. In *Ephydatia*, overall increase in miRNA expression in gemmule-hatched Stage 4 juveniles relative gemmules is observed. Differential miRNA expression during dissociation in *Spongosorites* (lowered global expression, and during activation, growth, and differentiation of *Ephydatia* gemmules (increased global expression) is a possible indication that miRNA expression is responsive to physiological changes related to heightened cellular activity, providing an interesting direction for future research. Continuing investigation into the molecular, cellular, developmental mechanisms of Porifera provides important comparative model for understanding evolutionary dynamics of the early-branching metazoan phyla.

58-7 RODRIGUEZ DE LA VEGA, Ricardo C*; MORGENSTERN, David; GIRAUD, T; UMR8079 Univeristy Paris-Sud/CNRS; ESE, GEE, New York University, Proteomics Resource Center;
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Evolutionary tinkering in animal venoms

Animal venoms share some striking similarities which have been explained on the light of three concurrent paradigms: 1) the "proteome to venome" model of venom protein emergence, highlighting the close relationship of some known and assumed toxins with "normal" (i.e. non-toxin) proteins from the same or a different organism; 2) the "convergent recruitment and expansion" of a few protein folds into phylogenetically unrelated venoms, in other words, independently evolved venoms are built upon lineage specific expansions of homologous genes, and; 3) a prey-driven "evolutionary arms-race" scenario of venom-protein evolution. These paradigms were tremendously helpful when the high-throughput screenings became routine analysis; for a while, it seemed that almost every new venomomics study supported these models. However, this proliferation of venom surveys, with no or little reference to venom ecology and organismal biology, has the intrinsic risk of propagating annotation errors and a tendency of ecological over-interpretation based on undersampled phylogenies. Here, based on de-novo assemblages of over twenty deep-sequenced scorpion transcriptomes and surveys for toxin/toxin-like genes, we will show that: 1) few protein families have evolutionary histories which are congruent with the current paradigms of venom evolution; 2) most of the diversity and selection on these protein families is restricted to a single scorpion lineage, and; 3) a single scorpion family has evolved an over-kill venom, likely driven by few major ecological shifts. We call for a revision of the current (scorpion) venom evolution paradigms to a model where strong directional selection pressure results in sparse structural and functional recruitments, while allowing the accumulation of paralogs under neutral selection.

64-2 ROBINSON, H.E.*; STRICKLER, J.R.; LENZ, P.H.; University of Hawai'i at Manoa, University of Wisconsin Milwaukee;
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Evading Nemo: prey escape behavior and predation strategies of larval clownfish through early development

Copepods are among the most evasive prey in the plankton. These small crustaceans have sensitive mechanoreceptors to detect approaching predators, and perform high-speed escape jumps to avoid being eaten. Nevertheless, copepods are the preferred prey for many larval fishes, providing an important food source throughout the planktonic phase of reef fish development, from first feeding to settlement. During this critical life-history stage larval fish must acquire the ability to successfully capture these evasive prey. To investigate how behavior of predator and prey shape the outcome of their interactions, we studied larval clownfish, *Amphiprion ocellaris*, feeding on the copepod, *Bestiolina similis*. Predator-prey interactions were recorded with a high-speed camera configuration designed for manually following individual fish larvae to observe feeding events. Fish from day 1 post-hatch (first feeding) to day 14 post-hatch (end of larval stage) were fed copepods of different life stages. The copepods' sensory-motor escape performance improved with developmental stage, from nauplii to adults. At first feeding, *A. ocellaris* only successfully captured *B. similis* nauplii, but were unable to capture copepodites or adults. On day 7 post-hatch, larval fish were first observed attacking adult copepods but with limited capture success. By day 14 post-hatch, *A. ocellaris* were capable of successfully capturing all life stages of copepod prey. The differences between successful captures and successful escapes were characterized using frame-by-frame video analysis to measure strike distance, velocity, acceleration, and orientation. Since the gape width of the clownfish mouth can accommodate adult copepods as early as day 2 post-hatch, we suggest behavioral dynamics shape the diet of these larval fish.

29-5 ROGERS, D.C.; University of Kansas;
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Relating anostracan distribution to physical habitat characteristics in North America (Crustacea: Branchiopoda)

Nine anostracan biogeographical regions are defined for North America: Appalachia/Ozark, Southwest Arid, Great Plains, Coastal Plain, Neotropical, California, Cold Deserts, Beringia/Canadian Shield, and Transmontane. These regions are quantitatively defined using species distributions compared through Jaccard's Coefficient of Community Similarity and substrate geochemical components (%CaSO₄*H₂O, %CaCO₃, salinity, and dominate salt cations), and in relation to climate. Relationships between these parameters and the distributions of all 63 US species were discovered. Similar relationships were found for species assemblages as well. Community assemblages are quantified using Fager's Index of Recurring Species Groups. The average Fager's Index for each bioregion, as well as the percentage of taxa co-occurring, generally decreases with the length of geologic time the region has been available for colonisation. The strong Fager's Index/colonisation time availability relationship suggests that the Monopolization Hypothesis of De Meester et al. may function at larger landscape scales. Furthermore, two widespread species were found to occur in very different habitat types in different biogeographical regions. Upon closer examination, these two taxa were each found to be comprised of more than one species.

35-6 ROH, C.*; GHARIB, M.; California Institute of Technology; croh@caltech.edu

Dragonfly larva's unique ventilation strategy: directed jetting through a controllable tri-leaflet valve

Aquatic Anisopteran dragonfly larva possesses a modified hindgut pump that enables jet propelled locomotion and respiration. In supporting these functions, the associated flows are modulated by a tri-leaflet anal valve. Previous studies on this valve have been limited to showing larva's ability to modulate the aperture size through concurrent movement of the three leaflets. However, we have newly observed that the dragonfly nymph's anal valve is capable of more sophisticated movements via independent control of the leaflets. The impact of this unique feature on the two functions of the pump was investigated through simultaneous visualization of the dragonfly's anal valve kinematics and the corresponding anal jets. Our results indicate that by controlling the individual anal valve leaflets, the larva jets its propulsion jet straight by the symmetric nozzle opening, while diagonally deflecting its respiratory jet by the asymmetric nozzle opening. The straight jet during the propulsion appears to reduce the thrust loss due to a side-thrust generation. The deflected respiratory jet appears to induce a secondary entrainment flow in a favorable direction for a clean and efficient breathing.

16-6 ROLLINS-SMITH, LA.*; FITES, JS; REINERT, LK; LEE, JA; SHIAKOLAS, AR; UMILE, TP; MINBIOLE, KPC; Vanderbilt University School of Medicine, University of Wisconsin School of Medicine and Public Health, Vanderbilt University school of Medicine, Vanderbilt University, Gwynedd Mercy University, Villanova University; louise.rollins-smith@vanderbilt.edu
Lymphotoxic factors produced by the frog-killing fungus, *Batrachochytrium dendrobatidis*

Amphibians are declining in many parts of the world due to an emerging fungal disease, chytridiomycosis, caused by *Batrachochytrium dendrobatidis* (*Bd*). Previously, we showed that *Bd* cells and supernatant (Sup) factors inhibited lymphocytes by induction of apoptosis. Some of the toxic factors are associated with the cell wall. Cell walls alone inhibited lymphocytes, and interference with cell-wall synthesis inhibited the production of lymphotoxic factors. Other inhibitory factors are small metabolites. Using HPLC with UV-Visible detection, *Bd* and non-pathogenic *Homolaphyctis polyrhiza* (*Hp*) supernatants were analyzed. *Bd* Sup consisted of two major components not present in the *Hp* Sup. One major metabolite was identified as methylthioadenosine (MTA). MTA inhibited *X. laevis* splenocytes at concentrations of less than or equal to 100 μ M and inhibited survival of Jurkat T cells at concentrations of less than or equal to 10 μ M. Another major component was tryptophan, which was not inhibitory. However, an oxidized tryptophan metabolite, kynurenine, was detected in the *Bd* Sup and suppressed proliferation of frog lymphocytes and Jurkat cells at supraphysiological concentrations. Although kynurenine alone was only inhibitory at mM concentrations, the addition of 10 μ M MTA significantly enhanced the activity of kynurenine at much lower concentrations suggesting a synergistic inhibition of T cell proliferation. Support: National Science Foundation IOS-1121758 and DEB-1136662.

81-6 ROLES, AJ; Oberlin College; aroles@oberlin.edu

Freshwater conquistadors: The influence of hybridization and watershed structure in the invasion of the rusty crayfish into the native range of the congeneric Sanborn's crayfish in north-central Ohio.

Hybridization during species invasions may yield a variety of evolutionary results - from increasing reproductive isolation to fusion of the hybridizing populations, resulting in a well-mixed population or primarily replacement of one population by the other. However, the dynamic period of this process may be relatively transient, offering few opportunities for observation. We are investigating this transient stage of the ongoing invasion of the invasive rusty crayfish (*Orconectes rusticus*) into the native range of the congeneric Sanborn's crayfish (*Orconectes sanbornii*) in the Huron River in north-central Ohio. Yearly surveys (2010 to 2015) along the river's length reveal a relatively stable gradient in the ratio of native to invasive morphospecies: the most upstream sites most resemble the morphology of the native species while the furthest downstream sites exhibit morphology consistent with the invasive species. This spatial pattern of species abundance is surprisingly stable, possibly influenced by seasonal patterns of precipitation on streamflow; future changes to patterns of annual precipitation may alter this dynamic. Sites where both morphospecies are caught also reveal morphological intermediates and hybridization at two such sites has been confirmed with mitochondrial and allozyme markers. Recently, we have developed microsatellite markers for both species, giving us greater resolution into the population genetics of these taxa. Here, we examine the pattern of morphological and genotypic change at ten sites sampled throughout the Huron River watershed to further characterize the influences of hybridization and watershed structure in this ongoing species invasion.

49-4 ROMNEY, A. L. *; PODRABSKY, J. E.; Portland State University; arom2@pdx.edu

Gene expression during development and diapause in a vertebrate extremophile

The annual killifish, *Austrofundulus limnaeus*, survives in harsh and unpredictable environments through their ability to enter into embryonic diapause. Diapause is a pre-programmed exit from normal development that occurs towards the end of somitogenesis and is characterized by a severe metabolic depression and developmental arrest. Development in this species may also follow an alternative phenotypic trajectory where individuals can instead "escape" entry into diapause and continue to develop until hatching. While varying proportions of diapause embryos can occur within a clutch at 25 degrees C, an incubation temperature of 30 degrees C results exclusively in escape embryos while 20 degrees C results in diapausing embryos. Previous investigations have identified unique physiological, biochemical, and metabolic profiles in embryos developing along the diapause and escape trajectories induced by altered incubation temperatures. Furthermore, these unique molecular programs begin to appear many days prior to any morphological divergence in the two trajectories. I hypothesize that altering the embryonic incubation temperature results in expression of non-coding RNAs that regulate developmental trajectory. To assess the validity of this hypothesis, I generated expression profiles of mRNA and small non-coding RNA genes using Illumina RNA-seq in embryos developing at 20 and 30 degrees C. These data suggest diapause- and escape-specific gene programs that may be regulated by small non-coding RNAs. This coupled analysis of mRNA and small non-coding RNA expression provides an extensive view of gene expression that underlies phenotypic plasticity in vertebrate development and highlights how environmental variation may be integrated with genomic information to determine developmental outcomes.

39-1 RONCALLI, V*; CIESLAK, M/C; LENZ, P/H; Pacific Biosciences Research Center, University of Hawaii at Manoa, University of Hawaii at Manoa; roncalli@hawaii.edu
Using transcriptomics to investigate effects of a natural stressor on the physiology of a crustacean Calanoid copepod

In their natural environment, organisms typically encounter natural stressors throughout their lifetime. Although these organisms are well-adapted to succeed in their habitat, "non-optimal" conditions can require costly physiological adjustments. These physiological responses are still poorly understood. Harmful algal blooms are a common stressor for herbivorous copepods that ingest toxic phytoplankton such as the saxitoxin-producing dinoflagellate, *Alexandrium fundyense*. The effect of this toxic alga on the physiology of the calanoid copepod, *Calanus finmarchicus* was investigated using transcriptomics. Gene expression in *C. finmarchicus* was determined after 2 and 5 days feeding on *A. fundyense* and compared with females on a control diet. A significant time and dose response was observed in *C. finmarchicus* with over 1,000 genes being identified as differentially expressed (DE) in response to *A. fundyense*. At 2 days, the response was similar to the cellular stress response with genes involved in chaperone and redox reactions, intracellular signaling, protein degradation and energy metabolism (lipid and carbohydrate). At 5 days, the transcriptional response reflected a physiological adjustment towards the new environmental conditions. Transcripts encoding proteins involved in energy metabolism were significantly regulated, suggesting a difference in the energy balance between the control and experimental females. Surprisingly, detoxification was not a major component of the copepod response to the dinoflagellate. Overall, the results suggest that the copepod is able to consume the toxic dinoflagellate with little effect on survival, but its energy budget is affected and fewer resources are available for growth.

17-1 ROSENCRANS, WM*; HATCH, KA; BRUMMEL, T; Colgate University, Long Island University Post; wrosencrans@colgate.edu
The effect of TOR signaling on nitrogen stable isotope fractionation

Stable Isotope analysis (SIA) is used to non-invasively determine the nutritional status or trophic level of animal populations. However, the molecular mechanisms that affect the fractionation of stable isotopes are poorly understood. The focus of this study is to investigate the relationship between $\delta^{15}\text{N}$ fractionation in animal tissue and the Target of Rapamycin (dTOR) signaling pathway. We subjected, *Drosophila melanogaster* to dietary, pharmacological, and genetic manipulations that alter dTOR activity. The $\delta^{15}\text{N}$ of these flies were then analyzed. We found that manipulations that lowered dTOR signaling (e.g. protein restriction, ethanol, rapamycin, and the *inaE^{EP101}* mutation) raised $\delta^{15}\text{N}$ approximately 1per mil while enhancing TOR signaling via the *inaE^{KG08585}* mutation genetically prevented the increase in $\delta^{15}\text{N}$ the associated with dietary restriction ($p < 0.05$). The dTOR pathway activity helps explain variations and anomalies in expected trophic level shifts. Furthermore the $\delta^{15}\text{N}$ assay may prove useful in analyzing TOR activity, which has been implicated in aging, cancer, Alzheimer's, and various metabolic diseases.

116-7 ROSEN, HE*; GILLY, WF; BELL, L; ABERNATHY, K; MARSHALL, G; Stanford University, National Geographic Society; hannahr@stanford.edu
Serotonin (5-HT) and control of chromatophores in ommastrephid and loliginid squids.

Research on squid chromatophores has been largely restricted to loliginids, a family of primarily coastal species whose displays rely heavily on spatial patterning. Comparatively little work has been done on the pelagic ommastrephids, the family that includes *Dosidicus gigas*. This species displays dynamic "flickering" characterized by seemingly chaotic activity of chromatophores that can be rapidly inhibited before an episode of coordinated flashing. In this study we investigated the innervation of chromatophores in *Dosidicus*, particularly serotonergic pathways, in order to compare features with those in loliginids where 5-HT has inhibitory effects. We used topical application of 5-HT with skin preparations from *Dosidicus* (and the loliginid *Doryteuthis opalescens*) to study functional effects and immunohistochemistry to visualize serotonergic axons in the chromatophore system. We found that chromatophore activity in *D. gigas* was more sensitive to 5-HT and that the extent of serotonergic innervation is greatly reduced in comparison to *D. opalescens*. These features correspond to a different level of spontaneous chromatophore activity in skin preparations from *D. gigas* and *D. opalescens* as well as in the living animal. Chronic denervation of chromatophores in *D. opalescens* leads to complete degeneration of serotonergic axons and the appearance of spontaneous waves of chromatophore activity that are inhibited by 5-HT, similar to activity normally observed in *D. gigas*. We suggest that the sparse serotonergic innervation in *Dosidicus* results in minimal resting inhibition that facilitates flickering, and that the extensive serotonergic innervation in *D. opalescens* leads to strong inhibition of spontaneous, coordinated chromatophore activity in the normal, innervated condition.

98-1 ROSENDALE, A.J.*; ROMICK-ROSENDALE, L.E.; WATANABE, M; DUNLEVY, M.E.; FARROW, D.W.; BENOIT, J.B.; Univ. of Cincinnati, Cincinnati Children's Hospital Medical Center; rosendaw@ucmail.uc.edu

Physiological and molecular mechanisms of dehydration tolerance in the American dog tick, *Dermacentor variabilis*

Ticks are obligate blood feeders but spend the vast majority of their lives off-host, where they must contend with a multitude of environmental stresses. Survival under desiccating conditions is a considerable issue for ticks and is a major determinate of habitat suitability. Despite the attention paid to water balance characteristics in ticks, little is known about the molecular and biochemical mechanisms underlying dehydration stress. To uncover specific aspects associated with dehydration exposure in ticks, we examined the transcriptomic, metabolomic, and energetic responses of the American dog tick, *Dermacentor variabilis*, in relation to desiccation stress. RNA sequencing was used to analyze transcriptional changes and revealed the enrichment of stress-response and proteolysis pathways as well as shifts in expression of metabolic- and feeding-related genes. NMR-based metabolomics indicated there was an accumulation of several amino acids, supporting the importance of proteolysis, and glycerol and gamma-Aminobutyric acid (GABA), suggesting these molecules may act as osmoprotectants. Finally, analysis of the energetics of dehydration demonstrated that sufficient energy stores are critical to dehydration tolerance and preliminary data suggest that protein reserves are particularly important. Overall, our results identified several candidate molecules and pathways that contribute to dehydration tolerance in ticks and lay the groundwork for future studies on stress tolerance in these important disease vectors.

9-6 ROSS, C.F.*; IRIARTE-DIAZ, J.; GERSTNER, G.E.; TAYLOR, A.B.; University of Chicago, University of Illinois, Chicago, University of Michigan, Duke University; rossc@uchicago.edu

Scaling of cycle period in feeding and locomotion systems

The relationship between inertial properties and the scaling of oscillation frequency has been studied in locomotor but not in feeding systems. We estimated the moment of inertia of primate mandibles from CT scans. We hypothesized that if mandibular momentum plays an important role in chewing dynamics, accurate estimates of the rotational inertia of the mandible would improve the ability of simple models to predict the scaling of primate chewing frequencies. If this hypothesis was falsified, this would suggest that mass-related momentum effects are of negligible importance in the scaling of primate chewing frequency. We found that the rotational inertia of primate mandibles increases with jaw length across primates due to slight positive allometry of jaw mass to length, and to size-correlated changes in the distribution of jaw mass relative to a transverse axis through the center of mass. Positive allometry of the rotational inertia of primate mandibles lowers the predictive ability of the Spring Model, suggesting that scaling of primate chewing frequency is more strongly influenced by the dynamic properties of the jaw muscles and neural control than by scaling of inertial properties of the mandible. Differences in cycle period scaling between chewing and locomotion systems are suggestive of differing design criteria: displacement and force control are more important in the design of feeding systems and energetics and speed are more important in the design of locomotor systems.

2-6 ROTH, E.*; HALL, RW; DANIEL, TL; SPONBERG, SN; Univ. Washington, Georgia Tech; danielt@uw.edu

Parallel visual and mechanosensory pathways mediate flower-tracking in the hawkmoth *Manduca sexta*

In studying insect flight behaviors, the sufficiency of the visual system often overshadows the contributions of other sensory pathways. Illuminating the roles of non-visual pathways is complicated by the fact that insect flight *requires* vision. Thus the roles of other modalities cannot be isolated by suppressing vision. Here we present a novel paradigm that disentangles the behavioral contributions of multiple intact sensory pathways by means of *sensory conflict*, the simultaneous and independent presentation of multimodal sensory stimuli. We examine flower-tracking behavior in the hawkmoth *Manduca sexta*. Moths hover in front of a flower while feeding by means of a long proboscis. As the flower sways, the moth weaves side to side, maintaining a frontal position. The potential role of non-visual sensory pathways in this behavior has received little attention. But the proboscis is covered with mechanosensors and could provide sensory information. To explore this possibility, we constructed a robotic two-part fictive flower that allows independent presentation of visual and mechanosensory cues. Moths track lateral flower motion stimuli in an assay spanning both coherent motion, in which visual and mechanosensory cues are the same, and sensory conflict, in which the modalities receive different motion stimuli. Our frequency-domain system identification analysis shows that the tracking behavior is, in fact, multi-sensory and is predominantly mediated by the mechanosensory pathway. Furthermore, empirically derived models are consistent with a parallel neural computation in which visual and mechanosensory pathways sum linearly and each pathway in itself is sufficient for driving tracking behavior robustly. When multiple sensory pathways elicit strong behavioral responses, this parallel architecture furnishes robustness via redundancy.

S6-9 ROSVALL, KA*; BERGEON BURNS, CM; JAYARATNA, SP; KETTERSON, ED; Indiana University; krosvall@indiana.edu
Molecular mechanisms of testosterone production: a gonad-centric view of behavioral evolution

Hormones are dynamic signaling molecules that influence both gene activity and behavioral phenotypes, and are thus thought to play a central role in phenotypic evolution. The steroid hormone testosterone (T), for example, mediates many life history and behavioral traits that influence fitness, and it is therefore hypothesized that changes in T or its regulation contribute to phenotypic evolution. The mechanisms by which T might bring about such evolutionary changes are unclear, however, in part because T is not a direct gene product but is instead synthesized via a multi-enzyme biosynthetic pathway, which is itself activated by a complex endocrine cascade. Here, we sought to identify mechanistic sources of variation in T production, by comparing two behaviorally divergent subspecies of dark-eyed junco (*Junco hyemalis*), in the wild and in captivity. In a series of experiments, we show that variation in (a) the gonad's molecular capacity to produce T and (b) the timecourse over which T elevates following HPG axis stimulation explain more phenotypic variation than has been appreciated to date. Critically, our results point to specific genes in the gonadal steroidogenic pathway that fulfill key conditions for phenotypic evolution, i.e. they vary functionally in their expression among individuals and between populations, and they map onto population variation in T and T-mediated traits in a common garden. We also present findings on gonadal sensitivity to corticosterone and gonadotropin-inhibitory hormone, which may act directly on the gonad to suppress steroidogenesis. Our findings support the view that variation in endocrine signaling in tissues other than the brain may be a far more important contributor to phenotypic variation and evolution than previously thought.

51-4 ROTT, K.H.*; CAVIEDES-VIDAL, E.; KARASOV, W.H.; Univ. of Wisconsin, Madison, Universidad Nacional San Luis & CONICET; katherine.rott@gmail.com

Intestinal enzyme activity in nestling house sparrows (*Passer domesticus*) is modulated within 24 hours of a diet switch

It has already been shown that house sparrow nestlings are capable of modulating their intestinal digestive enzyme activity to match changes in substrate levels in their diet. However, it is not known how quickly nestlings can adjust to new diets with different substrate compositions. Wild house sparrows are primarily fed a low-carbohydrate insect diet during the first few days post-hatch and are gradually transitioned to a high-carbohydrate seed diet that they eat as adults, and it is possible that sometimes rapid diet switches are necessary in the wild in order to ensure survival. In the current study, 3-day-old nestlings were captured and fed a low-carbohydrate diet for three days before being switched to a high carbohydrate diet. Intestinal tissue was then harvested at 24, 48, and 72 hours after the diet switch and analyzed for enzyme activity per gram tissue. We found that activities of the intestinal carbohydrases maltase-glucoamylase and sucrase-isomaltase approximately doubled within 24 hours of the switch to high carbohydrate, and activity did not significantly increase in nestlings with further time on the new diet. Intestinal aminopeptidase-N activity significantly decreased once the animals were switched to the higher carbohydrate, lower protein diet within 24-48 hours. Future studies will determine the time course for reversed trends when nestlings are switched from initially high-carbohydrate diet to low-carbohydrate diet and will also test for underlying changes in intestinal enzyme mRNA. Supported by NSF IOS-1354893 to WHK.

56-6 ROWAN, T.N.*; FASSBINDER-ORTH, C.A.; Creighton University; troyrowan@creighton.edu

Buggy Creek virus distribution and dynamics in swallow bugs (*Oeciacus vicarius*) in cliff swallow (*Petrochelidon pyrrhonota*) colonies in Southeast Nebraska and Southwest Iowa

Alphaviruses are positive sense RNA viruses carried by arthropods that are responsible for a number of encephalitic and rheumatic diseases in vertebrates. Buggy Creek Virus (BCRV) is an alphavirus that is transmitted to birds by the cimicid swallow bug (*Oeciacus vicarius*) via infestation of the birds' nests. It is hypothesized that in times of high stress (such as in overwintering bugs), BCRV produces incomplete particles called defective interfering (DI) particles that prevent assembly of the full wild type phenotype. We located five active cliff swallow colonies with swallow bugs and tested swallow bugs for the presence of BCRV over time and in different age classes of swallow bugs. Upon collection, bugs were sorted into five age groups, homogenized and frozen for downstream testing of viral presence and cytopathic effect. Viral RNA was detected through RT-PCR, and viral infectivity was measured using a modified TCID₅₀ procedure. Over the course of three months, we saw a positive correlation between cliff swallow nesting activity and swallow bug populations, as well as detectable BCRV. Specifically, detectable BCRV decreased 52% in bug pools after cliff swallows left our sites. The results of this project indicate that BCRV persistence in swallow bugs is highly dependent on the presence of cliff swallows, with peak BCRV RNA being detected during the nesting season. Although high levels of BCRV RNA were detected across multiple swallow bug age classes and sites, BCRV isolated from bugs at all time points was only minimally cytopathic. Future work is needed to determine the genomic structure of BCRV isolates from swallow bugs and to confirm possible involvement of DI particles in the viral dynamic patterns detected in this project.

58-6 ROWE, A.H.*; ROWE, M.P.; Michigan State University; roweashl@msu.edu

Scorpion neurotoxins and their ion channel targets: diversity through coevolution?

A goal of venom evolution studies is to identify the causes and consequences of intra- and interspecific variation in venom. Determining the effects of drift and selection is complicated by the difficulty linking phenotype with genotype. While selection is often demonstrated through geographic patterns in venom toxicity and target resistance, identifying the molecular changes that regulate toxicity may be problematic because many venoms have complex compositions. Scorpions in the genus *Centruroides* are ideal for investigating venom diversity; the venoms exhibit intra- and interspecific variation in lethality and pain-inducing capability, and because both the toxins (proteins) and their targets (sodium and potassium ion channels in nerve and muscle) are encoded by genes, changes in venom toxicity and target resistance can be linked to molecular changes. In the Sonoran desert, *Onychomys torridus* (grasshopper mice) prey on *C. sculpturatus*. Mice are resistant to venom pain via molecular changes to a sodium channel that enables the channel to bind a venom protein and block the pain signal the venom is initiating. Thus, the mice have adapted to the defenses of their prey. If reciprocal selection is driving this system, scorpions may have responded by expressing less of the protein that blocks pain signals in the mice, or via changes in the protein's structure so it no longer binds the mouse's channel. We compared venom proteins and ion-channel genes from Sonoran desert species to orthologs from Chihuahuan desert species (*C. vittatus*, *O. arenicola*) that differ in painfulness and resistance, respectively. While sodium channel genes did not differ between *O. torridus* and *O. arenicola*, *C. vittatus* appear to have lost the venom protein that blocks pain in grasshopper mice, suggesting that *C. vittatus* have "countered back".

51-2 ROWE, A.H.*; ROWE, M.P.; Michigan State University; roweashl@msu.edu

The influence of venom-induced pain on predatory behavior in the southern grasshopper mouse *Onychomys torridus*

Pain, though unpleasant, is adaptive in calling an animal's attention to potential tissue damage. Many animals have evolved specialized sensory structures, including mammalian nociceptors, for detecting and responding to noxious stimuli. Animals representing diverse taxa (platypuses to snakes to scorpions) possess venom-mediated, pain-inducing bites or stings that activate the pain-sensing pathways of potential enemies (predators, competitors). While the fitness benefits of possessing a painful sting seem obvious to anyone who has been stung by a wasp, few studies have demonstrated such benefits. Southern grasshopper mice are voracious predators of scorpions. The mice consume a diversity of species, including intensely painful Arizona (AZ) bark scorpions and nearly painless stripe-tailed scorpions. AZ bark scorpion venom induces pain by activating Nav1.7, the sodium channel that initiates pain signals in sensory neurons. Southern grasshopper mice reduce their sensitivity to venom pain via molecular modifications to a second channel, Nav1.8, which blocks transmission of pain signals to the brain. However, mice are not completely resistant to pain, they respond to stings by grooming briefly. We asked if brief pain influences prey choice. Results from laboratory experiments demonstrate that painful stings do matter; grasshopper mice preferred to prey on stripe-tailed scorpions rather than bark scorpions when both species could sting; the preference disappeared when each species had their stingers blocked. Foraging choices were also mediated by the mice's condition; lean wild-caught mice preferred stripe-tailed scorpions to bark scorpions, but readily consumed both. Captive-born, well-nourished mice with unrestricted access to mouse chow, in contrast, often chose to stop feeding on scorpions altogether.

17-8 ROZNERE, I.*; WATTERS, G.T.; WOLFE, B.A.; DALY, M.; The Ohio State Univ.; rozner.1@osu.edu

Health assessment of freshwater mussels using metabolite profiling

Freshwater mussels (family Unionidae) are long-lived filter-feeding bivalves that are important in maintaining ecosystem function by filtering particulate matter and sequestering nutrients in our waterways. Unfortunately, native freshwater mussels are the most imperiled group of animals in North America with more than 2/3 of nearly 300 identified species considered threatened, endangered, or extinct. Threats to these species include habitat degradation due to waterway manipulation, pollution, erosion and sedimentation, and invasive species. While translocation and captive propagation are widely supported as appropriate conservation measures, a high proportion of unionids die within the first year of relocation, reducing the effectiveness of such efforts. Historically, our ability to evaluate the health of freshwater mussels has been limited primarily to behavioral changes, mortality rates, and non-survival assays. New research is utilizing metabolite profiling to evaluate the effects of environmental changes. A study was designed to characterize the metabolic profile of *Amblema plicata*, the Threeridge mussel, subjected to low nutrient availability. Eight mussels brought into captivity from the wild were isolated for 18 days without a food source. Hemolymph samples were taken prior to, and 9 and 18 days after the start of the study. Samples were analyzed on GC/MS and LC/MS/MS platforms, and 71 metabolites of known identity were detected. Captivity and fasting resulted in changes in energy metabolism, free amino acids, fatty acids, nucleic acids, and proliferation pathways. While fasting resulted in severe metabolite depletion, changes were also evident in many captive fed mussels, indicating that mussels may be experiencing nutritional deficiency and other metabolic stressors under common captive conditions.

S12-1 RUEBNSTEIN, Dustin R.; Columbia University; dr2497@columbia.edu

Animal behavior: past, present and future

Animal behavior is a varied and dynamic discipline that has been evolving since the beginning of 20th century. Classical approaches to the study of animal behavior have been limited to relatively simple processes and questions, which often failed to holistically explain the complexity of animal behaviors in natural systems. Nikolaas Tinbergen recognized over 50 years ago that the integrative study of animal behavior required an understanding of both the proximate and ultimate and mechanisms. Yet, for many years, studies of the proximate and ultimate explanations of animal behaviors typically proceeded independently. With the development of new resources and tools in genomics, physiology, neurobiology, behavioral tracking, animal movement, and more, it is now possible to integrate across levels of analysis in the same studies. However, the true integration of animal behavior is more than just combining levels of analysis. It is asking questions at a variety of levels of biological organization, in a diversity of taxonomic groups, and at a range of spatial and temporal scales, and then answering those questions using a variety of tools and techniques. I will summarize a variety of innovative tools and technologies that have, over the last half century, helped push the field of animal behavior forward, often in new directions. Using examples from my own work on social birds and crustaceans, I will highlight some of the newer technologies that are changing the field by allowing us to study proximate mechanisms and ultimately explanations simultaneously in free-living organisms. I will discuss how the integration of ecology, evolution, and development can also enrich our understanding of complex behaviors. Finally, I will highlight some of the emerging technologies that are likely to change the field over the next decade, many of which we will hear about in more detail during this symposium.

76-6 RUSCH, T.W*; SEARS, M.W; ANGILLETTA, M.J; Arizona State University, Clemson University; trusch@asu.edu

Beyond lethality - costs of varying thermal resources under the perceived risk of predation

When resources become concentrated in space, the perceived risk of predation can prevent prey from accessing those resources. We studied both the thermoregulatory and foraging behaviors of male lizards (*Sceloporus jarrovi*) under the perceived risk of a predator in spatially explicit landscapes. In a previous study, these lizards thermoregulated best in landscapes with patchy distributions of shade and the absence of perceived predators, compared to landscapes with clumped distributions and/or perceived predators over a 2-day period. But do these differing thermoregulatory strategies persist over time? And if so, do they impose differing physiological costs? To test these ideas, males were placed in outdoor arenas (20 x 20 m) with either a clumped or patchy distribution of shade and exposed to an artificial aerial predator (*Buteo jamaicensis*) for 14-days. Additionally, a food patch containing cups of beetle larvae (*Tenebrio molitor*) was placed in each arena to prevent food from being a limiting factor. However, these food patches were placed in open areas, forcing lizards to make foraging and thermoregulatory decisions while in the presence of an artificial predator. We predicted that lizards would again have greater thermoregulatory performances in patchy environments compared to clumped environments, which should result in increased foraging performance, and thus reduced physiological costs. We will report the interactive effects between thermal landscapes and predation risk on the costs of varying foraging and thermoregulatory performances by these lizards.

37-4 RUIZ-JONES, LJ*; PALUMBI, SR; Stanford University, Hopkins Marine Station; gjrj@stanford.edu

Transcriptomic time series of coral and Symbiodinium in a coral reef reveals environmental transcriptional plasticity

Corals living in back-reef environments regularly experience fluctuations in temperature, pH, and oxygen, yet we do not know what physiological mechanisms allow them to deal with this variation. The back-reef around Ofu Island in American Samoa can have daily temperature fluctuations of up to 6°C and pH can vary by 0.58 units within a day. We used transcriptomics to monitor coral physiology in the reef as the tide changed environmental conditions from day to day. We sampled three colonies of *Acropora hyacinthus* once a day for 17 consecutive days. Transcriptomes for each day were sequenced and we identified modules of co-expressed genes in the host and symbiont. There are large portions of the *A. hyacinthus* and *Symbiodinium* transcriptomes that are co-regulated and stable though time regardless of environment, and have expression level differences between colonies. Interestingly, transcription of these modules is more stable in the host than in the symbiont. We also see transcriptional variability from day-to-day in *A. hyacinthus* and *Symbiodinium*. We looked for strong associations between module expression patterns and changes in the environment. One coral transcriptional module had a very significant relationship to temperature, pH, and dissolved oxygen saturation. At the same time, some *Symbiodinium* genes showed a response to environmental shifts; however, even though coral expression was more stable than *Symbiodinium* expression across most of the transcriptome, the coral response to the environment was greater than the *Symbiodinium* response. By looking at gene expression at short temporal scales, we see that corals have quick transcriptomic reactions to tidally driven environmental shifts demonstrating they are highly responsive to their environment and may be stressed by temporary extremes.

30-1 RUSSELL, AL*; REBEKAH, AG; ANNE, AS; DANIEL, DR; University of Arizona, University of Nevada, Reno; averyrussell@email.arizona.edu

Learning of Floral Preference by Bees in the Absence of Nectar Rewards

Bees foraging on flowers constitute a model system in the study of animal cognition. Although flowering plants offer a variety of rewards and pollinators must collect multiple types of rewards in order to survive, the literature on bee learning is skewed nearly exclusively towards learning in the context of nectar rewards. Bees in particular must collect two nutritionally complementary floral rewards in order to survive: nectar, their primary source of carbohydrates, and pollen, their primary source of protein. While many flowering plants offer both rewards, 6-8% of angiosperm species offer only pollen rewards. In this study, we asked if bees can learn preferences for pollen-only species and what components of the flower are involved. To ensure that nectar was not involved in learning, we used plant species that offered only pollen as a reward. Using an absolute conditioning protocol, bees were given experience collecting pollen from a single species. Their preference for flowers of that species relative to a second species was tested either one or 24 hours later. We found that the preference of experienced bees was shifted strongly towards the experienced species, relative to the preference of naïve bees. Results of the 24 hour test provided strong evidence of long-term memory. These changes in preference are best explained as associative learning. Additionally, we evaluated the role of corolla and anther in learned preferences. While both the corolla and anther responses are involved, anther responses are more strongly influenced by experience. We discuss how learned preferences, such as those shown here, can influence the evolution of floral traits, particularly with respect to pollen-only species.

8-8 RUVINA, K*; FRANQUI DIAZ, N; JOHNSTON, T; HAYDEN, N; BERGMAN, D; Grand Valley State University, University of Puerto Rico-Arecibo; ruvinak@mail.gvsu.edu
Neuropharmacological Alterations of the Aggressive Behavior of Crayfish

Serotonergic-related compounds often facilitate aggression in various animals, including crayfish. However to date, studies have seldom shown the mechanism by which serotonergic-related compounds alter aggressive behavior. It is assumed that serotonin changes the neurochemistry of those injected. In our study, we have attempted to report an observable mechanism by examining the communication system of crayfish. Crayfish use urine to communicate aggressive status, thus we analyzed the frequency of urine release from those injected with serotonergic-related compounds. For each trial, two size-matched crayfish, within 5% body weight, were allowed to interact after injection with serotonin, an agonist, an antagonist, or vehicle control. The concentration of all drugs was 3mM at a delivery dosage of 0.1ml/g. Aggressive interactions were recorded under black light to illuminate a fluorescein dye that was added to all injections. Urine release and aggressive behaviors were then analyzed.

28-3 SALIN, K.*; AUER, S.K.; RUDOLF, A.M.; ANDERSON, G.J.; SELMAN, C.; METCALFE, N.B.; University of Glasgow, UK; karine.salin@glasgow.ac.uk

Mitochondrial properties as the proximate cause of variation in whole-animal metabolic rate

Standard metabolic rate (SMR) and maximal metabolic rate (MMR) typically vary 2-3 fold amongst individual animals of the same species, size and life history stage, despite these traits being presumed to have a significant impact on fitness. Yet, the underlying physiological differences that determine such intraspecific variation in metabolism are largely unknown. Here we tested the hypotheses that variability among individuals in SMR and MMR is influenced by mitochondrial functioning, and that if SMR support the cost of maintaining the machinery needed for MMR, their underlying mitochondrial capacities should be shared. We examine the role of variation in mitochondrial respiratory capacities (leak and phosphorylative respiration rates) of key metabolic tissues (liver and white muscle) in brown trout *Salmo trutta* from the same life stage, environment and nutritional state. Mass-independent MMR and SMR were found to be uncorrelated, indicating that they are under the control of separate physiological processes. Moreover, the leak respiration in liver was significantly greater in high SMR individuals and the difference in MMR between fish was positively related to the leak respiration in the white muscle. Trout with high SMR or high MMR, far from signalling a higher respiratory capacity for mitochondrial ATP synthesis, can be those individuals whose tissue-specific mitochondria have a greater leakage of proton across the mitochondrial inner membrane. These results open up a range of avenues for future research on the consistent variability among individuals in the aerobic metabolism, including the fitness consequence of such variation in mitochondrial function, given the importance of mitochondria in the conversion of resources into ATP.

84-3 SALCEDO, MK*; COMBES, SA; MAHADEVAN, L.; Harvard University, University of California, Davis; maryksalcedo@fas.harvard.edu

Wing expansion in dragonflies and field crickets: a tightly folded solution to a complex behavior

As a winged insect undergoes its final molt, it must unfold, inflate, and harden its wings. Wing expansion is critical to the survival and reproductive success of the insect. Despite its importance, the physics mediating wing expansion remain unexplored. These physical mechanisms are thought to involve pressure in the wing veins and elastic energy storage in the folded wing. Folding patterns and packing methods of premature wings differ across insect orders. For example in both Odonate (Family: Libellulidae) and Orthopteran (Family: Gryllidae) nymphs, wings develop inside oblong wing pads against the body. These wing pads contain compressed mature wings that begin to expand upon emergence, even in the absence of pressure. Previous work also shows that during emergence, hemolymph pressure builds both in gut and trachea, causing cuticle to stretch. While it is known that this pressure increase is important, the dynamics of pressure driven wing expansion are not well understood. To understand these mechanisms, kinematics of ecdysis and wing expansion in both Odonates and Orthopterans were analyzed through video analysis. Specimens were frozen at various stages of wing expansion and were analyzed with imaging techniques to allow for 3D reconstruction and analysis of wing veins. In order to understand the role of pressure in the wing, these images were then used to inform a model of fluid flow through the wing veins. Inherently vital to insect flight and development, the principles of wing inflation and expansion can be applied to current air-craft designs and artificial inflatable structures.

104-6 SALIN, K.*; AUER, S.K.; RUDOLF, A.M.; ANDERSON, G.J.; CIARNS, A.G.; MULLEN, W.; HARTLEY, R.C.; SELMAN, C.; METCALFE, N.B.; University of Glasgow, UK; karine.salin@glasgow.ac.uk

Oxidative stress as the physiological cost associated to metabolic rate

There is increasing interest in the effect of energy metabolism on oxidative stress, but much ambiguity over the relationship between the rate of oxygen consumption and the generation of reactive oxygen species (ROS). Production of ROS (such as hydrogen peroxide, H₂O₂) in the mitochondria is primarily inferred indirectly from measurements *in vitro*, which may not reflect actual ROS production in living animals. Here, we measured *in vivo* H₂O₂ content using the recently developed MitoB probe that becomes concentrated in the mitochondria of living organisms where it is converted by H₂O₂ into an alternative form termed MitoP; the ratio of MitoP/MitoB indicates the level of mitochondrial H₂O₂ *in vivo* (Salin et al., 2015). Using the brown trout *Salmo trutta*, we tested whether this measurement of *in vivo* H₂O₂ content over a 24h-period was related to inter-individual variation in standard metabolic rate (SMR). We showed that the H₂O₂ content varied up to 26-fold amongst fish of the same age and under identical environmental conditions and nutritional states. Inter-individual variation in H₂O₂ content was unrelated to mitochondrial density but was significantly associated with SMR: fish with a higher mass-independent SMR had a lower level of H₂O₂. The mechanism underlying this observed relationship between SMR and *in vivo* H₂O₂ content requires further investigation, but may implicate mitochondrial uncoupling which can simultaneously increase SMR but reduce ROS production. To our knowledge, this is the first study in living organisms to show that individuals with higher oxygen consumption rates can actually have lower levels of H₂O₂. Salin, K. et al. 2015. Individuals with higher metabolic rates have lower levels of reactive oxygen species *in vivo*. Biology letters.

44-6 SALINAS-SAAVEDRA, M*; MARTINDALE, MQ;
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Interactions of Par/aPKC complex components are necessary for endodermal epithelial integrity of *Nematostella vectensis* embryos
The emergence of organized epithelia was undoubtedly one of the most significant events in metazoan evolution. The integrity of this tissue depends on the polarization and adhesion of its cells. One of the most studied systems in epithelial cell polarity is the Par system: a core set of five proteins (Par-1, Par-3, Par-6, aPKC, and Lgl) that, in bilateral animals, localize asymmetrically at the cell cortex beginning at the earliest stages of development. But, in embryos of *Nematostella vectensis* (phylum Cnidaria), Par components do not display asymmetric localization until later stages epithelial layers form. Are the protein-protein interactions within this system described in the Bilateria present in *N. vectensis* embryos? Immunoprecipitation experiments showed that NvaPKC, NvPar-6, and NvLgl all interact with one another throughout embryonic development, even though they are not asymmetrically localized at pre-blastula stages. In addition, experimental dominant-negative modifications of NvPar-3 and NvPar-6 resulted in modifications of their localization causing defects in cell adhesion, cell shape, and the integrity of cells in the endoderm (where Par proteins are not normally expressed). This suggests that the interactions of the Par/aPKC complex in the ectoderm maintain epithelial integrity of the entire embryo. From our data we conclude that some other factors that are expressed during later stages are not present during early cleavage stages. These factors were likely temporally co-opted in bilaterian taxa to be expressed at earlier embryonic stages to regulate embryonic polarity and that, therefore, different molecular mechanisms operate to set up polarity in early cnidarian embryogenesis.

10-4 SANTINI, F*; CARNEVALE, G; MARRAMÀ, G;
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Can we detect adaptive radiations in marine fishes?

The concept of adaptive radiation, according to which a biological lineage undergoes elevated rates of species diversification while at the same time experiencing divergence along ecological axis, is often invoked in evolutionary studies to explain the astonishing diversity of groups such as the cichlids of the African rift lakes, silverswords plants and honeycreeper birds in Hawaii, and anole lizards in the Neotropics. Recent surveys of the scientific literature, however, revealed that most studies of adaptive radiation do not recover the expected signal of early burst of lineage diversification, and in several animal groups rates of cladogenesis and phenotypic evolution may often be unlinked, thus creating complex patterns in the tempo of lineage and trait diversification. Furthermore, in spite of the dramatic increase in number of studies of the tempo and mode of evolution in marine fishes during the past decade, very little evidence has been uncovered to support the idea that adaptive radiations played a role in generating their staggering diversity, and even when a signal of radiation is recovered this virtually never conforms to the "traditional" early burst scenario. Using examples from our research on diverse groups of marine teleost fishes such as jacks and allies (Carangidae), pufferfish and allies (Tetraodontiformes) and snappers (Lutjanidae), we will discuss why it is so difficult to recover a signal of adaptive radiation in general, and early burst in particular, and offer some suggestions on how to test for these patterns.

S10-6 SANTANA, S.E.*; MILLER, K.E.; University of Washington;
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Analyses of bat ecomorphology at ontogenetic and macroevolutionary scales

Ecomorphology focuses on understanding how anatomical and behavioral diversity result in differences in performance, ecology and fitness. In mammals, the determinate growth of the skeleton implies that bite performance should change throughout ontogeny until the feeding apparatus attains its adult size and morphology. Then, interspecific differences in adult phenotypes are expected to drive food resource partitioning and patterns of lineage diversification. Formal tests of these predictions are lacking for the majority of mammal groups, and thus our understanding of mammalian ecomorphology remains incomplete. By focusing on a fundamental measure of feeding performance, bite force, and capitalizing on the extraordinary morphological and dietary diversity of bats, we investigate how the intersection of ontogenetic and macroevolutionary changes in feeding performance may impact ecological diversity in these mammals. We integrate data on cranial morphology and bite force gathered through longitudinal studies of captive animals and cross-sectional studies of free-ranging individuals. We demonstrate that ontogenetic trajectories and evolutionary changes in bite force are highly dependent on changes in body and head size, but cranial morphology explains a large proportion of the interspecific variation in bite force upon accounting for size differences. While more research is needed to determine how ontogenetic changes in size and bite force specifically impact food resource use and fitness in bats, interspecific diversity in cranial morphology and bite performance closely match functional differences in diet. Altogether, these results provide support for linear ecomorphological relationships at ontogenetic and macroevolutionary scales in bats.

S11-11 SANTOS, Scott R.; Auburn University; santos@auburn.edu
Evolutionary physiology of euryhalinity and developmental transcriptomics in anchialine crustaceans

Technological advances in DNA sequencing such as Illumina's Sequencing By Synthesis have made the generation and analyses of transcriptomes a rapid and economical endeavor across life. For crustaceans, characterizations of physiological or developmental mechanisms and processes have mainly focused on a handful of taxa or species of economic interest. Shrimp from the anchialine ecosystem, in contrast, present an opportunity to expand transcriptomic studies to both a novel taxonomic and ecological niche. This ecosystem is comprised of landlocked coastal ponds and caves with subterranean influences from both the ocean and freshwater aquifer. Given this, anchialine shrimp species must physiologically cope with continuously fluctuating salinities due to tides, rainfall, and vertical salinity stratifications. Transcriptomic studies of four anchialine shrimps from the Ryukyus Islands, Japan (*Antecaridina lauensis*, *Caridina rubella*, *Halocaridinides trigonophthalma*, *Metabetaeus minutus*) found that classic crustacean osmoregulatory mechanisms, like up-regulation of ion transporters during salinity change, are characteristic for these species. On the other hand, the endemic Hawaiian anchialine atyid *Halocaridina rubra* appears to employ unusual osmoregulatory processes via high and constitutive ion transporter expression under all salinities as well as the differential gene expression of unexpected transcripts in its gill tissues. Additionally, developmental transcriptomics of *H. rubra* identified significant differential expression of transcripts involved in pathways like energy production via peptide and carbohydrate catabolism, mitochondrial function, protein synthesis, respiration and photoreception that correlate to biological differences between life stages of the species.

82-5 SAPIR, N.*; WOLF, M.; ORTEGA-JIMENEZ, V.M.; DUDLEY, R.; Univ. of Haifa, Lund Univ., Univ. of California, Berkeley, Univ. of California, Berkeley; *nsapir1@univ.haifa.ac.il*
Biomechanical consequences of asymmetric wingtip deficits in Anna's Hummingbird (*Calypte anna*)

Wings are the primary aerodynamic surface for volant taxa, but the consequences of wing degradation for flight performance are unclear. We artificially introduced wing tip deficits in Anna's Hummingbirds by reducing the length of the four outermost primary wing feathers. Group 1 birds were measured throughout three consecutive sessions: a control, reduction of 15% of primary feather lengths in one wing only, and reduction of 15% of primary feather lengths in both wings. Group 2 birds were measured twice, once during control sessions and following a reduction in primary feather length by 7.5% for both wings. We used respirometry to determine flight metabolic rate, particle image velocimetry (PIV) to estimate wingtip circulation, and high-speed videography for wing and body kinematics analysis for birds flying within a variable-speed wind tunnel at 0, 6 and 12 m/s. Rates of oxygen uptake substantially increased in Group 1 birds with asymmetric wingtip ablation compared with controls, but only slightly further increased when the wingtip deficit was introduced to the contralateral wing. In Group 2 birds, effects of wingtip ablation on bird energetics were significant but slight. PIV measurements indicated increased circulation on ablated wings. Morphologically associated bilateral asymmetry of the wing motions alters flight performance and incurs considerable metabolic cost, suggesting selective benefits to maintenance of wing symmetry.

S7-7 SATTERFIELD, D.A.*; ALTIZER, S.; University of Georgia; *dara7@uga.edu*

Monarchs as a model system to understand mechanisms linking animal migration and infectious disease dynamics

Monarch butterflies inhabit islands and continents worldwide and undergo a long-distance, seasonal migration in temperate regions. Past work showed that migratory populations experience lower infection prevalence by a specialist protozoan compared to non-migratory populations, and that within migratory populations, infection risk declines after migratory movements. In this talk, we synthesize previous work with new data from wild monarchs to identify mechanisms by which migration limits pathogen spread and to examine how the loss of migration due to human activities alters pathogen dynamics. The results of field monitoring and small scale experiments within the eastern North American monarch population, which undergoes the longest distance migration, show that parasites pose significant costs for monarch migratory success (leading to 'migratory culling'), and that parasites accumulate in host breeding habitats during the summer months (setting the stage for 'migratory escape'). More recent observations show that sedentary monarchs in the southern U.S. that forego migration to breed year-round on exotic milkweeds face a high risk of infection that could increase pathogen spillover risk to the larger migratory population. New findings show that a small proportion of monarchs overwintering in Mexico originate from exotic tropical milkweeds and that these monarchs have a slightly higher probability of infection. The body of work from this system underscores the importance of conserving animal migrations and motivates future studies of infection risk and transmission between residents and migrants in monarchs and other species.

49-7 SATO, A; Ochanomizu University; *sato.atsuko@ocha.ac.jp*
The endoplasmic reticulum chaperones control canalization of animal development under environmental stress

Canalization is a result of intrinsic developmental buffering that ensures phenotypic robustness under genetic variation and environmental perturbation. As a consequence, animal phenotypes are remarkably consistent within a species under a wide range of conditions, a property that seems contradictory to evolutionary change. Study of laboratory model species has uncovered several possible canalization mechanisms, however we still do not understand how the level of buffering is controlled or whether these mechanisms are important for natural populations. We exploit wild populations of the marine chordate *Ciona intestinalis* to show that levels of buffering are maternally inherited. Comparative transcriptomics show expression levels of genes encoding canonical chaperones such as HSP70 and HSP90 do not correlate with buffering. However the expression of genes encoding endoplasmic reticulum (ER) chaperones does correlate. Furthermore, pharmacological impairment of ER function also reduces buffering levels. We also show that these ER chaperone genes are widely conserved amongst animals, and that their experimental knockdown compromises developmental robustness in the nematode *Caenorhabditis elegans*. These results show ER associated chaperones comprise a cellular basis for canalization, and that variation in their expression in natural populations may explain variation in the ability of embryos to buffer environmental insult. ER chaperones have been neglected by the fields of development, evolution and ecology, but their study will enhance understanding of both our evolutionary past and the impact of global environmental change.

90-5 SATTERLIE, RA; University of North Carolina Wilmington; *satterlier@uncw.edu*

Mechanisms of wing stiffening during fast swimming in a pteropod mollusc

Acceleration from slow to fast swimming in the Pteropod Mollusc *Clione limacina* includes two biomechanical changes in wing activities: a change in angle of attack and wing stiffening. In our search for mechanisms of the latter, we investigated three very different potential contributors to wing stiffness. Dorsoventral muscles run from the dorsal epithelium to the ventral epithelium, and are used to collapse the wing during wing retraction. Indirect evidence suggests they may also contract during the change from slow to fast swimming. During the acceleration, heart rate increases significantly. An analysis of the circulation of hemocoelomic fluid indicates that blood is directed from the heart directly to the wings, then the head, and via a restricted pathway, to the body and tail. The fluid motion during fast swimming indirectly supports an increase in fluid pressure in the wings in the early stages of fast swimming. Finally, an electrophysiological investigation of slow-twitch swim muscles (which drive slow swimming, and whose activity is enhanced during fast swimming) show that 10% of the muscle fiber sustain a high-frequency firing activity that is independent of rhythmic drive from the swim pattern generator. The high-frequency activity sustains contraction of the muscle cells during both phases of the wing-beat cycle.

31-3 SAUER, EL.*; SPERRY, JH; RICHARDS-ZAWACKI, CL; HOVERMAN, JT; TREJO, N; ROHR, JR; Univ of South Florida, Univ of Illinois, Univ of Pittsburgh, Purdue University; erinsauer@mail.usf.edu

Some like it hot: thermoregulation and amphibian disease and decline

Many animals, both endothermic and ectothermic, regulate their body temperature to cope with environmental stressors, including infection. Behavioral thermoregulation in response to disease has been observed in almost all ectothermic taxa including reptiles, amphibians, bony fish, and invertebrates. Using amphibian hosts and two waterborne pathogens, we aim to: (1) determine the desired temperatures of amphibian hosts and the degree of variability in temperature among individuals by observing animals in thermal gradient chambers, (2) determine how the thermal preferences of individuals change after pathogen exposure, and (3) determine whether changes in behavioral preference reduce actual pathogen abundance on hosts relative to uninfected hosts and infected hosts that are kept at their preferred temperature and cannot thermoregulate. The waterborne pathogens I will utilize in my experiments, the chytridiomycosis causing fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*) and the ranavirus frog virus 3 (FV3), have been implicated in global amphibian declines. Additionally, both pathogens have some level of temperature sensitivity: *Bd* can be cleared from amphibian hosts when housed above 30°C and *Ambystoma tigrinum* virus (ATV) (a ranavirus closely related to FV3) can be cleared from hosts when housed above 26°C.

1-4 SCHIEBEL, P.E.*; ZHANG, T.; GONG, C.; DAI, J.; ASTLEY, H.C.; TRAVERS, M; CHOSSET, H.; GOLDMAN, D.I.; Georgia Inst. of Technology, Carnegie Mellon Univ., Carnegie Mellon Univ.; pschiebel3@gatech.edu

Slithering on sand: kinematics and controls for success on granular media

Elongate, legless organisms, such as snakes, seemingly use simple body undulations to move on and within deformable substrates like sand. Previously, we have gained insight into the response of granular media (GM) to subsurface intrusion and used this understanding to find principles of subsurface undulatory locomotion. However, our knowledge of the physics of GM at the surface is limited. Therefore, when we challenged a variety of snake species to travel across the surface of a GM we found that performance was widely variable--ranging from efficient movement to complete failure--without an immediately obvious connection between various locomotor strategies and success. To understand what factors contribute to successful locomotion on challenging GM substrates, we focused on the study of a desert-dwelling snake *Chionactis occipitalis* (the Mojave Shovel-nose snake). We collected high-speed video of *Chionactis* (N = 10) moving on ~0.3 mm glass particles (a similar size to the GM in its natural habitat) and digitized the snake body for analysis. Using the organism studies in combination with resistive force theory calculations, GM drag experiments, and tests of a physical model (a snake-like robot), we find several factors which, acting together, contribute to animal performance: the body kinematics targeting an ideal waveform, the ability to lift portions off of the substrate, and the properties of the GM. Based on the sensitive nature of the relationship between these factors, we hypothesize that having an element of force-based control, where the waveform is modulated in response to the forces acting between the body and the environment, is necessary for successful locomotion on flowing, granular substrates.

113-3 SCALES, J.A.*; DEBAN, S.M.; University of South Florida; jscases@usf.edu

Temperature effects on the performance and motor control of tongue projection in lungless salamanders.

Temperature significantly impacts organismal performance through its effects on muscle contractile rates, making the maintenance of performance across temperatures a critical environmental challenge for many animals. Thermal effects on performance can be mitigated in movements powered by elastic recoil, such as the ballistic tongue projection of salamanders. Here, we examine the effect of body temperature (5-25°C) on the feeding performance and muscle activity in plethodontid salamanders that exhibit muscle-powered or elastically powered tongue projection to examine how motor control maintains performance in these two kinds of systems. Kinematic analysis of feeding combined with electromyography of projector (SAR) and retractor (RCP) muscles reveals that elastically powered tongue projections are faster and less sensitive to temperature changes compared to their muscle-powered counterparts, but that, motor control is similarly affected by temperature in both kinds of systems. The SAR was activated earlier relative to tongue projection and for longer durations at lower temperatures, while RCP activity was less influenced by temperature. Muscle activation intensity in both the SAR and RCP did not vary at higher temperatures, but decreased at the lowest temperatures. These results demonstrate that muscle activity appears to be modulated to maximize performance in a similar manner at all temperatures in both muscle and elastically powered projections. However, motor control in elastically powered systems allows comparable energy to be stored in elastic tissues over a wide range of temperatures, reducing the temperature sensitivity of feeding performance.

54-10 SCHMIDT, T.M.*; SONODA, T.; ALAM, N.M; CHEN, S.; KOFUJI, P.; LI, W; PRUSKY, G.T.; HATTAR, S.; Northwestern Univ., Weill Cornell Medical College, National Eye Institute, National Institutes of Health, University of Minnesota, Weill Cornell Medical College, Johns Hopkins University; tiffany.schmidt@northwestern.edu

New roles for ganglion cell photoreceptors

Distinct populations of retinal ganglion cells (RGCs) drive image forming and non-image forming vision. Intrinsically photosensitive (ip)RGCs express the photopigment melanopsin and drive non-image forming functions such as circadian photoentrainment and the pupillary light reflex. Ablation of ipRGCs results in loss of non-image forming behaviors but intact rod/cone dependent image forming vision. These findings have led to the conclusion that ipRGCs are simple photoreceptors that convey brightness information to mediate non-image forming vision, while conventional RGCs mediate image formation via relay of more complex features of the visual scene. Contradictory to this prevailing view, we find that a conventional RGC type, the ON alpha RGC, is intrinsically photosensitive. Furthermore, we find that melanopsin allows ON alpha RGCs to signal both lighting history and changes in environmental luminance over long periods of time. Consistent with the high contrast sensitivity of alpha RGCs, animals lacking melanopsin or completely lacking ON alpha RGCs have a clear deficit in visual contrast sensitivity as assayed by optokinetic tracking, demonstrating that melanopsin plays an unexpected role in contrast detection. Furthermore, this phenomenon is not specific to mice as the ON alpha-like RGCs of the ground squirrel are also intrinsically photosensitive. These findings suggest that melanopsin functions in the image-forming visual system to influence physiology and behavior.

22-1 SCHNITZLER, CE*; NGUYEN, AD; KLASFELD, SJ; BOND, SR; PLICKERT, G; BUSS, L; WOLFSBERG, TG; MULLIKIN, JC; NICOTRA, ML; CARTWRIGHT, P; FRANK, U; BAXEVANIS, AD; NHGRI, NIH, U of Cologne, Yale U, NIH Intramural Sequencing Center, U of Pittsburgh, U of Kansas, National U of Ireland, Galway; christine.schnitzler@nih.gov

Genomics of *Hydractinia*: A Cnidarian Model for Regeneration, Allrecognition, and Developmental Biology

Cnidarians are well-positioned to answer key questions about the evolutionary and functional biology of animals, as they are the sister group to the bilaterians. We have chosen to focus on the colonial cnidarian *Hydractinia*, a hydrozoan that forms colonies of polyps interconnected through a stolonal network. *Hydractinia* has lost the medusa stage and produces gametes directly from polyps known as gonozooids. *Hydractinia* displays remarkable traits, such as the ability to regenerate all tissues throughout its life from pluripotent stem cells (called i-cells) and the ability to recognize self from non-self via cell-cell contact, a phenomenon called allrecognition. *Hydractinia* is easy to culture, spawns daily, and is amenable to transgenesis and gene knockdown studies. We have sequenced and generated preliminary assemblies for the genomes of *H. echinata* and its sister species, *H. symbiolongicarpus*, based on PacBio and Illumina sequence data at high coverage. Similar to *Hydra*, the genomes are AT-rich (65%) and highly repetitive (47%). We have assembled transcriptomes for both species and performed shotgun proteomics on *H. echinata* as a first step towards comprehensive annotation of the genomes. We are using a comparative genomics approach to assess their genomes in relation to other model species and are characterizing genes, small RNAs, methylation status, and repeat content. With complete, high-quality genomic data, these *Hydractinia* species are emerging as robust models for developmental, evolutionary, and stem cell biology.

87-2 SCHRAM, J.B.*; SCHOENROCK, K.M.; MCCLINTOCK, J.B.; AMSLER, C.D.; ANGUS, R.A.; Univ. of Alabama at Birmingham; jbschram@uab.edu

Seawater acidification rather than warming a significant challenge for two common Antarctic macroalgal-associated amphipods

Elevated atmospheric pCO_2 concentrations are reducing seawater pH and elevating seawater temperatures along the western Antarctic Peninsula (WAP). These two factors may antagonistically, additively, or synergistically influence benthic macroalgal-associated amphipods. The gammaridean amphipods *Gondogeneia antarctica* and *Paradexamine fissicauda* are key members of the mesograzer assemblages associated with the macroalgae of the WAP. We exposed individuals of both amphipod species over a 90-day period to combinations of pH and temperature based on ambient conditions (pH 8.0, 1. 5°C) and those predicted for 2100 (pH 7.6, 3.5°C). We recorded amphipod survival and molt frequency, as well as feeding rates. Following the 90-day exposure period, we assessed growth and body composition. Reduced seawater pH significantly impacted survival in both species and an initial decline in survival corresponded with higher molt frequency. Mean feeding rates for *G. antarctica* were significantly higher in the reduced pH treatment. There was a significant pH-temperature interaction effect on feeding rates in *P. fissicauda* resulting in higher feeding rates in the reduced pH and elevated temperature treatment. Proximate body composition analysis revealed a significant pH-temperature interactive effect on whole body lipid content of *G. antarctica*, and lower protein levels in *P. fissicauda*. Overall, reduced pH dramatically impacted survival in both species, while elevated temperature induced sublethal impacts on feeding, growth, and whole body composition. Changes in pH and temperature associated with climate change are likely to impact the structure of mesograzer-macroalgal ecosystems along the WAP.

72-2 SCHOENLE, LA*; MOORE, IT; BONIER, F; Virginia Tech, Queen's University; schoenle@vt.edu

Tolerating malaria: The role of glucocorticoid hormones in mediating adaptive physiological responses to chronic infection

Glucocorticoid hormones provide a mechanism for individuals to rapidly adjust their physiology and behavior to meet the challenges of a variable environment. An individual's baseline levels of glucocorticoids reflect shifts in life history stage and resource demands while mediating a suite of physiological and behavioral changes that include immune modulation and resource allocation. Thus, glucocorticoids could facilitate a response to parasites that is optimized for an individual's specific challenges and life history stage. We used an observational field study and a controlled experiment to test the role of glucocorticoids in mediating the response to Haemosporidian parasites (including those that cause avian malaria) in red-winged blackbirds (*Agelaius phoeniceus*). We found that increased circulating glucocorticoids were associated with reduced costs of parasite infection but were unrelated to parasite burden in free ranging breeding male birds. We then manipulated glucocorticoid levels in male birds held in outdoor aviaries and measured individual changes in the costs of infection and parasite burden. To address the mechanisms underlying the effects of glucocorticoids on the costs of infection, we evaluated effects of the hormone on the inflammatory immune response and tissue repair. Our findings suggest a potentially adaptive role for glucocorticoids in shifting the response to parasites to align with an individual's current physiological challenges.

55-9 SCHULTZ, N.; INGELS, J.; HILLHOUSE, A.; WARDWELL, K.; CHANG, P.; GOOD, J.M.; CHEVERUD, J.; LUTZ, C.; LU, L.; WILLIAMS, R.; DEAN, M.D.*; University of Southern California, University of Tennessee, Texas A & M, Jackson Labs, University of Montana, Loyola University; matthew.dean@usc.edu

Evolutionary genetics of baculum size and shape variation in mice

The rapid evolution of male genitalia is a pre-eminent evolutionary pattern, but testing functional hypotheses have been traditionally hampered by two obstacles. First, like many biological structures, many male genitalia lack obvious landmarks, so comparing them in three dimensions is not straightforward. Second, we lack a basic understanding of the genetic basis of genital variation, so techniques of genetic manipulation remain unavailable. Here we develop a novel morphometric approach to characterize size and shape variation from three dimensional micro-CT scans taken from 342 bacula (a bone in the penis of many mammals), representing 75 distinct strains of the "BxD" recombinant inbred panel of mice. We identify a quantitative trait locus (QTL) that explained 32% of the variance in baculum size, and two QTL that together explained 46% of the variance in shape. From the QTL, we identified candidate genes using bioinformatic investigations and new data on RNA expression from the baculum. Several promising candidate genes affecting baculum size and shape are discussed. Our study opens the way to experimental manipulation and powerful functional characterization of this bizarre structure.

38-5 SCHULZE, A.*; GLASBY, C. J.; Texas A&M University, Museum and Art Gallery of the Northern Territory; schulzea@tamug.edu

Genetic and reproductive diversity of palolo worms (*Palola*, Eunicidae, Annelida) around the world

Palolo worms (*Palola*, Eunicidae, Annelida) are well known for their mass spawnings or "risings" which occur at very predictable times, once or twice a year, throughout the tropical Indo-Pacific. These events have great cultural significance in many locations, as the swarming epitokes are commonly harvested for food as part of community celebrations. Palolo festivities have captured the attention of visiting naturalists for centuries, resulting in detailed accounts and providing extensive datasets for analyzing temporal and geographical patterns of reproductive behavior. *Palola viridis*, originally described from swarming epitokes in Samoa, is a widely reported species in the genus. *Palola siciliensis* was originally described from Sicily but has a reported pantropical distribution. Although epitoky has been described for *P. siciliensis* as well, it appears that most populations do not exhibit mass spawning. Most of the remaining *Palola* species are only known from their type localities. However, many reported species identifications may be erroneous because morphologically diagnostic characters are few. On the other hand, genetic diversity in the genus is remarkably high, both within and among localities. Phylogenetic analyses indicate multiple genetic lineages which can be roughly separated into two groups: one of which exhibits epitoky and mass spawning and one that does not. Some genetic clades are geographically widespread whereas others are localized. Here we review and analyze historical records of reproductive timing as well as the genetic diversity within the genus in an attempt to characterize species ranges within *Palola*.

112-6 SCHWALBE, MAB*; WISE, TN; BODEN, AL; TYTELL, ED; Tufts University; margot.schwalbe@tufts.edu

Muscle activity during forward accelerations versus steady swimming in bluegill sunfish

Fishes need to swim long distances efficiently and accelerate quickly to escape predators or capture prey. To swim, fish contract the muscles on either side of their bodies to propel forward. Faster swimming requires higher muscle forces, but may also require an overall stiffer body because the reaction forces from the environment are also higher. How do fish modulate force production and body stiffness over a range of swimming speeds? One strategy fish may use is to increase the effective stiffness of their bodies while accelerating by co-contracting antagonistic muscles or activating more muscle during lengthening (eccentric contractions). To measure the muscle activity, we implanted bipolar electromyographic electrodes in the superficial red axial muscle of bluegill sunfish (*Lepomis macrochirus*) and recorded muscle activation during forward accelerations and steady swimming between 0.5-2.5 body lengths/second. We used a new digital inertial measurement unit, containing three-axis accelerometers and gyroscopes, to quantify the acceleration and 3D orientation of a fish's body. We also quantified swimming kinematics using high speed video. In forward accelerations, the muscles were active for a larger portion of the tail beat cycle and came on at a different time compared to that in steady swimming. Further, duty cycles (percentage of strain cycle period) was greater in forward accelerations than in steady swimming and varied by location on the body. These results suggest that muscle on both sides of a fish's body may co-contract during accelerations but not in steady swimming. Fishes likely change their effective body stiffness by shifting the timing and duration of muscle activity. These changes in muscle activity may allow a shift between impulsive, high force movements and efficient, low force, steady movements.

83-2 SCHWAB, D.B.*; NEWSOM, K.D.; MOCZEK, A.P.; Indiana University; schwabd@indiana.edu

Serotonin regulates larval growth and adult morphological plasticity in the horn-polyphenic beetle, *Onthophagus taurus*

Elucidating the physiological mechanisms that link environmental conditions to the development of alternative phenotypes is a central question in developmental plasticity research. In insects, studies have traditionally focused on the role of ecdysteroids and juvenile hormone in the specification of environmentally-cued alternative phenotypes, yet more recent work has examined additional classes of signaling molecules such as the biogenic amines. Here we investigate the role of the biogenic amine serotonin in regulating the ontogeny and evolution of polyphenism in the horned beetle, *Onthophagus taurus*. In this species, males exhibit a nutrition-sensitive dimorphism, developing into either hornless sneaker (low nutrition) or horned fighter (high nutrition) adult morphs. Transcriptomic data show that serotonin receptors are differentially expressed among i) the putative horn tissue of adult morphs and ii) recently established populations of *O. taurus* that are rapidly diverging in relative horn investment. To assess the role of serotonin in the development and evolution of morph specification, we use a pharmacological approach to manipulate systemic levels of serotonin in the final larval stage of *O. taurus*. We find that increasing serotonin signaling suppresses larval growth and delays pupation, whereas decreasing serotonin signaling has the opposite effect, consistent with findings in *Drosophila*. Results to date additionally suggest that serotonin signaling shapes the highly sigmoidal body size-horn length allometry of this species. Specifically, decreasing serotonin signaling appears to lower the threshold body size at which horns are expressed, but does not appear to alter the scaling relationships of additional traits. Here we present our latest results and discuss them within the context of developmental plasticity and population divergence.

S6-5 SCHWARTZ, Tonia/S*; BRONIKOWSKI, Anne/M; Auburn University, Iowa State University; tschwartz@auburn.edu

Evolution of the insulin and insulin-like signaling network in a garter snake metapopulation

The insulin and insulin-like signaling network (IIS) is a key molecular network (consisting of 70+ genes, circulating hormones, membrane-bound receptors, cellular signaling proteins) that integrates environmental signals with growth, reproduction, physiological stress, and aging. Previously we have demonstrated that the IIS network is rapidly evolving in amniotes (reptiles and mammals), particularly the interactions between the hormones (IGF1 and IGF2) and their receptors. Here we focus on the evolution of the IIS network within a species. We utilize a metapopulation of garter snakes (*Thamnophis elegans*) that has diverged along life-history, physiological, and genetic axes into two ecotypes that correspond to two habitat types. At the level of life history strategies, individuals of these two ecotypes differ in their growth rates, reproductive rates, and lifespan. Thus we hypothesize they have also diverged in various aspects of their IIS network. We compile results from hormone assays of circulating IIS hormones, gene expression from quantitative PCR data across tissues and high throughput RNA sequencing, and gene sequence variation from sequence capture data, to evaluate variation in the IIS network within and among the life-history ecotypes. Because the IIS network is the main stress-response network, we further explore plasticity within this network in response to environmental variation. We discuss the results in an integrative format extending from the genetic networks, to the physiology, and the life-history traits of each ecotype within the context of their respective habitats and selection pressures.

116-6 SCHWEIKERT, LE*; GRACE, MS; Florida Institute of Technology; lschweikert2011@my.fit.edu

Red Fish, Blue Fish: Wavelength Sensitivity of the Marine Fish Retina Adjusts to Transient Changes in Environmental Light Color
The marine light environment is highly variable in color and brightness due to ecological and anthropogenic variables such as depth, turbidity, and eutrophication. Recent studies indicate adaptive plasticity of the fish retina to light spectrum during development, but retinal plasticity to more transient changes in environmental light remains unknown. Here, we performed a study aimed at determining how light spectrum affects wavelength sensitivity and opsin gene expression in the Atlantic tarpon (*Megalops atlanticus*) on two- and four-month time scales. Sixteen juvenile tarpon were placed in either 590nm (red) or 420nm (blue) light conditions and retinal function was measured by electroretinography (ERG) and quantitative PCR (qPCR). At two months, tarpon of the red condition had a longer-wavelength peak sensitivity than fish in the blue condition. No significant change in wavelength sensitivity occurred between two and four months within each color condition. Relative expression of long-wavelength sensitive (LWS) and short-wavelength sensitive (SWS2) opsin genes across conditions was non-intuitive, with both genes having significantly higher expression levels in the blue condition. It appears by ERG that fish retina rapidly adjust color sensitivity to environmental spectra and only fine-tune sensitivity thereafter, and that these adjustments are governed by post-transcriptional regulation of the cone opsin genes or other processes undetectable by qPCR. The results suggest that fish have the ability to adjust wavelength sensitivity to environmental light spectra, making them resilient to disturbances in underwater light quality.

59-11 SEARS, Michael*; ANGILLETTA, Michael; APANOVITCH, Evan; CARLO, Michael; LEVY, Ofir; RIDDELL, Eric; RUSCH, Travis; Clemson University, Arizona State University; thermalecology@gmail.com

The influence of thermal heterogeneity on species interactions

Understanding range dynamics for any given species will not only require an understanding of how that individual species will respond to climate, but also how that species will respond to other species in its community. Such an understanding, then, will require some knowledge of how the strength of species interactions respond to both changes in magnitude and variance of relevant temperatures through time and space. Though implicit to many of our studies, few ecological experiments have explicitly examined how thermal heterogeneity shapes species interactions. Temporally, species-specific traits can produce activity profiles that minimize direct (exploitative) interactions through specialization on different preferred temperatures. Spatially, the arrangement of thermal habitat will dictate the outcome or frequency of competitive interactions. When preferred thermal environments are aggregated, the potential for interactions are intensified. When preferred thermal environments are dispersed, coexistence of potential competitors can be sustained. Here, we have three goals. First, we will provide theoretical expectations from spatially explicit, individually based models for the outcomes of competitive interactions both within and among species. Next, we will review the literature on competition in light of these thermal heterogeneity. Last, we will hypothesize how predicted climatic change may affect the future state of ecological communities. From these insights, we will outline future directions for research with respect to climate driven species interactions.

103-3 SCOTT, B. R.*; WILGA, C.; BRAINERD, E. L.; University of Rhode Island, Brown University; bradley_scott@my.uri.edu
Long-axis rotation of the lower jaw in white-spotted bamboo sharks (*Chiloscyllium plagiosum*) with discussion of deformation (strain or bending) during suction feeding.

Suction feeding is one of the most common modes of feeding in aquatic vertebrates, representing an exceptionally successful strategy for capturing prey. Suction feeding has been well studied in ray-finned fishes, but has seen less study in other taxa. Suction feeding in an elasmobranch species, white-spotted bamboo sharks, has shown noticeable functional differences from actinopterygians including posterior to anterior peak in pressure, and a decrease, rather than increase, in mediolateral width of the buccal cavity during suction. Kinematic data for jaw elements during feeding was quantified using XROMM. Long-axis rotation of the lower jaw during feeding was detected in three bamboo shark individuals. This rotation coincides with depression of the hyoid following peak gape and maximum jaw protrusion. This timing coincides with previously reported delays in the peak pressure gradient during feeding in bamboo sharks and may aid in generating suction, while the buccal cavity is compressed, by increasing total volume. Changes in marker to marker distances within the lower jaw indicate possible deformation of the posterior ventral region during feeding. Models of stress and strain during feeding typically incorporate forces perpendicular to the long axis of the lower jaw; however, this study demonstrates torsion as a potential source of stress and strain in the jaws during suction feeding, and therefore is important to modeling biomechanics as well as in functional morphological studies of the lower jaw.

13-2 SEGRE, PS*; DAKIN, R; ZORDAN, VB; DICKINSON, MH; STRAW, AD; ALTSHULER, DL; University of British Columbia, University of California, Riverside, California Institute of Technology, Institute of Molecular Pathology; segre@zoology.ubc.ca
Burst muscle performance predicts the speed, acceleration, and turning performance of hummingbirds

Despite recent advances in our understanding of animal flight, the biomechanical determinants of maneuverability in birds are poorly understood. It is thought that maneuverability is influenced by morphological features such as body mass, wing size, and wing shape, as well as by physiological traits such as muscle capacity. This hypothesis has not been evaluated for any animal because large numbers of measurements of free flight maneuvers from the same individuals have been lacking. We recorded a large number of flight sequences for 20 Anna's hummingbirds (*Calypte anna*) in a flight chamber to determine if an individual's maneuvering performance is 1) repeatable across trials, 2) associated with morphology, burst muscle capacity, or both, and 3) influenced by the presence of a competitor. Using a multi-camera tracking system, we analyzed performance metrics based on body position and orientation. Most measures were highly repeatable. Burst muscle capacity was associated with most performance metrics, such that birds with higher burst capacity flew with faster velocities, accelerations, and rotations, and performed more demanding complex turns. Wing morphology predicted only a few performance metrics, such that birds with higher wing aspect ratio had higher centripetal acceleration and performed more arcing turns. In the presence of a competitor, birds exhibited faster changes in pitch and altered the types of complex turns used, but surprisingly, they had lower horizontal accelerations. Collectively, these results indicate that burst muscle capacity is a key predictor of maneuverability, and that body angular velocity and arcing turns are associated with competition in flight.

S2-7 SEIBEL, B. A.; University of South Florida; seibel@uri.edu
Physiological strategies of vertical migrating organisms in pronounced oxygen minimum zones

Large populations of oceanic nekton and zooplankton undergo daily migrations from shallow water at night to depths greater than 200 m during the daytime. In some regions, these migrations cross extreme gradients of temperature, oxygen and carbon dioxide. Oxygen minimum zones (OMZs) are extensive and characterized by deep-water (100-800 m) oxygen partial pressures that would be lethal to most marine organisms, yet are tolerated by vertical migrators. Climate change is predicted to further deplete oxygen, and measurable reductions in oxygen have already been documented in some regions. Increases in shallow water temperature and carbon dioxide are occurring simultaneously. Oxygen levels and temperature are important drivers of biodiversity and distribution, and documented changes in community structure and function are reportedly associated with OMZ expansion and warming. Here I answer fundamental questions concerning zooplankton distributions, adaptations, and functions in oxygen minimum zones. In particular I report that metabolic suppression is a common strategy that facilitates diel occupancy of extreme hypoxia in many oceanic taxa. Anaerobic metabolic pathways play a minimal role in compensating for reduced aerobic ATP production. Numerous epigenetic mechanisms lead to reductions in energetically costly cellular processes, such as transcription and translation. Total metabolism is reduced by 50% or more during exposure to levels of hypoxia that characterize the daytime habitat for most vertically-migrating zooplankton. I further show that many migrators approach their upper thermal maximum in shallow water at night. Thus expanding OMZs and global warming may together compress the habitable depth range for many species.

74-5 SERB, J.M.*; HARLEY, A.; FAGGIONATO, D.; Iowa State Univ.; serb@iastate.edu

Expression and spectral analysis of two Gq-opsins from the mantle and the eyes of the scallop *Placopecten magellanicus*

Despite having complex mirror eyes and showing mantle shadow response, the molecular details of scallop light perception have been poorly studied. To unravel the molecular components responsible for light perception in scallop, our lab has assembled a transcriptome from the eyes of the scallop *Placopecten magellanicus*. Among other components of the phototransduction pathway, we have identified scallop opsins that are phylogenetically similar to rhabdomeric opsins and homologous to melanopsin in vertebrates. We present a detailed molecular and functional characterization of two melanopsin-like Gq-opsins (Pma-OPSGq2 and Pma-OPSGq3) from the scallop *Placopecten magellanicus*. While we could not express Pma-OPSGq3 in vitro, spectral analysis of Pma-OPSGq2 demonstrates that it is light sensitive and it is a bistable pigment that can convert its retinal chromophore from the 11-cis to the all trans conformation multiple times. Semi-quantitative RT-PCR data show that the two opsins are differentially expressed in eye and mantle with Pma-OPSGq2 being expressed at higher level compared to Pma-OPSGq3. Our data suggest that the two opsins are light absorbing Gq-opsins expressed in photosensitive tissues in *P. magellanicus*. We speculate that Pma-OPSGq2 and Pma-OPSGq3 contribute to the shadow response of the mantle and eye-mediated vision. Differential expression of the two opsins may indicate instances of neofunctionalization and/or neocompartmentalization of light perception in scallop. Future work will elucidate the temporal expression of the two opsins at different life stages and expand the spatial resolution by probing their expression in single eyes and subregions of the mantle.

65-8 SENNER, N.R.*; STAGER, M; VERHOEVEN, M.A.; BOUTEN, W.; CHEVIRON, Z.A.; PIERSMA, T.; University of Groningen, University of Montana, University of Groningen, University of Amsterdam, University of Groningen; n.r.senner@rug.nl

Flying High With No Barrier in Sight: Extreme High Altitude Migration in Black-tailed Godwits

Optimal migration theory posits that migratory birds should migrate at the lowest elevation at which they can find wind conditions profitable for migratory flight. This follows from the fact that climbing flight is more energetically expensive than horizontal flight and thus something to be avoided unless necessary. Additionally, high altitudes present other hurdles as well, such as reduced partial pressure of oxygen and extremely cold temperatures. As a result, even species such as Bar-headed Geese crossing the Himalayan Mountains attempt to minimize the altitude at which they migrate. Using GPS transmitters that record an individual's altitude, flight speed, and flapping rate, we tracked the migrations of Black-tailed Godwits breeding in The Netherlands and wintering in sub-Saharan Africa. We found that godwits migrate at unexpectedly high altitudes (>5500 m) for long portions of their migratory flights and appear to do so irrespective of the profitability of the winds at lower altitudes or the elevation of the land below them. We then couple our measures of in-flight performance with analyses of the blood chemistry enabling such high-altitude flights. Our results challenge long-held theories about both the capabilities of low-elevation species to perform energetically costly activities at high elevations and the optimality of minimizing climbing flight during migration. As a result, it may be necessary to reassess when, where, and how high we expect birds to migrate.

36-1 SEROTA, MW; Simon Fraser University; mserota@sfu.ca

Individual variation in foraging effort during parental care

Parental care (e.g. provisioning nestlings) is widely assumed to be costly, and life-history theory predicts that individuals that invest more in parental care should benefit in terms of number of offspring produced but that increased parental care might come at a cost in terms of decreased future fecundity and/or survival. However, the notion that parents that work "harder", commonly measured by the rate at which parents visit the nest box to provision their chicks, produce more, fitter chicks is surprisingly poorly supported. One potential reason for this apparent lack of relationship between measured work load during parental care and breeding productivity is that nest visit rate does not provide a good measure of foraging effort (even though this is the most commonly used metric). During chick-rearing, provisioning birds can adjust their foraging behavior in many other ways, e.g. varying load size, prey type, foraging distance, etc. Here, we investigated effects of handicapping (i.e. wing clipping) on parental effort during reproduction on breeding European starlings, *Sturnus vulgaris*. Using an automated radio telemetry system we tracked individually breeding females for the entirety of the breeding period. Our data suggests that there is marked variation in foraging behaviour (activity level, load size, and prey type). Given that provisioning rate is highly variable, but not correlated with breeding productivity, we predict that load size will be negatively correlated with provisioning rate and that individuals who bring a greater proportion of Tipulidae larvae, the primary food source of starlings, will have greater reproductive success. From this multivariate data we examined the repeatability, during the first and consequent breeding attempts, of several foraging metrics (activity level, load size, and prey type) and whether that individual variation is correlated with breeding productivity.

33-6 SERVETNICK, MD*; STEINWORTH, B; BABONIS, L; SIMMONS, D; MARTINDALE, MQ; Univ of Washington Bothell, Whitney Laboratory for Marine Biosciences, Univ of Florida; *mservetnick@uwb.edu*
CRISPR/Cas9-mediated excision of the brachyury gene disrupts endoderm development in the sea anemone *Nematostella vectensis*.
 We have applied CRISPR/Cas9, a recently developed gene editing technology, to study embryos of *Nematostella vectensis*. *Nematostella* is a member of the early-branching phylum Cnidaria, the sister group to Bilateria. Bilaterians form three embryonic germ layers: ectoderm, mesoderm, and endoderm as a key step in early development. Since cnidarians form only two embryonic germ layers, ectoderm and endoderm, this taxon is important for understanding evolutionary origins of mesoderm. We therefore chose to use CRISPR/Cas9 in *Nematostella* to study the developmental gene *brachyury*, a highly conserved T-box transcription factor which plays important roles in specification and differentiation of mesoderm in bilaterians. We show that we can excise the *brachyury* gene from the genome with high efficiency, and that the resulting embryos fail to express *brachyury* RNA. While *brachyury*/Cas9 embryos appear to undergo normal gastrulation movements, the endoderm is disorganized, and fails to form a normal epithelium. Expression of several genes involved in gastrulation (*bmp2/4*, *FoxA*) is disrupted in the absence of *brachyury*. Markers of aboral development - opposite the normal site of *brachyury* expression - often show expanded expression domains, suggesting that there are interactions between the oral and aboral domains during axial patterning. These results demonstrate that CRISPR/Cas9 can be applied to study early development in F_0 *Nematostella* embryos, and that in the absence of *brachyury* expression, endoderm development is disrupted.

86-2 SHARMA, PP*; JONES, TE; WHEELER, WC; EXTAVOUR, CG; University of Wisconsin-Madison, Harvard University, American Museum of Natural History; *psharma37@wisc.edu*
Discovering the genetic basis for morphological differentiation of deutocerebral appendages across arthropods
 The deutocerebral (second) segment of the head is putatively homologous across Arthropoda. In Mandibulata, this segment bears a pair of antennae, and in Chelicerata, a pair of chelicerae. Our recent work revealed a common mechanism for differentiation of deutocerebral appendages across arthropods, via experimental data for *homothorax*, a determinant of deutocerebral appendage fate, in an arachnid exemplar. In spite of this discovery, the architecture of the archetypal insect antenna and arachnid chelicera is markedly different, suggesting the downstream interactions of *homothorax* may not be similarly conserved. To test this hypothesis, we explored gene expression and/or function of members of the appendage fate specification gene regulatory network (GRN) in multiple chelicerate and mandibulate species. Here we show that strong expression of *spineless* (a known distal antennal selector in holometabolous insects) in the distal territory of the developing insect antenna is similarly observed in the distal antennae of other mandibulate exemplars. Functional data from the hemimetabolous insect *Oncopeltus fasciatus*, which bears a simple, plesiomorphic antenna, demonstrate that RNA interference-mediated knockdown of *spineless* incurs homeotic distal antenna-to-leg transformations, comparable to data from holometabolous insect counterparts. By contrast, we show that *spineless* orthologs are not expressed at all in the cheliceral limb buds of spiders or harvestmen during developmental stages where appendage identity is conferred. These data demonstrate a strong correlation between the expression pattern of *spineless* and the distal architecture of the deutocerebral appendage. Together with ongoing experiments, this work aims to reconstruct the evolution of the appendage fate specification GRN across Arthropoda.

59-5 SHAH, AA*; GHALAMBOR, CK; Colorado State University, Fort Collins; *alishas0624@gmail.com*
Using Thermal Tolerance to Explain Aquatic Insect Distributions Across Elevation and Latitude

Thermal tolerance has been implicated in shaping the range limits of organisms along temperature gradients. Tropical environments, characterized by stable climatic regimes, are thought to favor the evolution of narrow thermal tolerances and greater species turnover across elevation gradients. On the other hand, temperate environments with variable thermal regimes may favor broader tolerance and species distributions. Few studies have examined thermal tolerance patterns in aquatic systems, where fluctuations in temperature are reduced relative to air. An understanding of thermal tolerance may be crucial in revealing which species are vulnerable to climate warming. We focused on phylogenetically related mayflies (Family: Baetidae) collected from low- to high-elevation shallow freshwater streams in the Ecuadorian Andes (tropical, stable climate) and the Colorado Rockies (temperate, variable climate). Thermal tolerance was measured using metabolic rate and critical thermal (CT) limits. Metabolic rate curves were calculated by measuring oxygen consumption across a range of temperatures to determine the thermal breadth for each species. We found that overall, tropical mayflies have narrower thermal breadths than their temperate counterparts. Moreover, thermal optima match the natural thermal variation experienced by mayflies in streams. But while CTmax values indicate that mayflies exhibit high heat tolerance, the metabolic rate experiments demonstrate that insects from both locations have a strong preference for colder temperatures. We therefore suggest that multiple experimental approaches should be used when assessing vulnerability to warming, as a single technique can lead to erroneous conclusions.

97-13 SHARMA, N*; MANDRE, S; VENKADESAN, M; Yale Univ, Brown Univ; *neelima.sharma@yale.edu*
Functional morphology of joints

Flexures and ligaments are the two predominant morphologies of articular joints in animals. Flexural joints use a soft elastic flexure that is contained entirely within the articular space, and constrains or permits rotations based on the cross-sectional geometry of the flexure. Ligamentous joints are formed by bands of ligaments at the periphery instead of an internal elastic member. Rotations that stretch the ligaments are constrained, and other rotations are free. Flexural joints help in passive posture maintenance and elastic energy storage, but are found only in small animals like insects. We show that this transition in joint morphology is driven by a severe restriction on the range of rotation and strength of muscle-driven flexural joints. A longer flexure can rotate by larger angles before the adjoining segments come in contact and prevent rotation. Slender flexures are however prone to elastic buckling unless the ratio of the thickness to the length is greater than a material dependent critical value. Therefore, to prevent buckling, longer flexures have to be thicker and the one with maximal range of rotation is as wide as the adjoining segment. The bending stiffness of a flexure is proportional to the cube of its thickness, but muscle cross-sectional area and strength are proportional only to the square of the segment diameter. This allometry limits the feasible range of rotation for biological tissues to less than 1 rad, and the joint can no longer support external forces. Distal adhesive pads are therefore necessary to exert forces or lift loads when using a flexure. This is consistent with the observation that animals with flexures have distal adhesive pads, and are smaller than a few millimeters. The length-scale of a millimeter, at which adhesion becomes ineffective, therefore governs the transition from flexures to ligaments. Funding: HFSP RGY0091.

S9-9 SHELDON, K.S.*; DILLON, M.E.; University of Wyoming; Kimberly.Sheldon@uwyo.edu

Integrating climatic variation and population-level variation into models to predict climate change impacts

The ability of species to cope with temperature change will vary according to the degree of change and the physiological ability of a species to handle change. The majority of studies on the impacts of climate change have used mean annual temperature to model and then predict species' response to warming. Though largely ignored, other "cryptic" changes in temperature may drive species' responses more strongly than mean annual temperature. In addition, although many studies have incorporated variation in physiological traits among species in predictions of climate change impacts, few have considered the effects of variation in physiology among populations within a species. Here, we contrast 1) biotic impacts based on mean temperatures with estimates using hourly temperature data and 2) biotic impacts based on models that incorporate population-level variation with those that do not. Modeling approaches that do not take into account climatic variation or physiological variation both among and within species may fail to accurately predict the ability of species to persist in the face of climate change.

26-7 SHERIFF, MJ*; BOONSTRA, R; PALME, R; BUCK, CL; BARNES, BM; Pennsylvania State University, University of Toronto, University of Veterinary Medicine, University of Alaska Anchorage, University of Alaska Fairbanks; mjs72@psu.edu

The constraints of time and place: the consequences of prolonged spring snow-cover on arctic ground squirrel fitness and function

There is abundant evidence that the world's climate is changing at an unprecedented rate with a general trend for an overall reduction in spring snow-cover extent and an earlier spring snowmelt. In the Arctic, however, warming is occurring 2-3 times faster than the global average, microhabitat spatial variation is resulting in highly heterogeneous snow-cover patterns. Understanding the potential physiological mechanisms and their fitness consequences that may allow animals to cope with environmental changes has been cited as one of the biggest challenges of current biology. Our study is one of the first to integrate marked differences in the relationship between animal phenology and snow-cover regimes, with associated differences in body condition and stress physiology, reproductive success, and ultimately recruitment. We found that, compared to areas with early spring snowmelt, in areas with prolonged spring snow-cover 1) adult females were larger and in better body condition but had significantly higher stress hormone levels; 2) females had similar number and sized offspring, but that offspring stress hormone levels were higher; and 3) that offspring had reduced survival to hibernation. This study provides novel insights into how animals may cope with environmental change and discusses the significance of our findings within the broader context of changing animal-environment relationships.

S3-10 SHIELDS, J.D.; SHIELDS, Jeffrey; VIMS, College of William & Mary; jeff@vims.edu

Environmental influences on disease processes in crabs and lobsters

Over the last two decades disease outbreaks have been increasingly reported from several commercially important crustacean fisheries. Environmental stressors, including increasing temperatures, extensive hypoxia due to eutrophication, and presumptive exposures to contaminants, have been implicated as contributory factors in these outbreaks. Environmental stressors can alter the homeostasis of crustacean hosts by weakening or compromising their defensive responses thereby increasing their susceptibility to pathogens. Such stressors also favor microbial pathogens by improving their reproductive capacity, particularly in response to temperature or nutrient loading, leading to faster rates of population growth that can overwhelm host defensive capabilities. The role of environmental stressors in the emergence of pathogens has been hard to delineate because stressors have complex biotic and abiotic interactions making them difficult to isolate and identify using classical field and laboratory techniques. This review highlights the role of increasing temperature due to climate change in the emergence of several syndromes and provides insights into how multiple factors contribute to the emergence of outbreaks in several crustacean host-pathogen systems. Examples include outbreaks of epizootic shell disease, *Neoparamoeba pemaquidensis*, calcinosis and blindness in clawed lobsters, *Hematodinium* in snow crabs and blue crabs, and viral infections in shrimp and spiny lobsters. Collaborative studies offer a means to coordinate sampling and focus research questions to gain further understanding of causality and the environmental factors that contribute to the emergence of diseases.

66-4 SHINE, C. L.*; ROBBINS, C. T.; NELSON, O. L.; MCGOWAN, C. P.; University of Idaho, Washington State University; shin0453@vandals.uidaho.edu

Grizzly Bear Joint Loading Across Speeds: Sagittal and Frontal Plane Analyses

The majority of locomotion studies have focused on parasagittal motion and all but ignored any forces or movement in the frontal plane. Our previous research has shown that grizzly bears produce higher medial ground reaction forces (lateral pushing from the animal) than would be expected for an upright mammal, suggesting frontal plane movement is an important aspect of their locomotion. We conducted an inverse dynamics analysis, of sagittal and frontal planes, on ground reaction forces and position data from three high speed cameras of four adult female grizzly bears. Speeds were separated into three ranges, which approximately correspond to gait transitions. Average work produced by the forelimb was 0.18-0.45 W kg⁻¹, with the lowest value at the middle speed range. At all speeds the shoulder produces positive net work in the sagittal plane, while the wrist absorbs energy. This pattern is reversed in the frontal plane. In both planes, at all speeds, the elbow has variable but low values of net work. The average frontal elbow angle across all speeds is 154° and the frontal angle of the foot relative to the forearm is 31°. The distribution of power in the sagittal plane, highest in the shoulder and lowest in the elbow, is similar to what has been reported for the forelimb of horses. However, the frontal joint angles for the elbow and wrist, as well as the lateral power produced at higher speeds, suggest a substantial proportion of energy produced by the limb is lost in lateral propulsion and not used to propel the animal forward. A detailed musculoskeletal model will be created to identify specific muscle contributions of the limb movements.

87-5 SHISHIDO, C.M.*; MORAN, A.L.; LANE, S.J.; TOBALSKE, B.W.; WOODS, H.A.; University of Hawai'i at Mānoa, University of Montana, University of Montana; *csmariko@hawaii.edu*

Temperature, body size, and pycnogonid metabolism

As global temperatures continue to rise, it is increasingly important to understand how key physiological processes such as obtaining oxygen from the environment are affected by environmental temperature. Body size is an important consideration because larger organisms need more oxygen but may have a more difficult time obtaining it. If so, larger organisms may be disproportionately sensitive to warming. We are investigating the interactions between temperature, size, and oxygen consumption in pycnogonids (sea spiders), a group that occurs in most marine environments and that contains spectacular examples of polar gigantism. We first worked with a temperate pycnogonid species in the genus *Achelica* collected at Friday Harbor, WA. To assess whether temperature and body size interacted to influence metabolism, we measured oxygen consumption of animals from a range of body sizes (0.36 to 5.95mg) that were exposed to temperatures of 12, 16, 20, 24, and 28°C. Oxygen consumption increased with both temperature and body size until 28°C, at which point larger animals showed a disproportionate reduction in oxygen consumption compared to small bodied pycnogonids. These data will be compared to similar data collected from pycnogonids in the Antarctic where body size varies over several orders of magnitude and most invertebrates are both highly stenothermal and hypoxia-intolerant. This research was funded by NSF PLR- 1341476.

10-3 SIDLAUSKAS, B*; ALFARO, M; BURNS, M; DILLMAN, C; FAIRCLOTH, B; FRABLE, B; HOEKZEMA, K; MELO, B; SABAJ PEREZ, M; OLIVEIRA, C; VARI, R; Oregon State University, UCLA, Smithsonian Institution, Louisiana State University, Universidade Estadual Paulista, Academy of Natural Sciences of Drexel University; *brian.sidlauskas@oregonstate.edu*

Molecular phylogenetics, morphometrics and osteology reveal convergences and shifts in the mode of diversification within Neotropical headstanding fishes (Characiformes: Anostomoidea)

We reconstruct the evolutionary history of Anostomoidea, one of the most ecomorphologically diverse components of the Neotropical fish fauna, and investigate why some anostomoid clades have diversified greatly in oral jaw shape and coloration, while others primarily diversified internally. Though morphological and molecular phylogenies share broad congruence, their conflicts suggest oral jaw shape convergence within Anostomidae and that numerous features of the pharyngeal jaws and other systems appear plesiomorphic for the superfamily rather than synapomorphic for Anostomidae and Chilodontidae. Gill arch shape has diversified throughout the superfamily's history, and may represent an axis of ecomorphological divergence for the detritivores in family Curimatidae, which are difficult to distinguish externally, and the trophically diverse members of Anostomidae and Chilodontidae. Evolutionary dynamics in Prochilodontidae differ and indicate early fixation of a highly specialized bauplan that allows prochilodontids to achieve relatively large body and population sizes but affords little opportunity for subsequent diversification. Overall, our results illustrate how combining molecular phylogenetics with osteology, geometric morphometrics, and comparative phylogenetic methods can spark new discoveries about diversification, ecomorphology and character evolution.

39-5 SHYAMAL, SD*; DURICA, DS; RUDKINS, JM; University of Oklahoma; *shyamal.sharmishtha@gmail.com*

Methoprene-tolerant: a putative juvenile hormone pathway gene in *Uca pugilator*

The physiological importance of sesquiterpenoid signaling has been recognized in both insects and crustaceans, particularly in the regulation of reproduction. Crustaceans use methyl farnesoate (MF) as the innate ligand whereas insects use an epoxide form of MF, JH III. In insects, the Methoprene-tolerant (Met) protein has been characterized as a JH receptor. The met gene belongs to the bHLH-PAS family of transcription factors, and *Drosophila* Met protein binds JH III with high affinity. Subsequent experiments have shown that Met heterodimerizes with steroid receptor coactivator (SRC). SRC in turn may function as a co-activator for ecdysone signaling. A met homolog was recently identified in cladocerans, and like insects, Met was found to interact with a crustacean homolog of SRC in the presence of JH III. The Met/SRC interaction was also found to be 10 times more sensitive to MF than to JH III. We are interested in characterizing the molecular basis of MF signalling in brachyuran crabs. We have identified a Met ortholog in *Uca pugilator* which is expressed during limb regeneration. Transcriptome analysis of developing limb bud RNA-seq libraries show hits throughout the molt cycle; a detailed analysis of met expression is in progress. BlastP results reveal conserved regional similarities to that of cladoceran met (34%), and similar correspondence to numerous insects. Homology modelling and structural validation of the PAS-B domain show a favorable ligand binding pocket with 8 specific amino acid (aa) residues that interact with JH III; there are 2 aa substitutions in *Uca* in comparison to insects. A SRC homolog, the heterodimer partner of Met-tolerant, is also observed in the limb bud transcriptome library. We are currently producing expression vector constructs to examine protein/protein and protein/ligand binding.

37-3 SIGWART, JD; Queen's Univ. Belfast; *j.sigwart@qub.ac.uk*
Deep trees: The role of wood fauna in biodiversity dynamics in present and past extreme environments

Marine deposits of sunken wood provide occur at moderate depths (generally less than 2000 m) and provide the fundament for chemoautotrophic deep-sea communities with an extensive wood-endemic invertebrate fauna. Wood-dwelling lineages have been proposed as a "transitional" fauna that gave rise to invertebrates in vent and seep systems; a deep time phylogenetic framework could thus help explain the colonization of many deep sea "extreme" environments. For example a major clade of polyplacophoran molluscs (chitons) incorporating the majority of deep sea species, Lepidopleurida, originated in the early Carboniferous (ca. 350 Mya). New fossil evidence indicates a major bottleneck in Polyplacophora at the late Devonian mass extinction event (ca 375-360 Mya) followed by the emergence and diversification of the modern fauna in the Carboniferous. Yet the chiton fauna on sunken wood does not comprise a clade or radiation; wood-endemic species encompass multiple colonization events with several independent evolutionary origins of co-occurring wood species. These separate lineages correspond to differences in microhabitat and feeding strategies a point that is remarkable only in light of the overall conservatism of chitons, which are often called 'living fossils'. Early fossil forms include fossils with strong similarities to modern wood-endemic taxa. Evidence from chitons and other marine invertebrates indicates that the availability of abundant woody debris entering marine systems in the early Carboniferous may have played a key role in biodiversity recovery after the late Devonian mass extinction. This phylogenetic context changes the interpretation of interactions among wood and other ever more geothermally extreme deep sea oases.

44-5 SIMMONS, D.K.*; CREAMER, K.E.; STEPHENSON, T.Q.; MARTINDALE, M.Q.; University of Florida; davidsim@whitney.ufl.edu

Insights into the Evolution of Bilateral Symmetry: a Cnidarians Perspective

Dorsal-ventral patterning in bilaterians is controlled by the highly conserved BMP signaling pathway. Morphogenic gradients of BMP signaling and their modulators control the specification of cell fates along the dorsoventral (DV) axis. In the cnidarian *Nematostella vectensis*, BMP signaling genes are expressed asymmetrically on one side of the directive axis, opposite the side of asymmetric Hox gene expression. Using CRISPR/Cas9 we have produced gene knockouts in F⁰ populations of key Hox and BMP signaling genes. Knockout animals show asymmetric morphological defects, such as improper formation of tentacles and endodermal structures. In addition, we assessed the spatial and temporal patterns of asymmetrically expressed genes in knockout animals by in-situ hybridization. The data generated allowed us to generate preliminary gene regulatory networks of bmp and hox gene interactions. We show that BMP signaling initially sets up the directive axis, and that proper morphological patterning is controlled by interactions of Hox genes. We propose that the DV axis in bilaterians is homologous to the directive axis of cnidarians, and is set up using conserved signaling pathways, and gene regulatory networks.

125-5 SINCLAIR, BJ*; SALEHIPOUR-SHIRAZI, G; FERGUSON, LV; Western University, Canada; bsincla7@uwo.ca

Thermal biology of insect immunity

Research on overwintering insects often focuses on their tolerance to abiotic stress. However, animals are also part of complex ecological webs, including a range of pathogens that can threaten survival. Previous work hinted at an upregulation of insect immunity after cold exposure, so we explored the thermal biology of insect immunity more closely by determining 1) which components of the immune system are upregulated by cold; 2) whether acclimation affects the shape of the thermal performance curve for immune responses; and 3) how the phenotypic plasticity of the host and the pathogen interact to determine the outcome of infection in a complex thermal landscape. We show that while cold exposure activates potential immunity in *Drosophila*, it does not appear to affect the fly's ability to fight off pathogens. We found that low temperature acclimation leads to a paradoxical narrowing of the thermal performance curve of some measures of immunity, and that phenotypic plasticity by a pathogen can negate any inherent advantages a host might gain through acclimation. Together, this demonstrates that the temperature-immune interaction is complex, and often counter-intuitive, but that the outcome of that complexity may not undermine attempts to predict responses to climate change based on thermal biology.

96-3 SIMPSON, R.K.*; GIVENS, J.; MCGRAW, K.J.; Arizona State University; rksimps1@asu.edu

Evolutionary Patterns of Hummingbird Coloration

Animals display an amazing diversity of colors. These colors are used for a variety of behavioral functions, such as mate attraction, predator avoidance, or camouflage. Reconstructing the evolutionary history of animal coloration is important for understanding how and why coloration evolves. These studies combined with knowledge of a taxon's natural history (e.g. habitat, range size) can shed light on how various environmental, geographical, or other natural/sexual selection forces influence the evolution of coloration. In addition to evaluating how external factors impact the evolution of color, it is also important to understand how internal factors, such as color production mechanisms or evolutionary linkages between multiple color patches/patterns influence the evolution of animal coloration. Using the Handbook of the Birds of the World and a recently published phylogeny, we performed ancestral state reconstructions to explore how a diversity of colors evolved across 250+ hummingbird species (family: Trochilidae). We reconstructed the evolutionary history of multiple color patches for each species. We then explored how both external and internal selection factors shape the evolutionary history of coloration in this group, and discuss what impacts these patterns of color evolution have on hummingbird natural history.

41-1 SINGLETON, J.M.*; GARLAND, JR., T.; Univ. of California, Riverside; jsing014@ucr.edu

Endurance capacity and home range size in Desert Iguanas (*Squamata: Dipsosaurus dorsalis*)

Interspecific comparisons have yielded insight into regarding relationships between field locomotor behavior and performance capacities. Among species of lizards, endurance capacity measured on a motorized treadmill is positively related to daily movement distance and time spent moving, but few studies have addressed such relationships at the level of individual variation within a sex and age category in a single population. Both endurance capacity and home range size show substantial individual variation in lizards, rendering them suitable for such studies. This variation may be positively related, as endurance capacity might act as one of the factors limiting home range size. In this preliminary study, we measured the endurance capacity and home range size of 16 adult male desert iguanas (*Dipsosaurus dorsalis*) near Palm Springs, CA during May-June 2015. Lizards were field-captured for measurements of endurance; home range data was gathered using visual identification of individuals. Endurance was repeatable between replicate trials, conducted 1-17 days apart ($r = 0.718$ for log-transformed values, $N = 16$, 2-tailed $P = 0.002$). The higher of two endurance values averaged 21.8 ± 14.6 min (SD; range = 3.2 - 51.5 min), while mean home range size was $109.8 \text{ m}^2 \pm 111.9$ (SD; range = 15.7 - 482 m^2). Log home range size (adjusted for # of captures) was not significantly related to log endurance, whether or not body mass was used to compute residual values. This result suggests the possible importance of additional factors impacting home range size, such as intraspecific interactions or variation in microhabitat characteristics. Further work will examine endurance-home range relationships in other seasons and incorporate data on relevant ecological factors and social interactions.

108-2 SIRSAT, T.S.; DZIALOWSKI, E.M.*; University of North Texas, Denton TX; edzial@unt.edu

Ventilation changes associated with hatching and maturation of an endothermic phenotype in the Pekin duck, *Anas platyrhynchos*

Birds begin embryonic life with an ectothermic phenotype and develop an endothermic phenotype after hatching. Precocial species, like the Pekin duck, make this transition rapidly upon hatching. Switching to endothermic phenotype requires high-functioning respiratory and cardiovascular systems to deliver sufficient oxygen from the environment and to the tissues. Here we measured tidal volume (V_T), breathing frequency (f), minute ventilation (V_E), and whole-animal oxygen consumption ($\dot{V}O_2$) during the developmental transition from externally piped (EP) parinate to endothermic hatchling. We measured $\dot{V}O_2$, V_T , and f as animals gradually cooled from 37.5C (EP) or 35C (hatchling) to 20C. An additional set of experiments examined hatchling responses to hypercapnia. Only hatchling $\dot{V}O_2$ significantly increased in response to cooling. EP parinates had high f that decreased with cooling, whereas hatchling f was significantly lower and increased with cooling. Hatchling V_T was significantly higher compared with that of EP parinates. During cooling, V_T increased in both ages, but only at the coldest temperatures. Hatchling V_E increased significantly during cooling, mainly due to increased f , whereas EP parinate V_E remained constant. In hatchlings, increasing CO_2 to 4% resulted in f , V_T , and V_E increasing significantly. We suggest that one potential constraint on an endothermic ventilatory response of EP parinates is the rigid eggshell, limiting air sac expansion during inhalation and constraining V_T . Upon hatching, V_T limitation is removed and the animal is able to increase V_T , V_E , $\dot{V}O_2$ and exhibit an endothermic phenotype.

102-6 SLEBODA, D.A.*; ROBERTS, T.J.; Brown University; david_sleboda@brown.edu

A simple physical model suggests a hydrostat-like interaction within individual skeletal muscles

Fluid filled cylinders reinforced by stiff fibers (commonly referred to as helically-wound hydrostats) are ubiquitous in biological systems. Functionally, they have been shown to provide locomotor and postural support to organisms, to prevent buckling during bending, and to prevent high internal pressures from causing nonuniform bulging. Their consistent biomechanical relevancy has led to the general hypothesis that when a new helically wound hydrostat is discovered, an accompanying biomechanical role for it will not be far behind. Individual vertebrate skeletal muscles have all the components of a typical helically wound hydrostat, but the possibility of a hydrostatic interaction present within them has not been widely explored. In the present study we investigate the hydrostatic nature of individual skeletal muscles by comparing the passive mechanical properties of bullfrog semimembranosus muscles to those of a simple physical model. The model comprises a fluid filled balloon enclosed in a helically wound sheath of plastic fibers, and represents a single muscle fascicle wrapped in perimysial connective tissue. We find that in response to stretch our physical model qualitatively mimics the length-tension and length-pressure characteristics of passively stretched muscles. We suggest that a hydrostatic interaction may control the passive behavior of skeletal muscles at relatively long muscle lengths, and that the rise in intramuscular fluid pressure that accompanies extreme muscle stretching may be an indicator of collagen's contribution to passive tension. Supported by NIH grant AR055295.

49-6 SLEADD, I.M.*; LEE, M.; HASSUMANI, D.O.; STECYK, T.M.A.; ZEITZ, O.K.; BUCKLEY, B.A.; University of North Alabama, Portland State University; isleadd@una.edu
Sub-lethal heat stress causes apoptosis in an Antarctic fish that lacks an inducible heat shock response

The coastal ichthyofauna of Antarctica has endured sub-zero water temperatures for millions of years. During the course of these animals' evolution, they have acquired a suite of adaptations to cope with the extreme cold and ice which characterize their environment. Polar organisms such as these are remarkably stenothermal and are therefore cause for concern in the context of climate change. The conserved cellular stress response is a crucial mechanism for coping with environmental insults. It typically involves changes in metabolism, molecular chaperoning, apoptosis and cell cycle modulation. The last two remain critically understudied, especially in Antarctic fishes. It is now widely accepted that such animals lack an inducible heat shock response--the ability to upregulate the production of key molecular chaperones--but the effect this may have on cell fate remains unclear. Here we present evidence that even sub-lethal heat stress can induce programmed cell death in the emerald rockcod *Trematomus bernacchii*. Temperatures as low as 2 °C may prove dangerously hot to this and closely related species.

46-2 SMALL, TW*; SCHOECH, SJ; Univ. of Memphis; twsmall@memphis.edu

Baseline CORT, what is it good for? Differences in stress responsiveness influence and obscure 'baseline' corticosterone values collected within 3 minutes of capture

Plasma glucocorticoid (CORT) levels collected within 3 min of capture/handling are commonly believed to reflect pre-stressor CORT levels. Differences in these 'baseline' values are often interpreted as differences in the amount of social or environmental stress individuals have been exposed to prior to capture. However, many studies find inconsistent or absent relationships between 'baseline' CORT, health, and fitness. When interpreting 'baseline' values it is generally assumed that either 1) capture/handling stress did not influence CORT values prior to sampling or 2) any increase in CORT prior to sampling was both small enough, and consistent enough among individuals, not to obscure pre-capture differences. Yet, CORT increases in less than 3 min post-capture in most species in which timing has been carefully assessed, and the rate that stress-induced CORT levels increase can differ among individuals of the same species (e.g., stress-response phenotypes). In Florida scrub-jays (*Aphelocoma coerulescens*), plasma CORT levels begin to increase approximately 2 min post-capture, but the rate of increase between 2 and 3 min differs markedly between individuals with different stress-response phenotypes. Further, an individual's stress responsiveness correlates with CORT levels collected within 1.5 min post-capture, suggesting that before capture there are intrinsic differences in basal CORT levels between the phenotypes. Together these data indicate that 'baseline' CORT values can be strongly influenced by an individual's stress responsiveness. This influence can obscure, or entirely supersede, differences in basal CORT due to social or environmental stressors, thus complicating the interpretation of 'baseline' CORT values.

15-7 SMILEY, K. O.; Cornell; *kos24@cornell.edu*
Prolactin and parental care in the zebra finch (*Taeniopygia guttata*)

Parental care, defined as any behavior that increases an offspring's fitness, is a widespread phenomenon observed in many diverse taxa which has evolved independently numerous times resulting in species-specific parental behavior. While it is clear that species have converged on parental care in order to increase fitness, it is less clear whether the diversity in parental care behavior has resulted from species-specific mechanisms or whether species have co-opted similar mechanisms to promote parental behavior. The hormone prolactin (PRL) is a promising candidate mechanism of parental care that may have conserved roles in parental care across taxa. PRL has a well-established role in maternal care in mammals and ringdoves and has been suggested to be involved in parental care in other birds, including songbirds. Currently, there are no published studies looking at PRL's involvement in the expression of songbird parental behavior. The zebra finch, a socially monogamous, biparental songbird, is an exceptionally useful animal model to study parental care and other close social relationships. Both sexes share parental care equally and show a marked improvement in breeding success with experience. We have found that plasma PRL significantly elevates from non-breeding baseline concentrations during late incubation and early post-hatch care and that this elevation is greater in reproductively experienced birds, compared to inexperienced birds. Plasma samples were assayed using an ELISA that we validated in zebra finches. In addition, plasma PRL concentrations are highly correlated with the amount of parental care behavior displayed during days 2 and 3 post-hatch, the number of chicks that successfully hatched, as well as chick survival to fledging. Findings from these studies will be used to inform hypotheses and predictions for future work involving experimental manipulations of PRL during parental care.

58-1 SMITH, W. Leo*; GIRARD, Matthew G.; STERN, Jennifer H.; University of Kansas; *leosmith@ku.edu*
Phylogenetic and anatomical diversity of venomous cartilaginous and ray-finned fishes

The presence of venom and its associated delivery structures has been demonstrated broadly across the cartilaginous and ray-finned fishes. No studies have explored the evolution of venomous structures across the ray-finned and cartilaginous fish trees of life. Thus, we will document the diversity of venomous structures across cartilaginous and ray-finned fishes and explore the evolution of these features in a phylogenetic context. A densely sampled, multi locus (nuclear and mitochondrial) and temporal phylogenetic hypothesis of fishes will be used to inform lineage diversification and character evolution studies. Each clade of venomous fishes will be identified using ancestral states reconstruction, and the diversity and biology of each clade and its associated venoms will be discussed. The potential impact of the evolution of venom on the inferred patterns of diversification among some groups will also be explored.

60-6 SMITH, AJ*; MEAGHER, MA; DUMONT, ER; Univ. of Massachusetts, Amherst, MA; *ajsmith@bio.umass.edu*
Latitudinal differences in jaw integration influences rates of morphological evolution in the Carnivora

More than a century ago, Allen and Bergmann observed that temperate mammals are often larger and have lower surface area to volume ratios than their tropical counterparts. Since then, many studies have documented morphological gradients associated with latitude, but few have linked these gradients to any one mechanism. Here we investigate how morphological diversity (disparity), phenotypic integration, and the rate of morphological evolution differ between temperate and tropical mammals. We gathered landmark data from the jaws of three large families of carnivores, Canidae, Felidae, and Mustelidae, which contain both temperate and tropical species. We compared the disparity, the level of integration between the anterior (corpus) and posterior (ramus) portions of the jaw, and the rate of jaw evolution between temperate and tropical species within each clade. Temperate and tropical species occupied similar regions of morphospace and exhibit similar levels of disparity across all clades. All clades exhibit significantly higher levels of integration in the tropics. Temperate canids also exhibit high levels of integration, but temperate felids and mustelids exhibit low levels of integration. Those groups with high integration (canids, tropical felids and tropical mustelids) also exhibit slow rates of morphological evolution, highlighting a potential relationship between morphological rates and phenotypic integration. We hypothesize that the difference in rates and integration between temperate and tropical members of a clade is influenced by the wider climatic fluctuations experienced by temperate taxa. Those taxa living in more hostile conditions may evolve less integrated phenotypes to more quickly respond to changing environmental conditions and as a result, are more evolvable.

27-6 SMITH, GD*; NEUMAN-LEE, LA; WEBB, AC; DENARDO, DF; ANGILLETTA, MJ; FRENCH, SS; Utah State University, Arizona State University; *gdsmith57@yahoo.com*
Lizards downregulate their metabolism in response to an immune challenge: implications for energy status

We measured changes in standard metabolic rates (SMR) in response to different immune challenges and feeding treatments in the side-blotched lizard (*Uta stansburiana*). In the first experiment, lizards were randomly assigned to treatments of lipopolysaccharide (LPS) injection, cutaneous biopsy, both, or none (control). Two and three days after biopsies were administered, lizards were placed into closed-system respirometry chambers and their SMR were measured. There was a significant downregulation in SMR and a significant reduction in body mass in response to healing a cutaneous wound. Additionally, lizards that healed greater percentages of their wounds lost more weight. In the second experiment, lizards were randomly assigned to an *ad libitum* or restricted diet, and all were wounded. Again, we observed a downregulation in metabolic rate in response to a wound, and this decrease was positively correlated with healing rate. We also observed, as was expected, that standard metabolic rate was correlated with food intake, but food intake was not related to the decrease in metabolic rate following biopsy. These experiments yield new insight to the costs of immunity and how energy is allocated when animals are faced with different immune challenges in different energetic states.

117-1 SMITH, BJH*; USHERWOOD, JR; Royal Veterinary College; bsmith@rvc.ac.uk

Measuring the effects of hypergravity on mouse locomotion

Walking in animals and birds is commonly modeled as an inverted pendulum, while running is often modeled as a spring loaded inverted pendulum. The dynamics of both systems are dependent on the length of the pendulum, which corresponds to the hip height of the animal, and the gravitational acceleration experienced by the centre of mass. Manipulation of an animal's gravitational environment therefore enables investigation of the fundamental principles behind walking and running, as well as informing related topics such as scaling. We have used a centrifuge to expose five female FVB mice to varying levels of hypergravity, and measured a number of biomechanical parameters, including preferred speed, running intermittency and stance and stride times.

The centrifuge has an overall diameter of 4m and has four arms, each of which carries a gondola. Inside each gondola is a standard mouse cage outfitted with an instrumented exercise wheel, and a Basler acA2000-165umNIR infra-red high speed camera capable of filming both in light and dark conditions, along with instruments to continuously monitor welfare and environmental conditions. Hall sensors are used to measure the deflection of pads on the exercise wheel, allowing vertical ground reaction forces (GRF) to be determined. Recordings of GRF and speed, as well as high speed video at 200Hz are triggered automatically when mice run on the wheel; this allows us to study how mice adapt their posture, gait and behavior in response to the increase in gravity, and hence provides empirical data for testing the predictions made by pendulum models of legged locomotion.

27-4 SMYTH, KN*; DAVIES, CS; DREA, CM; Duke University; kendra.smyth@duke.edu

The costs of being the boss: androgens and innate immunity in a female-dominant species

The reproductive benefits and health costs of androgens are well studied in males, but underappreciated in females, despite substantial variation in female androgen production. In the cooperatively breeding meerkat (*Suricata suricatta*), raised androgens may improve the competitive abilities of dominant females, ensuring their near-exclusive control over reproduction. If, as in the males of some species, female meerkats suffer from androgen-mediated immunosuppression, rank-related differences in androgens could produce rank-related effects on immunocompetence. Previously, we showed that (a) dominant females were the most heavily parasitized group members (Smyth & Drea, 2015), (b) within females, parasitism correlated with fecal androgen concentrations (Smyth et al. in prep), and (c) dominant females routinely have higher concentrations of sex steroids (androstenedione, testosterone, and estradiol) than do subordinates (Davies et al. 2016). Here, in 95 wild meerkats, we evaluated associations between constitutive immunity (bacteria killing ability and hemolytic-complement activity) and sex-steroid concentrations. Males, that show no rank-related differences in sex-steroid concentrations, also showed no rank-related differences in immunocompetence. Compared to subordinate females, however, dominant females were immunocompromised. Because both androstenedione and testosterone, but not estradiol, were strong predictors of constitutive immunity in females, androgens may mediate the health disparity in this female-dominant species. Supported by NSF IOS-1021633.

5-5 SMITH III, J.P.S.; Winthrop University; smithj@winthrop.edu
Structure of the Male Copulatory Organ in Schizorhynchia (Platyhelminthes; Kalyptorhynchia)

The flatworm clade Schizorhynchia comprises approximately 150 species of predators that use an anterior proboscis to capture prey. Taxonomy in this group has relied heavily on the light-microscopic structure of the proboscis. Recent molecular-phylogenetic studies do not support the current classification. In addition to the proboscis, schizorhynchids possess a rather complex male organ, variously armed with spines or cirri. However, the last comprehensive review of this organ in Schizorhynchia was published in 1956 using only light microscopy. My investigation of the male copulatory organ in several schizorhynch species by confocal-laser-scanning and transmission-electron microscopy reveals common features, including an outer sheath of longitudinal muscles surrounding the copulatory bulb (conflicting, in at least one case, with the description originally published), copulatory "hard parts" comprising an eversible cirrus and/or a tubular extension of the ejaculatory duct, muscular connections between the copulatory bulb and hard parts that appear to be capable of cirrus protrusion during copulation, and an epithelial lining of the ejaculatory duct through which pass neck-like extensions of the prostate glands (a feature that was usually missed in earlier light-microscopic studies). Mapping of these characters onto the existing molecular phylogeny suggests additional candidate taxa for investigation. Supported by funds from the Winthrop University Research Council and SC-INBRE (National Center for Research Resources [5 P20 RR016461] and the National Institute of General Medical Sciences [8 P20 GM103499] from the National Institutes of Health).

36-5 SNYDER, NM*; CLARK, ME; REED, WL; North Dakota State University; nicole.snyder@ndsu.edu

Inside the egg: Patterns of variation in melatonin in Franklin's gulls eggs

Maternal hormones present during embryonic development have the potential to direct and program future offspring phenotypes. Melatonin is a hormone that responds to photoperiod and has a wide range of effects on animal physiology. During development, melatonin neutralizes reactive oxidative species produced during high-metabolic growth periods, and acts as a diffuse neuroendocrine system in early embryonic development. Although melatonin and its enzymatic constituents have been found in egg yolks of domestic birds, their presence and potential ecological and evolutionary significance in free-living birds has not been explored. We measured patterns of melatonin in egg yolks of Franklin's gull (*Leucophaeus pipixcan*), a long-distance migratory bird, to understand whether melatonin may be playing a role in patterns of embryonic and post-hatching growth and development. We collected first laid eggs from three Franklin's gull colonies between 2009 and 2011, and in 2015 we collected 20 full two and three-egg clutches from a single colony for analysis of melatonin. Melatonin was extracted from egg yolks and assayed using an ELISA (enzyme-linked immunosorbent assay). Melatonin was detectable in egg yolks and varied over two-fold across eggs. We measured significant differences in melatonin concentrations in yolk across years and colonies, although within-year variation in melatonin concentrations did not differ among laying dates. Variation in melatonin concentrations across whole clutches indicates there are differences in investment between the initial and final egg of a clutch, which is consistent with previous findings. The presence and variation in yolk melatonin suggests that maternal melatonin could play a role in generating the observed variation in growth and development in these birds and warrants further experimental evaluation.

41-4 SOCKMAN, KW; Univ. of North Carolina, Chapel Hill;
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Performance-Based Feedback and the Adaptive Regulation of Behavioral Plasticity

Optimizing plasticity in behavioral performances requires the abilities to regulate physiological effort and to estimate the effects of the environment. One way to do so is through the use of performance-based feedback, which occurs when an individual adjusts behavior according to feedback from prior iterations of the behavior. To describe how performance-based feedback may regulate recursive or continuous behaviors, I developed two models, one (environmental feedback) that assumes an initial ability to regulate effort but not to predict the effects of the environment and the other (effort feedback) that assumes an initial ability to predict the effects of the environment but not to regulate effort. The models produce opposite predictions for how an individual should modulate performance based on feedback from a previous performance and should therefore be readily distinguishable when subjected to an experimental manipulation of feedback. I conducted such a manipulation using an egg-substitution experiment in wild, free-ranging Lincoln's sparrows (*Melospiza lincolni*) and discovered that females adjusted the size of their clutches' third-laid eggs in a directly proportional response to the size of an experimentally substituted first-laid egg. Moreover they did so in the manner consistent with the environmental feedback model but not with the effort feedback model. Thus, results support the hypothesis that a female bird modulates the size of an egg according to feedback from a previously laid egg on the cumulative effects of the environment. The models call for tests in other systems in order to assess their generalizability. Such feedback-based regulation may not only help female birds maximize net benefits of egg production, it also may be a basis for regulating a wide range of other behavioral performances as well.

98-4 SOMBATSAPHAY, V*; REITZEL, AM; UNC Charlotte;
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Functional characterization of aquaporins in the estuarine cnidarian *Nematostella vectensis*

Without tissues or organs dedicated to osmoregulation, cnidarians, such as the sea anemone *Nematostella vectensis*, cope with environmental salinity stress on a cellular level. To explore the means by which *N. vectensis* is able to tolerate a wide haline window, we sought to describe aquaporin (AQP) water channel transcription and protein function in transport. Using quantitative PCR we found that a subset of identified AQPs are up- and downregulated in response to salinity fluctuations that occur in their natural estuarine habitats. The pattern of expression for these genes varied when comparing over development, suggesting differential regulation for particular stages. In order to test for transport function of AQP proteins, we performed heterologous expression of anemone AQPs in the *Xenopus laevis* oocyte system. We demonstrate that select AQPs from *N. vectensis* transport water, as well as other cellular metabolites, reflecting their phylogenetic relationship with other AQP proteins from vertebrate species. Our data suggest that the aquaporin gene family underwent an independent radiation in cnidarians that is mirrored in the transcriptional dynamics and transport functions in osmotic response.

32-3 SOGHIGIAN, J*; LIVDAHL, T; Clark University;
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Molecular phylogenetics of *Aedes* mosquitoes

For the majority of the twentieth century, mosquito genera were defined by morphological characters useful in differential identification. Since 2000, there has been a rapid increase in the number of genera within the family, primarily due to the elevation of subgenera from within the genus *Aedes*. These elevations were based upon cladistics analyses of morphological characters. More recently, additional analyses with the same characters called into question the elevation of these genera. Given the conflicting results of morphological analyses, the need for a molecular phylogeny of the medically important *Aedes* was apparent. Here we present the results from the most comprehensive molecular phylogeny of mosquitoes to date, with a particular focus on the genus *Aedes*, including more than seventy mosquito species. We used a database-driven approach in R to build a supermatrix from five gene regions for use in subsequent analyses in RAxML and PhyML. We discuss our results, including implications for the monophyly of the genus *Aedes*. Finally, we highlight the usefulness of this phylogeny in future comparative studies, and discuss future directions to resolve lingering naming questions within the genus *Aedes*.

94-3 SORTE, C.J.B.*; PANDORI, L.L.M.; CAI, S.; DAVIS, K.A.;
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Coping with climate change: an integrated assessment of range shift potential and physiological tolerances of intertidal mussels

Marine communities face continuing and accelerating climate change; however, we are still far from being able to predict which species will go extinct and which will persist in future climates. To make these predictions, we need to understand the efficacy of mechanisms that allow species to persist in altered environmental conditions, including poleward range shifts of tolerant individuals. Shifts in distributions and the frequency of stress-resistant phenotypes may be particularly challenging for sessile marine species inhabiting regions where currents flow in the opposite direction of climate shifts, including along the northeast and northwest coasts of the USA. We developed an integrative approach to, first, estimate the proportion of individuals in cohorts of recruiting marine invertebrates (mussels in the genus *Mytilus*) that originated from northern versus southern sources. Estimates based on both shell geochemistry and oceanographic modeling indicated that individuals are able to disperse "against the flow" towards relatively cooler latitudes. We then collected intensive time-series observations of thermal tolerances for recruiting mussel larvae, finding that cohorts are phenotypically differentiated across time, possibly due to local adaptation in parent populations or selection during dispersal. These results highlight the important interplay between two natural climate-change coping mechanisms: redistribution and physiological tolerance to changing thermal conditions.

21-4 SOUL, L.C.*; BENSON, R.B.J.; Smithsonian NMNH, University of Oxford; SoulL@si.edu

Rates and mechanisms of axial body plan evolution in Sauropterygia

Sauropterygians were highly successful marine reptiles that survived throughout the whole of the Mesozoic. They exhibited a broad range of body plans, including a large variation in vertebral count ratios, with cervical vertebral counts ranging from 5 to 76, the largest number in any animal. They therefore provide a model system for the evolution of vertebral counts and axial regionalisation in tetrapods, which could shed light on the mechanisms of vertebrate body plan evolution. We present a dataset of axial body plan measurements and vertebral counts from 120 taxa spanning 180 million years of sauropterygian evolution. We use this dataset to test the following explicit hypotheses about sauropterygian evolution using phylogenetic comparative methods including phylogenetic independent contrasts and Bayesian estimation of evolutionary rates: 1) Neck length evolved via somitogenetic (vertebral number) and homeotic (axial regionalisation) effects rather than by differential post-patterning somitic growth. 2) Somitogenetic and homeotic effects were decoupled during sauropterygian evolution. 3) Somitogenetic effects were the dominant generating mechanism of axial body plan change in sauropterygians. Our results show that differential post-patterning growth of somites was not an important driver of macroevolutionary change in sauropterygian body plans, unlike in mammals. Furthermore, background patterns of somitogenetic and homeotic change are decoupled, as has previously been shown in tetrapods. However, the establishment of higher level taxa with novel body plans involved rare, high-magnitude changes to both somitogenesis and homeotic effects, which were highly correlated. Our results demonstrate the importance of heterogeneous statistical models in uncovering the links between the hypothesised developmental drivers of macroevolutionary change in vertebrate body plans.

S4-11 SPEISER, D.I.; University of South Carolina; dispeiser@gmail.com

Eyes most numerous: extracephalic visual systems in molluscs

New genomic and transcriptomic resources for non-model study systems have revealed that light-sensitive cells are distributed more broadly across metazoan taxa and tissue types than suspected previously. Combined with a phylogenetic perspective on the distribution of light-detecting structures across animals, it appears that eyes in different metazoan lineages have evolved separately through the co-option of particular sub-sets of these non-visual photoreceptors. Here, I will discuss how we can use the diverse array of extracephalic visual systems found in mollusks - particularly those in chitons (Class Polyplacophora) and bivalves (Class Bivalvia) - to ask how and why eyes evolve from less complex light-sensitive structures. To learn how eyes evolve, I will describe how we identify the molecular components of eyes using a high-throughput, tree-based approach and then infer the separate evolutionary histories of these components by studying their functions and patterns of expression across taxa. To illustrate these methods, I will present evidence that the unique shell-eyes found in certain species of chiton are homologous to light-sensitive, non-visual organs found in eyeless relatives. By inferring ancestral character states for these homologous organs, we can construct a step-by-step account of how the eyes of chitons may have evolved. To address why eyes may have evolved in some lineages (and may not have evolved in others), I will discuss the functional benefits, costs, and constraints associated with transitions from non-visual light-sensitive organs to those that provide spatial information about light. For example, spatial vision may help chitons and bivalves distinguish approaching predators from uniform decreases in illumination, thereby reducing costly defensive responses to non-existent threats, but it may come at the cost of decreased sensitivity to small or rapid changes in light levels.

119-4 SPARKMAN, A.M.*; HOWE, S.P.; HYNES, S.G.; HOBBS, B.E.; Westmont College, University of Akron; sparkman@westmont.edu

Convergent behavioural and morphological strategies in fence lizards on two college campuses

The spread of urban development has dramatically altered local habitats, modifying community relationships, abiotic factors, and structural features. Animal populations living in these areas must either perish, emigrate, or find ways to adjust to a suite of new selective pressures. Those that successfully colonize the urban environment may make behavioural, physiological, and/or morphological adjustments that are either heritable or a result of phenotypic plasticity. We tested for effects of urbanization on behaviour and morphology across an urban-wild gradient in the western fence lizard (*Sceloporus occidentalis*) in two California counties, Santa Barbara and San Luis Obispo. To compare college campuses in both counties with nearby undeveloped ("wild") locations, we conducted field trials that allowed us to characterize behavioural responses to acute capture stress, predator simulation, and release in adult lizards. We also collected head and limb measurements. We found several notable differences between campus and wild lizard behaviour, with campus lizards more frequently employing a strategy of tonic immobility. Furthermore, campus and wild females differed significantly in hindlimb length. We hypothesize that these differences may be influenced by a variety of novel ecological challenges, including increased anthropogenic activity, altered predatory regimes, and altered habitat structure.

47-3 SPENCER, T*.; BALLARD, M.; KALAITZIDOU, K.; ALEXEEV, A.; HU, D.; Georgia Institute of Technology; thomasls.gt@gmail.com

Pheromone Capture in Moth Antennae

Moths are reported to smell each other from over 7 miles away, locating each other with just 200 airborne molecules. In this study, we investigate how the structure of the antennae influences particle capture. We measure the branching patterns of over 40 species of moths, across two orders of magnitude in weight. We find that moth antennae have 3 levels of hierarchy, with dimensions on each level scaling with body size. We perform lattice-Boltzman simulations to determine optimal flow patterns around antennae branches allowing for capture of small particles. Using a combination of molding and soft lithography techniques we create a physical replica of the moth antenna on a 1:1 scale.

**21-2 SPERLING, EA; Stanford University; esper@stanford.edu
*The ecological physiology of the Cambrian 'explosion' and Earth's second oxygen revolution***

Living animals display a variety of morphological, physiological and biochemical characters that enable them to live in low oxygen environments. These features and the organisms that have evolved them are distributed in a regular pattern across O₂ gradients associated with modern oxygen minimum zones, providing a template for interpreting the stratigraphic covariance between inferred Ediacaran-Cambrian oxygenation and early animal diversification. Although Cambrian oxygen must have reached 10-20% of modern levels, sufficient to support the animal diversity recorded by fossils, it may not have been much higher than this, approaching today's level only later in the Paleozoic Era. Nonetheless, Ediacaran-Cambrian oxygenation may have pushed surface environments across the low, but critical, physiological thresholds required for large active animals, especially carnivores. Continued focus on the quantification of Proterozoic pO₂ will provide the definitive tests of oxygen-based co-evolutionary hypotheses.

**13-4 SQUIRE, ME *; SWEENEY, R; NEMETH, Z;
 RAMENOFSKY, M; The University of Scranton, UC Davis, UC Davis; maria.squire@scranton.edu
*Skeletal Changes Resulting from Migration in Gambel's White Crowned Sparrows***

In preparation for migration and during recovery from migration, birds experience widespread changes to their bodies including changes in fat, skeletal muscle, and digestive organ mass. While these changes have long been established, potential effects of these seasonal events on the skeleton, including changes to bone quantity and microarchitecture, have not been studied in detail. In the current study, we used micro-computed tomography to examine possible changes in the avian skeleton as a result of migration to the wintering grounds. We examined the humeri of Gambel's White-Crowned Sparrows (*Zonotrichia leucophrys gambelii*) that were collected before migration, shortly after migration, and months after arrival to the wintering grounds. MicroCT analysis revealed differences in cortical bone volume and cortical thickness however, with the exception of differences in tissue mineral density, no changes were found in trabecular bone morphology across any of the three groups examined. Additional work needs to be done to further understand the mechanisms underlying the observed changes to cortical bone as well as to explore why trabecular bone appeared to be unaffected by migration. Further studies with larger sample sizes and better understanding of the type(s) of loading the wing bones experience during migration may help us to better understand the changes that the avian skeleton undergoes during migratory events.

**40-1 SPONBERG, S.N.*; STÖCKL, A.; Georgia Inst. of Tech, Lund University; sponberg@physics.gatech.edu
*System identification of flower tracking in three species of hawkmoths reveals interspecific tuning of motor control to visual ecology***

Animals must maintain maneuverability despite difference in sensory ecology. Both sensory and motor conditions vary widely both across species and within individuals. Many species of hawkmoths forage from moving, wind-blown flowers and must track flower movements to feed. Yet light intensity can vary by up to 10 billion fold over the course of the day. We compared three species of hawkmoths active in diurnal, crepuscular and nocturnal environments. Using robotic flowers that sway with repeated movements composed of the sum of many sinusoids, we have characterized the dynamics of flower tracking. The crepuscular species, *Manduca sexta*, slows down its neural processing to increase sensitivity in dim environments, but only to a point that it does not affect how it tracks natural flower movements. We investigated if temporal slowing in neural processing changes could predict shifts in performance to the diurnal species, *Macroglossum stellatarum* and the nocturnal *Deilephila elpenor*. Across species the nocturnal *D. elpenor* demonstrated the greatest phase lag and gain overshoot consistent with the slowest visual processing. All species demonstrated a luminance-dependent tracking behavior, but the effects of changing luminance were much more pronounced in the diurnal and crepuscular species. The nocturnal species tracks more poorly at higher luminance levels and may have maximized its visual sensitivity to its extreme environment even at the cost of robust maneuverability. Comparing maneuverability across species reveals how neuromechanical processing matches the sensory demands of animals' environments.

**97-9 SRINIVASAN, M.; The Ohio State University; srinivasan.88@osu.edu
*Optimal quadrupedal locomotion***

Horses walk at slow speeds, trot at intermediate speeds, and gallop at high speeds. Other quadrupeds, including trained horses, can perform a variety of other gaits, such as an amble, pace, canter, tolt, etc. Here, we use a series of simple computer models of a quadrupedal animal to examine the metabolic energetic differences between these gaits. First, we considered perhaps the simplest model with the upper body consisting of a single extended rigid body and four ideal massless legs: for this quadruped, an inverted pendulum-like walking gait was energetically optimal at slow speeds and a perfect trotting gait is optimal at all higher speeds; galloping was never optimal. The walking gait was the exact analog a bipedal inverted pendulum walking motion: so that the front two legs were in synchrony with the rear two legs, so that the quadrupedal upper body moves without any rotation (no pitch or roll). Next, we considered a more realistic quadrupedal model, with a back that can bend and a neck attached to the body in a compliant manner: for this quadruped, a walking gait was optimal at slow speed, a trotting gait at intermediate speeds, and a more asymmetric gait reminiscent of galloping at high speeds. For our quadrupeds, we also found that other gaits such tolt and pace were sub-optimal. All these calculations were performed using large-scale numerical optimization, which attempted to obtain the energy optimal body motions and muscle (leg) force profiles for a given footfall sequence while systematically and simultaneously optimizing the footfall sequences from among a large set of possible footfall sequences. We will show how we obtain different gaits as we change some body size parameters. These methods could be generalized to other multipedal animals, say cockroaches and other insects, perhaps including other goal including other goal criteria than just energy minimization, e.g., improving stability.

97-3 SRINIVASAN, M.; The Ohio State University;
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Why spike: An energetic benefit for spiky muscle stimulation and oscillatory calcium transients

During muscle force production, each discrete neural spike results in a large fast efflux of calcium ions from the sarcoplasmic reticulum (SR) into the myofibrillar space, which is then more slowly pumped back into the SR by a Calcium pump. A sequence of neural spikes results in an oscillatory calcium concentration in the myofibrillar space. Why are muscles excited by an oscillatory calcium signal when a more gradually changing calcium signal would likely do as well (and even might provide more constant muscle forces)? Here, I provide an adaptationist argument, suggesting that an oscillatory calcium signal is better because it reduces the energy expenditure of the calcium pump in the sarcoplasmic reticulum. We construct a simple mathematical model of the dynamics and energetics of calcium pumping, consisting of two 'chambers': (1) the SR with an initially high concentration of Ca²⁺ and (2) the myofibrillar space with a lower initial calcium concentration. Calcium in the myofibrillar space eventually leads to actomyosin interaction, modeled here through some low order dynamics, a simplified reaction network -- the key necessary feature being that the dynamics are such that the force fluctuations are much smoother than the calcium fluctuations. Energy is needed for calcium pump and myofibrillar interaction. Using numerical optimization, we compute the energy optimal strategy to maintain an average muscle force and find that this optimal strategy is to use a sequence of large effluxes (neural spikes) combined with longer periods where the calcium is pumped back more slowly - similar to what is observed in nature. In addition, this model predicts, as observed, that a higher average force requires a higher frequency sequence of calcium effluxes from the SR (increased spike rate).

17-5 STAGER, M*; EDDY, DK; CARLING, MD; CHEVIRON, ZA; Univ. of Montana, Univ. of Wyoming;
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The consequences of getting high: reduced aerobic performance of a songbird at high altitude

Many avian species' distributions are expected to shift with climate change, but detailed predictions are limited by our understanding of the physiological constraints that shape altitudinal range limits. As elevation increases, temperatures decline, requiring enhanced aerobic performance to sustain shivering thermogenesis, yet O₂ availability declines in parallel. Birds adapted to life at high altitude harbor a number of unique physiological adaptations that enable superior O₂ uptake, circulation, and utilization allowing them to maintain aerobic performance under hypoxic conditions. But to what degree are these traits flexible in lowland species, facilitating colonization of high environments? Dark-eyed Juncos (*Junco hyemalis*) breeding at high altitude winter at lower elevations, suggesting that they maintain physiological flexibility for these different environments. We measured juncos along a transect from 2070m to 3556m in elevation. The expected temperature reduction across this transect (10°C) should correspond to increases in both resting (RMR; 70%) and cold-induced summit (M_{sum}; 19%) metabolic rates for summer-acclimatized juncos (per Swanson 1990, 1991). We documented little change in RMR (10% of the predicted rate; p = 0.08) while controlling for the acute effects of variation in PO₂. Unexpectedly, M_{sum} decreased with increasing elevation (= 2.5 × 10⁻⁵ ml O₂/g*min*m, p < 0.001). The reduced performance of highland birds suggests that acclimatization to hypobaric hypoxia may limit aerobic performance at moderate elevations in juncos. We explore the physiological modifications that might underlie this paradoxical pattern (e.g., blood parameters, cardiac and pulmonary physiology, body composition, and condition indices) and discuss the comparative selective forces of temperature and PO₂ on avian physiological range limits.

57-4 SRYGLEY, R.B.; USDA-Agricultural Research Service;
robert.srygley@ars.usda.gov

Hannibal goes for a stroll: How diet and migration can compromise immunity

Migration is often associated with movement away from scarce nutrients or other resources, and yet migration itself is energetically demanding. Mormon crickets walk in dense aggregations over rangeland. In some of these migratory bands, Mormon crickets seek protein and salts, and they readily cannibalize wounded or dead band members. Hence, cannibalism leads to a forced march in collective motion. In other bands, Mormon crickets are deficient in carbohydrates, although they too will cannibalize when given the opportunity. Do these nutritional limitations result in trade-offs between migration and immunity? Feeding protein to protein-limited crickets slows the migration and increases generalized immunity, measured as phenoloxidase. In contrast, feeding carbohydrates to carb-limited crickets slows their migration and increases anti-bacterial activity. Do dietary deficiencies result in differences in susceptibility to pathogens? Protein-restricted diets caused Mormon crickets to have lower phenoloxidase titers, slower encapsulation of foreign bodies, and greater mortality from *Beauveria bassiana* fungal infection than they had when fed high protein diets. Hence diet altered fungal immunity. Anti-bacterial activity, in contrast, was dependent on combined effects of diet and migration. These two generalized immune functions are common to all insects and so the dichotomous role of nutritional deprivation can be generalized to all insect migrants. Climate may play an important role in the availability of protein and carbohydrates, and ultimately which of these two basic immune functions is weaker. Hence a changing climate may alter defenses of migrating insects and enhance or impede the spread of bacterial and fungal disease.

56-7 STALEY, M*; BONNEAUD, C; HILL, GE; Auburn University, University of Exeter; mms0020@auburn.edu

Insights into the role of host access in limiting disease emergence in a natural host-pathogen system

In 1994, an endemic bacterial poultry pathogen, *Mycoplasma gallisepticum*, underwent a dramatic shift of host range into house finches (*Haemorrhous mexicanus*). The result was a devastating epizootic that killed tens of millions of house finches. The factors that enabled the bacteria to jump to the very distantly related and novel house finch host remain unclear. Transmission of *M. gallisepticum* requires exposure to moisture droplets with *M. gallisepticum* and thus a shared environment. Under most circumstances, house finches would not be in such close proximity to poultry. Here we tested whether lack of contact between house finches and poultry was a limiting factor in this host switch. We experimentally infected house finches (N=15) with a high dose of a known virulent chicken strain of *M. gallisepticum* (Rlow) through an ocular inoculation and then monitored infection development over several weeks. While Rlow colonized and persisted in the house finch mucosal epithelium of the upper respiratory tract (i.e., trachea), it did not cause clinical symptoms; the only exception was one bird that exhibited mild conjunctivitis after 7 days. Given that exposure to Rlow led to colonization of the respiratory epithelium but not infection levels or clinical disease symptoms comparable to what was seen at the start of the epizootic, our results suggest that the emergence of *M. gallisepticum* in the novel house finch population was unlikely to have been limited by host access. Rather, genetic changes in the bacteria would have been necessary to initiate this epizootic.

97-17 STANCHAK, K.E.*; SANTANA, S.E.; University of Washington and the Burke Museum of Natural History and Culture; stanchak@uw.edu

Morphology of the Bat Ankle: Novel Structures for Ecological Specialization

The derived postcranial morphology of bats reflects their specialized ecology - flying mammals with an inverted roosting position. While adaptations of the bat forelimb have been researched extensively, fewer studies have explored the evolution of the bat hindlimb. In particular, the calcar (a cartilaginous or bony spur projecting from the calcaneum into the hindlimb membrane) has received little attention, even though it varies considerably among bat species and may be a novel skeletal feature in mammals. We address two major knowledge gaps regarding the evolution of the calcar-calcaneum joint and shed light on their functional significance. First, is the calcar a bone or a cartilaginous element? Second, does ecological specialization explain the morphological diversity of the calcar and calcaneum in bats? To answer these questions, we integrated analyses of comparative histology and 3D morphology across 21 bat species from 16 families. By comparing the tissue anatomy of calcars in a subset of these species, we found evidence of ossification in at least one bat species, *Noctilio leporinus*. This raises questions about the homology of the calcar among mammalian tarsals. Our comparisons of the 3D morphology of the calcanea revealed that their shape is influenced by both phylogeny and ecological specialization. For example, the calcaneum of *N. leporinus* has a uniquely broad calcaneal tuberosity that corresponds with the laminar shape of its calcar. *N. leporinus* is a fishing bat, and its stiff, bony calcar may be adapted to support the hind limb membrane as it skims the water surface.

19-2 STEFFENSON, M.M.*; WHITINGER, J.A.; MULLINS, A.N.; BROWN, C.A.; Adams State University, Tennessee Technological University; mmsteffenson@adams.edu

Anti-predator diving behavior of two species of wolf spiders (Lycosidae)

The Red Queen hypothesis embodies one of the most prevalent interactions among predator-prey species, in that these species are constantly evolving new adaptations in an ever-evolving 'arms race.' Here, we examined the anti-predator diving behavior of two species of wolf spiders, the predatory *Rabidosa santrita*, and its prey, *Pardosa valens*. When attacked, *P. valens* will dive under the water, creating an air bubble around its abdomen. However, *R. santrita* has also evolved the ability to perform this behavior. The objectives of this study were to determine if there are any differences in the ability of each species of wolf spider to resuscitate themselves after being submerged, as well as to determine any differences in submersion ability between males and females within species. Spiders of each species and gender were submerged in centrifuge tubes to force them to remain submerged. After one hour, spiders were placed dorsal side down in plastic containers. The time that spiders took to right themselves was recorded. Preliminary analysis indicates that female *P. valens* righted themselves significantly faster than males of the same species, as well as male and female *R. santrita*. All preserved spiders were photographed using digital microscopy to measure several variables that may have affected the size of their air bubbles: leg hair density, average angle of leg hairs, and abdomen hair density. Preliminary analysis indicates that *P. valens* have a significantly higher density and angle of leg hairs than *R. santrita*. Thus, *P. valens* may resuscitate faster after submersion due to the ability to trap a proportionally larger air supply.

12-6 STARK, A. Y.*; YANOVIK, S. P.; University of Louisville, University of Louisville ; alyssa.stark@louisville.edu

Move it or lose it: adhesion and running velocity on rough substrates in a tropical canopy ant

Biological adhesive systems like those of the gecko and marine mussel have fascinated scientists for centuries, however other biological adhesive systems have received less attention. In particular, insects, especially flightless insects like ants, are far less studied despite their reliance on adhesion to move and interact with their complex environment. Furthermore, arboreal ants such as *Cephalotes atratus*, rely on adhesion to exploit canopy resources 30m above ground, where a fall from this height can be costly. In this study we investigated how relevant environmental conditions, such as substrate roughness and structure, affect adhesive and locomotor performance of this dominant canopy-dwelling species. Using laboratory studies we found that shear adhesion, normal adhesion and running velocity are all significantly impacted by variation in substrate roughness. Interestingly, static adhesion (normal and shear) was higher on rough substrates but running velocity was consistent across a variety of substrate roughness sizes, except smooth glass. This suggests that clinging to substrates with variable surface roughness is more difficult than running across them. These results were further confirmed on natural substrates like leaves, bark and vines typically found in their native habitat, and in field-based studies on Barro Colorado Island, Panama. Collectively, the results of this study support the hypothesis that life in the forest canopy poses specific selection pressures for wingless arboreal insects like ants.

91-7 STEGMAN, C.E.*; SHEDLOCK, A.M.; College of Charleston; stegman@g.cofc.edu

The development of genetic markers to sex subadult loggerhead sea turtles (*Caretta caretta*) using AFLP technology

The emerging field of genomics is transforming our ability to investigate the integrative biology of marine organisms. One technique for rapidly and economically sampling the genome-wide level of polymorphisms in a species without *a priori* genome data is amplified fragment length polymorphism (AFLP). AFLP can generate large datasets of potentially polymorphic loci using relatively few primer combinations and restriction endonucleases. The objective of this study is to develop sex-linked markers using AFLP to sex subadult loggerhead individuals non-invasively and efficiently. Loggerhead turtles possess temperature-dependent sex determination (TSD), in which incubation temperatures during a thermosensitive period of development determine sex. The mechanism behind TSD is not fully understood, and it is unclear to what extent genetics is involved. Currently, the sex of an individual is determined through hormonal assay, laparoscopic gonadal examination, or necropsy. These techniques are time consuming and difficult to perform in the field, however, and the question of how to genotype the sex of turtles accurately and efficiently remains an important research focus. For this study, DNA isolated from blood samples collected in Florida Bay was processed with an AFLP starter kit. AFLP products were visualized using the Beckman Coulter CEQ 8000 genotyping system. Sixty four primer pair combinations were run on 32 samples with known sex (16 male; 16 female). An analysis of sex-specific amplification patterns based on normalized fluorescent signal strengths, amplification frequencies, and fixed polymorphisms screened among thousands of amplified loci will be discussed in relation to identifying primer pairs warranting expanded genomic investigation.

75-8 STEPHENSON, TQ*; DUBUC, TQ; SIMMONS, DS; MARTINDALE, MQ; Whitney Laboratory for Marine Bioscience; tbs5@ufl.edu

Evolution of the Hox Code: Insights from the Model Sea Anemone, *Nematostella vectensis*

Hox genes are a set of highly conserved homeobox transcription factors that pattern the anterior posterior axis in bilaterally symmetrical animals. This conserved developmental function is known as the "Hox code" and is important for axial patterning in all bilaterian lineages. Hox genes are also found in cnidarians, the sister group to the bilateria that includes corals, anemones and jellyfish. This distinction has made cnidarian model systems crucially important for the study of Hox gene evolution. To define the developmental function of the cnidarian Hox cluster, we have performed CRISPR Cas9 mediated knockouts of individual Hox genes in the model sea anemone, *Nematostella vectensis*. Functional analysis of F0 mutants indicates that Cnidarian Hox genes are required for the formation of both the primary and directive axes during early development. Three Hox genes, Anthox1, Anthox6 and Anthox6a, appear to be important for the formation of the primary axis and are asymmetrically expressed along this axis at early developmental stages. To investigate their functional role at this stage we are assessing changes in spatial and temporal gene expression of important asymmetrically expressed markers in knockout animals. Preliminary data suggests that Hox gene function along the primary axis is dependent on novel regulatory relationships with components of the Wnt signaling pathway, which has been proposed as the primary axial patterning mechanism in Cnidarians. Further, we have adopted a forward approach (CEL-SEQ) for identifying downstream targets of Cnidarian Hox genes at important developmental stages. We are working to develop a detailed understanding of the Hox gene repertoire in Cnidarians and hope that this study will provide new insights into Hox gene evolution and the origins of the Hox code.

128-3 STEWART, J.R.*; ECAY, T.W.; WIESSNER, G.; HEULIN, B.; East TN State Univ., Station Biologique de Paimpont; stewartjr@etsu.edu

Embryos of the Viviparous Lizard, *Zootoca vivipara*, Maintain Calcium Homeostasis in the Absence of Exogenous Calcium and Respond to Calcium Availability

Calcium nutrition of embryos of the European common lizard is highly dependent on transport across the chorioallantoic placenta and embryonic uptake of calcium is correlated with expression of the calcium transporting protein, calbindin-D28K, in the chorioallantoic membrane. Maintenance of calcium homeostasis is a critical physiological property of intrauterine gestation. We manipulated calcium in incubation media of embryos removed from females to test two hypotheses: 1) embryos cannot conserve calcium in the absence of exogenous calcium, and 2) low calcium availability promotes expression of calbindin-D28K in the chorioallantoic membrane. Embryos were removed from six females prior to the phase of greatest embryonic growth and sampled immediately or incubated for 11 days in either calcium-free saline or saline + 2 mM calcium. We monitored calcium concentration in incubation media and analyzed calcium content of egg compartments. For embryos incubated in calcium-free saline, calcium flux between the incubation media and eggs remained low and calcium in eggs at the termination of the experiment did not differ from that of eggs in the initial sample. Embryonic calcium content of eggs incubated in media with 2 mM calcium was significantly higher than embryos from the calcium-free saline treatment and expression of calbindin-D28K was higher in the chorioallantoic membrane of these embryos. Our results suggest embryos have: 1) the capacity to protect against calcium loss in the absence of exogenous calcium and, 2) a mechanism for detection of exogenous calcium that initiates transcription of intracellular calcium transporting proteins in the chorioallantoic membrane.

109-5 STERNBERG, DR*; NELSON, HR; EDMUNDS, PJ; California State University, Northridge; sternberg.d.r@gmail.com
Asexual budding and aggregated spatial distribution of fungiid corals from disturbed reefs in Moorea, French Polynesia

In Moorea, French Polynesia, fungiid corals are important members of coral communities where their solitary and free-living life histories, combined with sexual and asexual reproduction, makes them interesting organisms to evaluate the processes driving coral community dynamics. We exploited this potential in Moorea following two major disturbances -- Cyclone Oli and an *Acanthaster* outbreak - that greatly reduced coral cover in multiple habitats by 2010. In April 2015, surveys of fringing reefs along the north shore revealed many fungiids that appeared to be dead with no visible tissue, and the greater size of "dead" versus live fungiids demonstrated that populations had not recovered from recent disturbances. However, fungiid recruits were abundant (0.5 ± 0.2 corals m⁻²), and accounted for 53% of all living fungiids. Surveys of growth locations of fungiid recruits revealed that 92% (n = 391) were attached to skeletons of "dead" fungiids, with which their densities were positively correlated. Given the well-known capacity of fungiids to regrow from relic tissue following catastrophic damage, it is likely that most fungiid recruits in Moorea were asexual propagules derived from regeneration of relic tissue. For these corals, asexual proliferation from relic tissue may be an important means of population recovery following disturbances that leave many fungiids apparently "dead".

8-2 STEWART, E.C.*; GREIVES, T.J.; North Dakota State Univ.; emily.c.stewart@ndsu.edu

Dominant black-capped chickadees maintain rank within winter social groups when faced with an immune challenge

In social species, groups of individuals that live, forage, or interact with each other often form a linear dominance hierarchy. Dominant individuals are thought to have greater access to resources and the ability to obtain higher-quality territories or mates, but maintaining status comes with an energetic cost. This cost could produce a trade-off between investment into behaviors that maintain dominance and other systems, such as innate immunity. A strong innate immune system enables individuals to resist infections and survive to reproduce but may be costly to maintain. The links between dominance rank, health and fitness have been studied extensively in systems where dominance is displayed year-round and across generations, but rarely in species that live in temporary or seasonal social groups. Many songbirds, such as the black-capped chickadee (*Poecile atricapillus*) form flocks during the winter then divide into pairs for breeding during the spring. Our study used chickadees to determine whether dominance status in the winter flock is related to innate immune function across seasons, and whether a challenge to the immune system affects social status. In captive flocks, top-ranked individuals were given an immune challenge in the form of a lipopolysaccharide (LPS) injection, and dominance behavior was observed to determine if status was altered. LPS injected individuals lost a significant amount of weight and increased feeding rate when compared to control injected birds, indicating an energetic cost, but did not exhibit a change in behavior or loss of rank. In addition, a negative trend was observed between dominance behavior and innate immune function in captive and wild populations.

2-7 STEWART, W.J.*; AKANYETI, O; THEOBALD, J; LIAO, J; Univ. of Florida, Whitney Laboratory, Florida International University; wstewart@whitney.ufl.edu

The response of the zebrafish lateral line to white noise stimulation
Assessing how sensory systems respond to complex stimuli is important to understanding how animals initiate and modify diverse behaviors. In the flow-sensitive lateral line system of fishes, clusters of hair cells called neuromasts lie on top of the skin and deflect to the slightest flow. Previous work has measured the responses of lateral line afferent neurons to simple sine wave deflections of individual neuromasts. However, natural stimuli are more complex and can elicit non-linear responses. To address this, we measured the responses of afferent neurons to a mechanical white noise stimulus applied to a single neuromast. This approach deflects the neuromast with different displacements, velocities, and accelerations randomly through time. Using 4-6 day post fertilization wild-type zebrafish larvae (n = 20), we simultaneously stimulated a single neuromast, video-tracked its deflection, and made extracellular recordings of the connected afferent neuron. Preliminary results show that the elicited afferent spikes are reproducible. When a neuromast was stimulated with a 10 second train of white noise, we found that 75% of the spiking pattern from the afferent neuron was reproduced across all repeated trials (n = 19). The timing of these spikes was reliable, exhibiting a mean jitter of less than 1 ms (0.6 ± 0.1 ms = mean \pm 1 SD). When we compared the motion of the neuromast that immediately preceded each spike, we found considerable variation, indicating that the time history of deflection and spiking are critical to afferent firing. On-going analyses focus on identifying the components of the stimulus that are most important to the afferent neuron.

39-3 STILLMAN, JH*; FAY, S; SWINEY, K; FOY, R; SF State Univ. and Univ. California, Berkeley, Invitae, Alaska Fisheries Science Center, Alaska Fisheries Science Center; stillmaj@sfsu.edu
Transcriptomic response of juvenile red king crab, *Paralithodes camtschaticus*, to the interactive effects of ocean acidification and warming

Impacts of elevated carbon dioxide on marine ecosystems depend on physiological responses to consequential decreased pH and increased temperature. Responses to these environmental factors vary among species and life stages, and interactive effects can be significant. To study effects of decreased pH and increased temperature on juvenile red king crab (RKC, *Paralithodes camtschaticus*) we exposed individuals to three levels of temperature: 11°C (ambient), 13°C, and 14°C, crossed with three levels of pH: 8.0, 7.8 and 7.5, for a total of nine treatments. To better understand the effect of these environmental changes at the level of genome regulation, we analyzed total RNA of whole crabs using Illumina-based RNA-seq whole-transcriptome sequencing. We assembled a RKC transcriptome using Trinity, annotated the transcriptome using Trinotate, and estimated expression levels using bowtie2, samtools and eXpress. Differentially expressed genes were identified using EdgeR. Genes were clustered by expression patterns. Interactive effects were determined by comparing sets of differentially expressed genes using three statistical models to examine the effect of temperature, the effect of pH, and the interaction between temperature and pH in EdgeR. The largest set of differentially expressed genes encoded proteins involved in regulation of extracellular and cuticular structures, including chitin-binding and calcification related proteins. Temperature had a larger effect on gene expression than pH, though there were also interactive effects. Our results indicate that growth and molt cycle regulation may be altered by increased temperature and reduced pH, and identify gene product targets for further study of these processes.

75-7 STEWART, TA*; AIELLO, BR; HO, RK; HALE, ME; Yale University, University of Chicago; tom.stewart@yale.edu

The adipose fin of *Corydoras aeneus* develops from the larval fin fold and is mechanosensitive

How do new fins evolve? A comprehensive answer must integrate multiple kinds of explanations: how does development evolve to generate these new body parts, and what adaptive functions might mediate their evolution? We studied adipose fins, appendages that have evolved repeatedly in teleost fishes and that are positioned posterior to the dorsal fin, to inform how new median fins originate. We demonstrate that the adipose fin of the catfish *Corydoras aeneus* develops by the retention and elaboration of the larval fin fold and that this fin is mechanosensitive. Immunohistochemistry reveals extensive reorganization of nerves in a portion of the larval fin fold that will become the adipose fin membrane, and neurophysiological recordings of these nerves demonstrate that the magnitude to which the fin is displaced laterally is encoded by fin afferents. These data demonstrate that the larval fin fold can act not just as scaffolding for the development of differentiated median fins, but also as a substantive source of material contribution to a new fin, which then can be modified over ontogeny and phylogeny to generate a structurally and functionally complex appendage. This is consistent with outstanding hypotheses for how the earliest dorsal and anal fins originated, by the retention and transformation of a median fin fold. Mechanosensitivity of the adipose fin of *C. aeneus* is consistent with the hypothesis of their function as pre-caudal flow sensors, raising questions about the practice of adipose fin clipping as a means of tagging hatchery-raised fishes and of the ecological consequences of adipose fin diversity.

113-2 STINSON, C.M.*; DEBAN, S.M.; University of South Florida, Tampa; cstinson@mail.usf.edu

Evidence of a high-power feeding mechanism in salamandrid salamanders

Differences in morphology between closely related species are known to impact function and consequently affect organismal performance. The diverse hyobranchial apparatus morphologies of salamanders enable varying degrees of tongue projection performance during terrestrial prey capture. Many plethodontid salamanders possess a specialized morphology and employ elastic mechanisms to achieve high-power tongue projection. The salamandrid salamanders *Salamandra salamandra* and *Chioglossa lusitanica* are also specialized terrestrial feeders. *Chioglossa*, however, possesses an extreme hyobranchial morphology similar to plethodontids, suggesting that it may approach the tongue projection performance of plethodontids. High-speed imaging (3000 Hz), in conjunction with kinematic and inverse dynamic analyses, reveals that feeding performance is increased in *Chioglossa* relative to *Salamandra*. Relative maximum tongue-projection distance is 1.4 times greater in *Chioglossa*, and maximum tongue-projection velocity, acceleration, and muscle-specific power are 10, 40, and 400 times greater, respectively. The high muscle-mass-specific power of *Chioglossa* is comparable to that estimated in plethodontid salamanders with elastic projection. These results reveal an elastic tongue-projection mechanism in *Chioglossa* that likely evolved independently of that of plethodontids.

47-6 STOCKING, J.B.*; REIDENBACH, M.A.; University of Virginia; jbs4yq@virginia.edu

Coral surface rugosity effects on turbulent boundary layer hydrodynamics

To investigate the interaction between flow and coral morphology, laboratory measurements of boundary layer hydrodynamics were obtained over 3-D printed artificial models of Scleractinian corals using a recirculating water flume. Measurements were collected using particle image velocimetry (PIV), and two-dimensional velocity fields were calculated upstream, above, and downstream of four idealized coral models. The models represented a range of surface rugosity values, from a smooth hemisphere to a highly convoluted natural coral skeleton, and flow conditions ranged from 2.5 - 15 cm/s. Estimates of Reynolds stress, turbulent kinetic energy (TKE), and vorticity were derived from the velocity measurements, and conditional analyses determined the degree of anisotropy in the flow. Results found that coral surface rugosity delays flow separation on the downstream edge of the models, allowing for a greater surface area to be exposed to turbulent mixing and mass exchange processes. Larger rugosity values also enhanced TKE values directly above and downstream of the corals, which enhanced rates of turbulent production and dissipation. The measurements suggest that increased rugosity in coral morphology can accelerate turbulent eddy formation and enhance scalar mass mixing. Increases in turbulent mixing, along with greater surface area contact with the turbulent boundary layer, should serve to promote nutrient and dissolved chemical flux at the coral-water interface and benefit coral health.

88-7 STOFFER, B.*; UETZ, GW; University of Cincinnati; stoffebm@mail.uc.edu

The effects of octopamine and serotonin on male courtship levels of a wolf spider

While individual variation in male courtship vigor exists, the underlying mechanisms often remain unknown. Biogenic amines, including octopamine (OA) and serotonin (5-HT) act as neurotransmitters, neuromodulators, or neurohormones and may regulate courtship. Recently, octopamine was found to be necessary for certain male courtship behaviors in *Drosophila*. However, the effects of OA and 5-HT (sometimes found to have opposite effects) on male courtship behaviors in other invertebrate taxa remain largely unexplored. Male wolf spiders, *Schizocosa ocreata*, use visual displays (leg tapping, body bounce, leg arch) in their courtship and have been shown to demonstrate behavioral plasticity in courtship levels in a variety of behavioral contexts. To examine the effects of OA and 5-HT on male courtship, we used topical application (via dimethyl sulfoxide) to manipulate male OA and 5-HT levels at different concentrations (2mg/uL and 10mg/uL). In general, males treated with OA had significantly reduced levels of courtship in comparison to control groups, demonstrating a decreased number of courtship bouts, a decreased sum of courtship behaviors, and a lower courtship rate. Results using topical application of 5-HT and epinastine (an antagonist of OA) will also be discussed. Further, preliminary data will be discussed concerning the effects of OA and 5-HT on mating success.

24-4 STOHR, A.*; DONLEY, J; AALBERS, S; SYME, D; SEPULVEDA, C; BERNAL, D; Univ. of Massachusetts, Dartmouth, MiraCosta College, Pflieger Institute of Environmental Research, Univ. of Calgary, Pflieger Institute of Environmental Research; astoehr@umassd.edu

Thermal sensitivity of red muscle in a deep-diving teleost and shark
Despite disparate phylogenetic histories, swordfish (*Xiphias gladius*) and bigeye thresher sharks (*Alopias superciliosus*) share a unique, pelagic ecology characterized by routine, long duration dives from surface waters (18-20°C) to well beneath the thermocline (5-10°C). Interestingly, swordfish red muscle morphology is comparable, albeit simplistic, to that of regionally endothermic fishes, suggesting red muscle operating temperatures are somewhat elevated above the environment, whilst that of bigeye thresher sharks experience dive-driven fluctuations. The thermal effects on contractile function of red, aerobic muscle from both species were investigated using the work-loop technique across naturally occurring temperatures (8, 16, 24°C). Swordfish, like regionally endothermic fishes, seem more responsive to temperature increases, with an enhanced ability to augment swimming speed at warmer temperatures relative to bigeye thresher sharks. Specifically, swordfish acquired faster cycle frequencies, namely 1-2Hz, at 16 and 24°C, while bigeye thresher sharks were unable to augment frequency above 0.5 Hz, even at 24°C. Regional endothermy could thus be advantageous to swordfish by allowing faster tail-beat frequencies during foraging in surface waters and initial dive periods. The increased thermal sensitivity of swordfish relative to bigeye thresher sharks, coupled with previous findings for endothermic fishes suggests a relationship between red muscle morphology, thermal strategy (e.g. endothermy versus ectothermy), and thermal sensitivity with more complicated endothermic morphologies exhibiting greater dependence on heat conservation for locomotion.

14-5 STOVER, KK.*; BRAINERD, EL; ROBERTS, TJ; Brown University; kristin_stover@brown.edu

Muscle mechanical performance in wild and domestic turkeys

The poultry industry has bred domestic turkeys to have much larger muscles than wild turkeys, but it is unclear if this intense artificial selection for greater muscle mass affects other muscle properties. Our recent work on the differences in force production during locomotion in the two strains has revealed low maximum speeds and low ground reaction forces in the domestic broad-breasted white strain. One possible explanation for these findings is that the hypertrophied muscles are somehow structurally or mechanically compromised. This study's goal was to assess the capacity for muscle force production in a domestic strain. To test for possible effects of muscle-force capacity, an in situ preparation of the lateral gastrocnemius (LG) muscle in the domestic turkeys (n=6) allowed comparison with past studies on wild turkeys. The domestic LG muscle produced 21% less force than wild strain (P=0.048), (mean muscle force of 31.8 N/cm² versus wild mean force of 40.3 N/cm²). However, the maximum velocity was high in domestic turkeys at 21.5 L/s, compared to 13.0 L/s in the wilds. The average peak instantaneous power was similar to the wild turkeys, at 362.1 W/kg. The architectural gear ratio (AGR) did not change with increased muscle force in the domestic turkeys (P=0.80), indicating there may be differences in intramuscular connective tissue. AGR remains high, which may explain the higher velocity of whole muscle and lower force we observe. These results suggest that artificial selection for increased muscle mass results in small differences in the contractile performance of domestic turkeys, but this alone does not explain the differences in ground reaction force. Nevertheless, however minor, these changes could exacerbate locomotor issues in commercial turkeys that already have many leg health issues.

84-2 STOWERS, AK*; LENTINK, D; Stanford University; astowers@stanford.edu

How the avian musculoskeletal system enables wing morphing

Birds are able to maneuver their wings into an impressive array of shapes to fly through a variety of environments and accommodate different flight modes. Their articulated wings have many similarities to human arms with corresponding elbow and wrist joints. These joints allow both flexion and extension as well as more subtle movements. This motion is caused by interaction of the humerus, radius, ulna and carpometacarpus and the smaller wrist bones with each other and the surrounding tendons and muscle tissue. We examine how the skeletal architecture causes these changes in wing shape by reconstructing the individual bone positions and joint axis of motions in a racing pigeon wing during several representative posture transitions. We show how the wrist and elbow joints compare to ideal pin and ball-and-socket joints by analyzing how the axes of each change during wing motion, as well as how these axes compare to the bone joint surfaces. We also examine coupling of different bone motions and how automating mechanisms, closed kinematic chains, and shared radioulnar motion effect the overall wing morphing mechanism.

23-4 STRADER, M E*; DAVIES, S W; KOOL, J T; MATZ, M V; The University of Texas at Austin, The University of North Carolina at Chapel Hill, Geoscience Australia; stradermarie@gmail.com

The role of larval traits on dispersal patterns of two dominant reef-building coral species from remote Gulf of Mexico reefs

Remote locations along a species' range edge have the potential to influence connectivity across large geographical areas and may serve as refugia from the effects of climate change. Here, we modeled source-sink dynamics for reef-building corals from one of the most isolated and high-latitude Caribbean coral reefs, the Flower Garden Banks (FGB) in the Gulf of Mexico. We experimentally determined the time courses of competency and mortality for two dominant reef-building corals (*Pseudodiploria strigosa* and *Orbicella sp.*). While mortality rates were nearly identical in these two species, their competency timing differed dramatically: *P. strigosa* larvae are capable of metamorphosis within 2.5 days of fertilization. In contrast, *Orbicella* larvae did not become competent until > 20 days post-fertilization. These biological measurements were used to parameterize a biophysical dispersal model to predict yearly particle transport between 2009 and 2012. Simulations of particle dispersal revealed that species with short (3-20 day) pelagic larval durations (PLDs), such as *P. strigosa*, are isolated from the rest of the Caribbean and self-recruitment is highly variable across years. Notably, species with long PLDs (20-120 days) have similar year-average probabilities of self-recruitment to the FGB but are also capable of exporting larvae to distant reefs in Florida, the southern Gulf of Mexico, Cuba and the Bahamas. Our results highlight the self-sustaining potential of FGB coral populations and the ability for FGB species with long PLDs, including endangered *Orbicella* species, to act as a source for adjacent Caribbean populations.

23-5 STRATHMANN, RR*; PECHENIK, JA; University of Washington, Tufts University; rrstrath@uw.edu

Transition from Larval to Juvenile Ciliary Feeding Mechanisms of a Slipper Limpet

Slipper limpets use different ciliary feeding mechanisms as a larva and as an adult. Before metamorphosis larvae of *Crepidula fornicata* developed the ctenidial (gill) filaments that produce the feeding current and the radula that aids ingestion in the postlarval feeding mechanism, but ctenidial feeding did not begin either in the larval stage or immediately after loss of the larval feeding apparatus (velum) at metamorphosis. Delay of settlement in the absence of a stimulus resulted in earlier postmetamorphic feeding. When younger larvae were induced to metamorphose, the juveniles began ctenidial feeding in about a day after metamorphosis. When older larvae were induced to metamorphose, juveniles began ctenidial feeding in a few hours after metamorphosis. Ctenidial feeding was recorded for juveniles attached to a coverglass, ventral side upward. In their first feeding, juveniles formed a food cord from phytoplankton caught on mucous strands, transported it to the mouth, and grasped it with the radula. Ctenidial feeding by juveniles resembled feeding by adults, except that there was no distinct food canal in the path from ctenidial filaments to the mouth. The juveniles became sedentary soon after metamorphosis and were not observed to feed by scraping the substratum with the radula, in contrast to the first feeding by juveniles of another *Crepidula* species, observed by Montiel et al. (2005).

66-5 STUBBS, AL.*; STUBBS, CW; Univ. of California Berkeley, Harvard University; astubbs@berkeley.edu

Spectral Discrimination in "Color Blind" Cephalopods via Chromatic Aberration and Pupil Shape

The only known or proposed mechanisms for color vision require either spectrally distinct photoreceptors or spectral filtering of a single photoreceptor type. Virtually all cephalopods (octopus, squid, and cuttlefish) have a single unfiltered photoreceptor type and lack the ability to determine color by comparing photon intensity across multiple spectral channels. Nevertheless, cephalopods dramatically change color both to produce chromatically-matched camouflage and to signal conspecifics. This presents a paradox - an apparent ability to determine color in organisms with a monochromatic visual system - that has been a long-standing puzzle. We demonstrate how chromatic aberration (focus variation with wavelength) can be exploited, especially through non-axial pupils, to obtain spectral information. This has potential applicability in any organisms with limited photoreceptor complements, such as spiders and dolphins.

117-3 SUMNER, BJ*; THOMPSON, NE; DEMES, B; LARSON, SG; STERN, JT; Stony Brook University; bonnie.sumner@stonybrook.edu

Arm swing in bipedally walking chimpanzees

Human walking is characterized by coordinated out-of-phase movement of the arms and legs. Arm movements counteract angular momentum of the swinging legs about a vertical axis, conserving whole body momentum. Arm swing is likely produced passively by the momentum of the legs, but with active tuning by shoulder muscles. The aim of this study was to determine if the fundamental mechanisms of arm swing extends to bipedal non-human primates. We measured electromyographic activity patterns of the anterior deltoid, posterior deltoid, trapezius, triceps (long head), biceps (short head), pectoralis major, and latissimus dorsi muscles, and quantified the 3D kinematics of arm movement in two chimpanzee subjects during bipedal walking. Interlimb coordination was the same in chimpanzees as in humans, with the upper arm being extended at the ipsilateral heelstrike and flexed at the contralateral heelstrike. We found consistent phasic muscle activity occurring at ipsilateral heelstrike, in the latissimus dorsi for both subjects, and in the long head of triceps for one subject. We also found almost constant low-level activity for the posterior deltoid in both subjects. Therefore like humans forward swing in chimpanzees is likely passive while the backward swing may in part be produced by the latissimus dorsi. Most human studies have also observed extensor activity, but a few report additional low-level activity in anterior deltoid and biceps (< 3% maximum contraction). Humeral movement in the sagittal plane had 16-30 degrees amplitude with significant abduction and humeral rotation. This range overlaps with 27 degrees mean amplitude reported for humans in the sagittal plane. These results suggest that the basic pattern, and potentially function, of arm swing extends to facultatively bipedal chimpanzees. Funded by NSF grant BCS-0935321.

SI-9 SUVER, M.P.*; DICKINSON, M.H.; NYU Medical School, California Institute of Technology; suver.marie@gmail.com

Sensory integration by descending interneurons in the flying fruit fly.

A flying fly relies on many senses, including vision, olfaction, and mechanosensation, to navigate through the world and locate an attractive food source. How are these sensory signals integrated in the central brain and relayed to the motor system to guide behavior? Integration of multiple sensory signals can be performed by descending interneurons, which relay this information to motor systems via circuits in the thoracic ganglion. We have identified a group of three descending interneurons in the fruit fly that integrate information from discrete sets of visual interneurons. Each exhibits a distinct preference for optic flow corresponding to self-motion. We measured the tuning properties of the presynaptic visual interneurons, and found that a simple linear model based on these inputs can explain much of the response of the descending interneurons. Projection patterns of the three descending interneurons in the thoracic ganglion suggest that they deliver self-motion information to circuits that control movement of the head, wings, and abdomen. We monitored the output of these motor systems during tethered flight and found evidence that suggests that these three neurons are involved in distinct motor programs. This circuit may play a crucial role in sensory-motor transformations used to guide stable flight, and provides insight into strategies employed by other flying insects.

35-3 SUTHERLAND, KR*; GEMMELL, BJ; COLIN, SP; COSTELLO, JH; University of Oregon, University of South Florida, Roger Williams University, Providence College; ksuth@uoregon.edu
Predation by the hydromedusa *Obelia*: it's a sticky problem
Obelia sp. are cnidarian hydromedusae with a cosmopolitan distribution but we currently lack a mechanistic basis of their feeding behavior. The small size of *Obelia* (Bell diameter ~1 mm, tentacle width ~0.05 mm) suggests that feeding occurs in a viscous regime characterized by thick boundary layers. Swimming kinematics from high speed videography confirmed that swimming was a low Re number process ($Re < 50$) and showed that maximum tentacle velocities occurred at the tentacle tips midway through a bell contraction. Flow visualizations from Particle Image Velocimetry demonstrated that fluid motion between the tentacles was limited and that velocity was highest at the tentacle tips, suggesting a thinning of the boundary layer. Feeding observations with a natural prey assemblage supported swimming kinematic and fluid motion measurements: the majority of prey were captured at the tentacle tips at the time when tentacle velocities were highest. Furthermore, nematocyst counts using differential interference contrast microscopy showed the highest numbers of nematocysts at the tentacle tips. Taken together, the body motion, fluid manipulation and nematocyst distribution of *Obelia* explain how these important predators are able to shed viscous boundary layers to effectively capture prey.

3-1 SWANSON, DL*; KING, MO; CULVER, W; ZHANG, Y; Univ South Dakota, Humboldt St Univ; david.swanson@usd.edu

Within-winter Flexibility in Muscle Mass, Myostatin and Cellular Metabolic Intensity in Passerine Birds

Metabolic rates are flexible traits that vary seasonally, but also among and within winters, with higher metabolic rates during colder periods. Seasonal variation in summit metabolic rates (M_{sum} = maximum thermoregulatory metabolic rates) in birds is consistently correlated with changes in pectoralis muscle and heart masses and sometimes with variation in cellular metabolic intensity. To examine mechanisms of within-winter M_{sum} variation, we examined the effects of short (ST, 0-7 d), medium (MT, 14-30 d) and long-term (30-yr means) temperature variables on pectoralis and heart masses, expression of myostatin and its proteinase activators TLL-1 and TLL-2, and activities of citrate synthase (CS; index of cellular metabolic intensity) in pectoralis and heart of house sparrows (*Passer domesticus*) and dark-eyed juncos (*Junco hyemalis*). For both species, pectoralis mass residuals were positively correlated with ST temperature variables, suggesting that cold resulted in increased catabolism of pectoralis muscle. Heart mass varied little with temperature in either species. Pectoralis mRNA and protein expression of the myostatin system was weakly correlated with ST and MT temperature variables for both species, consistent with the weak trends of ST temperature variables on muscle mass for both species. Pectoralis and heart CS activities were inconsistently correlated with temperature variables for both species, suggesting weak short-term regulation of cellular metabolic intensity for both tissues. Thus, neither muscle nor heart masses, their regulation by myostatin, nor cellular metabolic intensity varied consistently with winter temperature, suggesting that other factors regulate within-winter metabolic variation in these birds.

41-7 SWITZER, C.M.*; HOGENDOORN, K.; RAVI, S.; COMBES, S.A.; Harvard Univ., Univ. of Adelaide, RMIT Univ.; callin.switzer@gmail.com

Shakers and head bangers: Differences in sonication behavior between Australian blue banded bees and North American bumblebees

Many bees collect pollen via sonication, or buzz-pollination, during which they grasp the anthers of a flower and vibrate at high frequencies to remove pollen. Understanding the behavioral and mechanistic requirements of buzz-pollination may provide insight into the evolution and ecology of this plant-bee mutualism. Here we compare buzz-pollination in two bees that fill similar niches on different continents - in Australia, *Amegilla murrayensis* (blue banded bee), and in North America, *Bombus impatiens* (bumblebee). We compare buzzes of both species collecting pollen from flowers of *Solanum lycopersicum* (cherry tomatoes). We hypothesized that both bee species would employ similar behaviors to release pollen - grasping the anthers with the mandibles and vibrating while curling the ventral side of their body around the anther pores. We also hypothesized that buzz frequency, buzz length, and the time spent on a single flower would differ between the bee species, due to differences in body size. We found that the behavior of *A. murrayensis* is unique from previously reported buzz-pollination mechanisms. Instead of grasping the anthers with its mandibles and shaking them as most bees do, *A. murrayensis* taps the anthers with the ventral portion of its head at high frequencies to release pollen. We found that *A. murrayensis* buzzes at higher frequencies during pollination on *S. lycopersicum* flowers and flaps its wings at higher frequencies during flight, supporting our hypothesis. We found no difference in the length of a single buzz between the two bee species, but *A. murrayensis* visited individual flowers for a shorter period of time than *B. impatiens*, as *B. impatiens* generally buzzed the flower several times before departing.

97-15 TAFT, NK*; LAHTI, DC; University of Wisconsin-Parkside, Queens College, City University of New York; tafi@uwp.edu

Is the color of purple piranhas only skin deep?

For hobbyists, fish coloration is an issue of particular importance, and can affect the value of individuals in the pet trade. Piranhas of the genus *Serrasalmus* are popular aquarium species among experienced hobbyists, and they exhibit a variety of coloration patterns from silver-white to gold to the very desirable purple-black. This purple coloration can vary within and among individuals, and may deepen with age. To date, it is unclear whether the source of the color is in the skin itself, or in the scales. Here, we investigate the site of purple color in 11 individual *Serrasalmus rhombeus* that vary in the intensity of the purple color. Deceased and frozen individuals were obtained from the commercial pet trade. To examine the source of the purple color, we measured the reflectance of each fish using an Ocean Optics USB2000 spectrometer connected to a PX-2 pulsed xenon light. We measured at four separate, standardized "patches" on the left lateral surface of each fish, first with both skin and scales intact, and then with scales carefully removed. Three of these locations were chosen because of their strong purple coloration and a fourth, ventral patch was chosen because it appeared to lack purple coloration. Scales were tested individually from only one of the four purple patches in each individual. We assessed reflectance at 5-nm intervals over the wavelength range of 300-700 nm using a 400- μ m reflection probe (Ocean Optics R400-7). We found that almost all individuals exhibited reflectance that was indicative of a "true" purple color in all three treatments, scales and skin, skin only, and scales only, as well as a significant UV component. This is, to our knowledge, the first experimental investigation of color in piranhas, as well as the first description of the presence of UV coloration in this group.

50-5 TABOADA, S.; LEIVA, C. ; BAS, M.; SCHULT, N.; MCHUGH, D. *; The Natural History Museum, London, SW7 5BD, UK and Dept. of Animal Biology & Biodiversity Research Institute, Univ. de Barcelona, Spain, Dept. of Animal Biology & Biodiversity Research Institute, Univ. de Barcelona, Spain, Dept. of Biology, Colgate Univ., Hamilton, NY 13346, USA; dmchugh@colgate.edu

Colonization patterns of two species of dorvilleid polychaetes of the genus Ophryotrocha on mammal bones in the Mediterranean.

Mammal carcasses represent extraordinary marine benthic habitats that harbor diverse communities over the course of their depletion and decay. One invertebrate group that features prominently during the opportunistic-enriched stage of decay is the dorvilleid polychaete genus *Ophryotrocha*. Species of this genus have been recorded from whale-fall experiments in wide geographic and bathymetric ranges. They are small, opportunistic worms that have direct development and feed on microbial mats on decaying bones. We studied the colonization patterns of 2 species of *Ophryotrocha* on mammal bones in the Mediterranean. We deployed Minke whale bones, cow bones, and pig bones at ~20 m on 3 different background substrates. Bones were deployed for a year, with samples collected at 3-month intervals. *Ophryotrocha alborana* and *O. puerilis* comprised the vast majority of worms collected over the course of the study. Analyses of cytochrome oxidase I (COI) sequences for *O. alborana* revealed unique haplotypes for worms from different bones and trimester samples, whereas COI haplotypes were shared among the different bones and trimester samples for *O. puerilis*. Size frequency analyses of the worms suggest that *O. alborana* colonized the bones through 3 separate recruitment events, while continuous recruitment is inferred for *O. puerilis*. Our study suggests that these different species of *Ophryotrocha* have different patterns of bone colonization despite sharing similar life histories.

76-2 TALBOT, WA*; WOLF, BO; University of New Mexico; wtalbot@unm.edu

Thermoregulation in the heat: Sonoran Desert Nightjars

In the Sonoran desert, where current summer surface temperatures can reach 70°C and air temperatures can reach 50°C, it is imperative for birds to defend body temperatures below lethal levels. Cooling occurs primarily by evaporative water loss. Lesser Nighthawks (*Chordeiles acutipennis*) and Common Poorwills (*Phalaenoptilus nuttallii*) are exposed to these ambient temperature extremes, particularly in their nesting behavior. An understanding of the thermoregulatory capacity of these two nightjars may offer some prediction of their ability to adapt to changes in climate. Field studies were performed to assess rates of heat dissipation and maximum thermal tolerances using flow-through respirometry. As birds were exposed to increasing ambient temperatures, metabolic rates, body temperature, and rates of evaporative water loss were measured in real-time. Compared to desert passerines, these caprimulgids are able to tolerate significantly higher ambient temperatures and are able to dissipate heat with greater efficiency. This appears to be due, at least in part, to the mechanism of gular flutter, which allows evaporative heat loss with little increase in energy expenditure.

10-2 TAN, M*; ARMBRUSTER, JW; Auburn University;
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The All Cypriniformes Tree of Life: A Resource for Comparative Studies Applied to Diversification and Evolution of Body Size
Understanding patterns and processes underlying diversity is one of the core motivations of evolutionary biology. The order Cypriniformes is the most diverse monophyletic order of vertebrates with over 4000 species, and presents a potential model clade to study evolution. However, studying the origins of this diversity in relation to its morphological evolution and biogeography depends on a robust phylogenetic hypothesis to provide a comparative framework. Many recent studies have collected sequence data to infer phylogenetic relationships among cypriniform taxa, including phylogenomic-scale data. This has resulted in approximately 2000 species with relatively few sequenced loci, as well as relatively few taxa with hundreds of sequenced loci. We integrate phylogenetic-scale and phylogenomic-scale data to infer a time-calibrated phylogeny for the order Cypriniformes. We demonstrate the utility of this tree for comparative phylogenetic analysis by applying this phylogeny to studying diversification and body size evolution across Cypriniformes.

S11-3 TARRANT, AM*; BAUMGARTNER, MF; LYSIAK, NSJ; HANSEN, BH; ALTIN, D; NORDTUG, T; OLSEN, AJ; Woods Hole Oceanographic Inst., Boston Univ., SINTEF, Biotrix, Norwegian Univ. Sci. Tech.; atarrant@whoi.edu

Transcriptomics of diapause and lipid accumulation in the marine copepod *Calanus finmarchicus*

The copepod *Calanus finmarchicus*, an important primary consumer in North Atlantic ecosystems, has a flexible life history in which individuals may either delay maturation during the last juvenile stage (C5) and enter into diapause or skip diapause and molt directly into adults. Researchers are currently unable to induce *C. finmarchicus* diapause in the lab. We have combined morphological and transcriptomic approaches to understand the physiological changes that occur during progression of *C. finmarchicus* along each of these two paths by sampling lab-reared and field populations in which individuals molt directly into adults and enter diapause, respectively. 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 in the lab-reared population. We found that progression through the stage was associated with substantial accumulation of lipids within the oil sac and changes in many genes necessary for the synthesis of storage lipids. By comparing lab-reared and field-collected copepods, we have compiled a list of candidate genes that are differentially expressed prior to entry into diapause. Homologs of many of these genes, including heat shock proteins, phosphoenolpyruvate carboxylase kinase, and RAS-related protein Rab-10, are associated with diapause preparation in other animals. These candidate genes may serve as biomarkers to distinguish *C. finmarchicus* that are preparing to initiate or skip diapause. Robust markers will enable laboratory and field studies to understand the factors that influence the decision to enter diapause.

6-2 TANNER, RL*; OBAZA, AK; GINSBURG, DW; Univ. of Southern California, NOAA Fisheries; rtanner@berkeley.edu
Secondary Productivity and Habitat Composition of Eelgrass Beds in a Southern California Marine Protected Area

Modeling annual biomass production in fish populations is crucial for resource management and conservation. For example, improved estimates of secondary productivity in juvenile and adult cohorts are important metrics for evaluating Essential Fish Habitat and Marine Protected Area management. We evaluated the fishery value of eelgrass within the Blue Cavern State Marine Conservation Area by measuring the inferred growth of juvenile kelp bass over a 2-year period. Using Akaike's Information Criterion, the preferred model for predicting kelp bass abundance in eelgrass beds includes eelgrass length and density, but not eelgrass frequency. This information is useful in designing surveys that evaluate eelgrass function as both a food resource and nursery habitat. Using existing production models, kelp bass length and abundance data were converted to secondary productivity with values ranging from 0 to 189 g m⁻² yr⁻¹ (average 28 ± 4 g m⁻² yr⁻¹). This scope of annual production values highlights the importance of standardizing sampling times relative to fish recruitment events and habitat seasonality. This study improves the accuracy of modeling secondary productivity and quantifies the nursery value of eelgrass for juvenile kelp bass while highlighting the importance of accounting for seasonal variation to better inform management decisions.

91-2 TASSIA, MG*; HALANYCH, KM; Auburn University;
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Illuminating the Toll-like receptor pathways in hemichordates

Most invertebrates must rely solely on their innate immune system to defend against pathogenic microbes. Unlike the immunoglobulins of vertebrate adaptive immunity, innate immune receptors do not recombine to diversify their ligand specificity - thus it is the plurality of these receptors encoded in the genome which provide breadth of protection. In this study, we investigate the diversity of Toll-like receptor (TLR) and Interleukin-1 receptor (IL-1R) pathway genes in hemichordates. Hemichordates, alongside echinoderms, belong to the Ambulacraria - sister group to the chordates. While research has shown echinoid echinoderms exhibit a vast diversification of TLRs, the hemichordate TLR repertoire has been largely uninvestigated. Using available TLR/IL-1R pathway genes from the SwissProt database, hemichordate TLR homologues were determined through reciprocal BLAST searches cross-referenced with their associated Pfam-domain predictions (via HMMER). Our results suggest both colonial and solitary hemichordates do not possess the diversification of TLR genes observed in the echinoids. Furthermore, hemichordates may possess the genetic machinery necessary for MYD88-dependent and MYD88-independent signal transduction of the TLR/IL-1R pathway. These data provide a strong foundation for future experiments in hemichordate and ancestral deuterostome innate immunity.

66-6 TATRO, KL*; CARREIRA, KL; UYENO, TA; Valdosta State University; klatro@valdosta.edu

The Internal Morphology and Strength of Spanish moss

Spanish moss (*Tillandsia usneoides* (L.)) is a perennial flowering epiphyte with a large distribution across the moister parts of the Americas. Since it sustains itself with airborne particulates, rainfall, and photosynthesis, this epiphyte uses other plants as support to grow in clumps of hanging strands without great damage to the host. Despite its distribution and considerable number of growth and toxicity studies, there have been few explorations into its functional morphology. In this study, we describe the construction of the nodes (the point at which leaves sprout) and their internode connections that form individual Spanish moss strands. We used a light microscopical analysis to reconstruct the morphology from serial plastic sections (low viscosity GMA; Ladd Research Industries, Williston, VT) stained with toluidine blue. This analysis suggests that the strands function as purely tensile mechanisms in which the lignin core bears the strain and the nodes represent points where the breaking strength can be modulated. We used a material properties testing system (Imada, Northbrook, IL) to measure the breaking strength of the nodes (in our tests, the strands never broke within the internode) and then confirmed the mode of failure using subsequent histological reconstructions. The tensile core failed by tearing at a point of constriction within the node. The plant's ability to modulate how and where it fragments may provide important insights into its unique mode of asexual reproduction as well as contribute to the mechanical understanding of "break-away" tensile structures.

119-1 TEMPLETON, CN*; ZOLLINGER, SA; BRUMM, H; Pacific University, University of St Andrews, Max Planck Institute for Ornithology; templeton@pacificu.edu

Traffic noise drowns out a songbird's alarm calls

Anthropogenic noise negatively impacts acoustic signals in a variety of animals. Recent research has shown that birds can reduce signal masking by adjusting acoustic parameters of their sexual signals (songs) in noisy environments, but we know little about other types of vocalizations. Masking of other types of vocalizations, like anti-predator signals, could have major fitness consequences. We investigated whether traffic noise impacts avian alarm call production or perception with a combination of lab and field experiments in great tits (*Parus major*), a common songbird that frequently inhabits noise-polluted environments. In response to experimental noise manipulation in controlled laboratory conditions, great tits increased the amplitude, but not frequency parameters, of their calls. Playback experiments conducted in the wild indicate that traffic noise masks alarm calls, impeding great tit perception of these signals. Thus, despite the vocal adjustments used to compensate for anthropogenic noise, great tits are not able to overcome the challenges posed by even moderately noisy environments.

120-5 TELEMECO, R.S.*; SMITH, C.; ANGILLETTA, M.J.; BUCKLEY, L.B.; Univ. of Washington, Arizona State Univ.; telemeco@uw.edu

Lizards (*Sceloporus tristichus*) fail to adaptively adjust nesting in response to thermal stress

Phenotypic plasticity is commonly observed in organisms responding to climate change, and might buffer populations from decline. However, the potential of phenotypic plasticity to counter climate change-induced stressors has rarely been examined experimentally. We experimentally assessed behavioral nesting plasticity in lizards (*Sceloporus tristichus*). Exposure to temperatures > 44C causes instant death of embryos. While below ground nests rarely reach such high temperatures currently, biophysical modeling predicts that *S. tristichus* nests will rise above 44C for brief periods annually by 2100. Modeling also indicates that females could fully buffer their offspring by subtly altering nesting sites: increasing nest depth or shade cover. To test the capacity for females to sufficiently adjust their nesting, we exposed gravid females to an optimal or stressful (temperatures hotter than preferred 3hrs/d) thermal regime for the majority of egg development. We then released the lizards immediately prior to oviposition in individual outdoor enclosures that provided three shade environments (30, 60, and 90%) and 30cm-deep soil within which to nest. The temperature regime that females experienced while gravid did not affect nesting. By contrast, temperature at the time of nesting affected nest depth, although not in the direction expected: females dug shallower nests when exposed to warmer temperatures. We suggest that females failed to adaptively adjust their nest-sites because, throughout their evolutionary history, critical high nest temperatures were so rare and unpredictable as to not select for an avoidance mechanism. Similar failures of plasticity will likely be common whenever climate change is predicted to induce novel stressful conditions, such as an increased incidence of critically high temperatures.

SI-11 TER HOFSTEDE, Hannah M*; SCHÖNEICH, Stefan; ROBILLARD, Tony; HEDWIG, Berthold; Dartmouth College, USA, University of Leipzig, Germany, Muséum national d'Histoire naturelle, France, University of Cambridge, UK; Hannah.ter.Hofstede@Dartmouth.edu

Evolution of a Communication System by Sensory Exploitation of Startle Behavior

New communication signals can evolve by sensory exploitation if signaling taps into pre-existing sensory biases in receivers. For mate attraction, communication signals are typically similar to attractive environmental cues like food, which amplifies their attractiveness to mates, as opposed to aversive stimuli like predator cues. Female field crickets approach the low-frequency calling song of males, whereas they avoid high-frequency sounds like predatory bat calls. In one group of crickets (Eneopterinae: Lebinthini), however, males produce exceptionally high-frequency calling songs in the range of bat calls, a surprising signal in the context of mate attraction. We found that female lebinthines, instead of approaching singing males, produce vibrational responses after male calls, and males track the source of vibrations to find the female. We also demonstrate that field cricket species closely related to the Lebinthini show an acoustic startle response to high-frequency sounds that generates substrate vibrations similar to those produced by female lebinthine crickets. Therefore, the startle response is the most likely evolutionary origin of the female lebinthine vibrational signal. In field crickets, the brain receives activity from two auditory interneurons: AN1 tuned to male calling song controls positive phonotaxis, and AN2 tuned to high frequency bat calls triggers negative phonotaxis. In lebinthine crickets, however, we found that auditory ascending neurons are only tuned to high-frequency sounds, and their tuning matches the thresholds for female vibrational signaling behavior. Our results demonstrate how sensory exploitation of anti-predator behavior can evolve into a unique communication system that benefits both senders and receivers.

40-7 THANIGAIVALEN, I*; MURELI, S; FOX, JL; Case Western Reserve University; jlf88@case.edu

Haltere influence on gaze control in tethered *Drosophila* flight

Animal behavior requires the integration of multiple sensory information streams. For flying animals, stability and control require the rapid integration of visual and mechanosensory information. Information about body rotations in flying flies is provided with high speed and precision by the halteres, reduced hindwings that are essential for fly flight. Previous studies have shown that halteres are not strictly necessary for visually-guided wing steering responses in fruit flies, but their influence on wing-steering behavior can change depending on visual context. In this study, we asked whether the halteres might influence head movements in the same way they influence wing steering. We examined the head movement behavior of intact fruit flies, flies with the haltere mass ablated (leaving the sensory cells intact but reducing the force on them), and flies with complete haltere ablations. Each group of flies flew on a rigid tether in multiple visual contexts. Although haltere input is necessary for spiking activity in some neck motoneurons of larger flies, we found that haltere removal did not decrease the flies' range of head movements. When the flies were stimulated with visual motion, we found that haltere ablation decreased head movement responses to wide-field motion, but not to moving figures. In closed loop, fast head movements (saccades) occurred more frequently during periods in which the fly was fixating a figure in the frontal field, but did not occur more frequently during wide-field fixation. Our results suggest a complex role for the haltere in gaze control that is modulated by visual context. Although the wing-steering and head movement behaviors are different in the visual contexts tested here, the influence of the haltere appears to be similar for both.

116-5 THEOBALD, J.C.*; HERNANDEZ, V.; Florida International University; theobald@fiu.edu

Flies use stabilizing visual cues to approach virtual targets

Flying insect process and integrate a variety of visual and other sensory cues to find and approach targets. Even with coarse vision and tiny brains, they can find flowers, prey items, trees, or other resources with startling skill. But it is often unclear how they use the dynamic images in their visual field to navigate to their intended destination. We set out to determine how fruit flies balance the wide-field optic flow with the motion of the smaller target they wish to approach when they chart a course towards it. To do this we put tethered flies in a closed-loop, virtual environment with a vertical target to approach, and wide-field features to help stabilize flight. Fruit flies have long been noted for their interest in vertical features, in both tethered and free flight, and their strong responses to wide-field visual stimuli. Although the tethered arena fails to capture all the aspects of natural flight, it is sufficiently convincing that our flies robustly steered towards the vertical bar. We characterized the probability that flies could find and arrive at the target, and then the shape of the path they used to approach it. We found that both the density and location of wide-field cues affected the likely success of getting to the bar, and the path of approach. These effects are consistent with the hypothesis that flies adjust their flight paths towards small targets to increase the information they acquire from wide-field optic flow.

18-6 THAWLEY, C.J.*; GOLDY-BROWN, M.; MCCORMICK, G.L.; GRAHAM, S.P.; LANGKILDE, T.; Penn State University, Sul Ross State University; cthawley@gmail.com

Invasion of a novel predator reverses latitudinal gradients of multiple traits in a native lizard

Ecologists have long been fascinated by latitudinal gradients and the selective mechanisms that drive their formation and maintenance. Environmental change, including climate change and invasive species, can alter selective pressures across large portions of species' ranges. Resulting changes in species' traits are generally assumed to be adaptive, but could alter existing latitudinal patterns, potentially imposing costs. We examined how latitudinal patterns of morphology, behavior and physiology in the eastern fence lizard, *Sceloporus undulatus*, are affected by invasion of the red imported fire ant, *Solenopsis invicta*, which occupies the southern half of this species' range. When moving from north to south along a latitudinal gradient outside of the fire ant's range, lizard populations become less responsive to ants, have relatively shorter legs, and have lower stress responses. However, the direction of these gradients is reversed in the presence of fire ants; in more southern areas invaded by fire ants, lizard populations are more responsive to ants and have longer legs, adaptations to surviving attack by fire ants, and have higher stress responses, likely a response to frequent attack by these predatory ants. These changes represent shifts away from trait values that evolved under natural conditions, suggesting that these adaptations may incur costs.

25-6 THIBODEAU, M*; WATSON, CM; Midwestern State University; marcthib72@gmail.com

Prey Composition and Associated Digestive Efficiency of the Texas Horned Lizard, *Phrynosoma cornutum* from Prairie Habitat.

Phrynosoma cornutum is currently listed as a threatened species in Oklahoma and Texas. This species is known to inhabit both arid to semi-arid environments. However, relatively little data exist regarding the ecology and biology of this species in semi-arid prairie compared to more arid habitats such as desert scrub. This study investigates prey composition of Texas Horned Lizards in prairie habitat using fecal dissections (n=29) and compares it to published findings from desert scrub. Also, this research compares the digestive efficiency of Texas Horned Lizards consuming harvester ants (*Pogonomyrmex*) and beetles (Coleoptera), the two groups of prey items most prevalent in fecal samples. Total prey items found in feces are highly variable but prey composition is relatively consistent. This is presumably owing to variation in size of the horned lizard and prey availability. Ground beetles (Carabidae) were found in over 93% of all samples even though many other arthropods are encountered as frequently in the field, indicating that they may be selected for along with harvester ants, which made up the majority of every sample. Novel prey items, including Halictidae bees, Hister beetles, weevils, Caligrapha beetles, and vegetation were also noted in quantities that represent opportunistic or incidental consumption. Horned lizards are more efficient at digesting beetles than ants, which may indicate that they are required as a dietary supplement at least in times of high caloric requirements. Alternatively, they may represent periodic "treats" as an opportunistic additive to the diet. Future research will seek to resolve this speculation.

90-4 THIEL, D.*; JÉKELY, G; HEJNOL, A.; Sars Centre for Marine Molecular Biology, Bergen, Max Planck Institute for Developmental Biology, Tübingen; daniel.thiel@uib.no

Changing the mode: neuropeptide evolution in trochozoans

Animal nervous systems utilize a wide array of neuropeptides for signal transmission and neural modulation. Contrary to classical neurotransmitters, which only transfer action potentials, neuropeptides can act in different ways and are often involved in triggering or altering physiological and behavioral responses. Since most studies of marine protostomes have focused on annelids or molluscs, so far nothing is known about neuropeptides in brachiopods and nemertans. Using an integrative approach that combines comparative genomics, transcriptomics, mass spectrometry, molecular biology and behavioral studies, we identified and characterized a set of neuropeptides in the larvae of two brachiopod species (*Novocrania anomala* and *Terebratalia transversa*) and two nemertean species (*Lineus longissimus* and *Lineus ruber*), and identified their neurosecretory regions. Behavioral assays show the specific involvement of the FMRFamide-like peptide (FLP) FLRFamide in the defense behavior of *T. transversa* larvae that are triggered by muscular contraction. This mirrors the role of FLPs in the myoactivity of other metazoans. We also examined the trochozoan specific "excitatory peptide" that is connected with myoactivity in annelids and molluscs, and demonstrate that it specifically influences the ciliary beating of *L. longissimus* larvae. These two examples demonstrate that neuropeptides show a high variation regarding their utilization during evolution. Although broadly conserved functions can be found throughout metazoans, we also demonstrate that even lineage specific neuropeptides can be recruited for different functions, which indicates rapid evolution of these essential molecules.

85-1 THOMAS, K.N.*; ROBISON, B.H.; JOHNSEN, S.; Duke University, Durham, NC, Monterey Bay Aquarium Research Institute, Moss Landing, CA; kate.thomas@duke.edu

The perks of being cock-eyed: Orientation and visual characteristics of histioteuthid squids

The Histioteuthidae are a family of deep-sea oegopsid squids with a striking morphological feature: their left eye can be up to twice the diameter of their right eye, earning them the name of the "cock-eyed" squids. These strange eyes are thought to serve different visual functions in the dim waters of the mesopelagic ocean. The larger eye may be adapted to viewing dim downwelling light from above, while the smaller eye may be specialized for detecting flashes of bioluminescence. However, the *in situ* posture of histioteuthids and the orientations of their eyes have not been previously reported. We used ROV video to document depth, posture, body orientation, and eye orientation in two histioteuthid squids from the Monterey Submarine Canyon: *Histioteuthis heteropsis* (n=152) and *Stigmatoteuthis dofleini* (n=9). We found that both histioteuthids are consistently found in either a j-pose posture with the arms curled up around the mantle or a straight-arm posture with an oblique mantle. The large left eye orients upward between 15° and 75° from a horizontal axis (n=32, mean=45, SD=12), and the small right eye orients slightly downward 10° to 70° below a horizontal axis (n=25, mean=33, SD=11). We also noted the presence of a yellow pigment in the large left lenses of some adult individuals. Preliminary investigation of this pigment indicates that it acts as a long-pass cutoff filter and may develop late in life. The implications of observed *in situ* histioteuthid orientation and lens pigmentation are discussed in the context of vision and camouflage in the twilight zone of the deep sea.

26-8 THOMAS, J.R.*; MAGYAN, A.M.; FREEMAN, P.E.; WOODLEY, S.K.; Duquesne University, Carnegie Mellon Univ.; thomasj6@duq.edu

Seasonal variation in corticosterone in male and female free-living salamanders

Glucocorticoids (GCs) are hormones involved in metabolism that are also released in response to stressors, where they induce numerous behavioral and physiological responses to help the organism cope with the stressor. In many vertebrates, both baseline and stress-induced GCs change on a seasonal basis. It is hypothesized that seasonal variation in GCs is related to seasonal changes in energy balance, reproduction, and immune function. To better understand seasonal patterns of GCs, we measured baseline and stress-induced corticosterone (CORT) in field-caught male and female Allegheny Mountain Dusky salamanders across three seasons (spring, summer, and fall). In this species, mating occurs in the spring. Baseline plasma CORT was highest in the spring and declined over the course of the summer. Additionally, the CORT response to capture and handling was less in the spring compared to summer and fall. Both the seasonality of baseline CORT and the magnitude of stress-induced GCs were greater in females relative to males. In addition, plasma CORT was negatively correlated with relative fat body condition, but had no interaction with white blood cell differentials. We are currently measuring gonadal masses to determine whether reproductive investment contributes to seasonal CORT patterns. Overall, this study showed that plasma CORT does vary seasonally, and the variation is influenced by sex and fat body condition, suggesting that reproductive investment and energy balance play a role in seasonal patterns of GCs.

63-4 THOMETZ, N.M.*; DUNKIN, R.C.; NOREN, D.P.; HOLT, M.M.; WILLIAMS, T.M.; Univ. of California, Santa Cruz, NOAA NMFS Northwest Fisheries Science Center, NOAA NMFS Northwest Fisheries Science Center; nthometz@ucsc.edu

Aerobic and Anaerobic Capacities of Sound Production Muscles in Two Odontocetes

Cetaceans rely on sound production for successful foraging and communication. Most mammals produce sound via the larynx, but odontocetes produce sound via the nasal complex. In addition, odontocetes produce sound on breath-hold dives and must manage oxygen stores at depth in response to locomotor and vocal muscle demands. Elucidating the physiological properties of sound production muscles can provide key information as to how cetaceans evolved to produce sound underwater. We examined aerobic [myoglobin (Mb) concentration] and anaerobic [acid buffering (AB) capacity] capacities of cetacean vocal muscles in two odontocetes: *Tursiops truncatus* (n=4) and *Phocoena phocoena* (n=2). Vocal muscles included the nasal musculature (NM) around the phonic lips and the palatopharyngeal sphincter (PPS), which is involved in pressurizing air within the nasal complex. When available, matched locomotor muscles were compared. The vocal muscles of *T. truncatus* had lower [Mb] (NM=1.33±0.1g Mb·100g tissue⁻¹; PPS=1.72±0.29g Mb·100g tissue⁻¹) and AB capacities (NM=29.07±1.50 slykes; PPS=34.27±3.78 slykes) than published locomotor values. Similarly, the vocal muscles of *P. phocoena* had lower [Mb] (NM=1.90±0.09g Mb·100g tissue⁻¹; PPS=1.70±0.15g Mb·100g tissue⁻¹) and AB capacities (NM=21.45±0.19 slykes; PPS=29.67±3.89 slykes) than matched locomotor muscles. Overall, the vocal muscles of both species exhibited similar aerobic and anaerobic capacities, but these values were less than half of species-specific locomotor muscle values. Our results suggest a relatively low energetic cost of sound production compared to locomotion in these species.

59-7 THOMPSON, D.M.*; LIGON, D.B.; PAPES, M.; Oklahoma State University, Missouri State University; denise.thompson17@gmail.com
Assessing Climatic Constraints On The Distribution of an Oviparous Reptile: The Alligator Snapping Turtle (*Macrochelys temminckii*)

Understanding the proximate factors that limit species geographic distributions is a fundamental aspect of ecology. Ecological niche modeling (ENM) is a tool that is used with increasing frequency to aid in understanding species distributions and conservation planning. Both survival and reproduction are essential for species' persistence, but the set of environmental conditions that support each of these components may not be the same. In this study we used ENM to examine the climate envelope of the alligator snapping turtle and assess potentially limiting environmental variables on the distribution of this species. We also incorporated incubation temperature requirements with our modeled distributions to determine if embryonic development constrains the species' northern limits. We discuss our results with respect to conservation management practices aimed at restoring this species at the northern edge of the species' range. We found that low annual precipitation likely constrains the western distribution of alligator snapping turtles while the northern distribution is likely constrained by thermal requirements during incubation. Only a portion of the range predicted to have a high probability of suitability for survival was estimated to be capable of supporting successful embryonic development. If historic occurrence records are accurate, adult alligator snapping turtles appear to be able to survive colder climates than they would be able to consistently and successfully produce offspring in. Our study highlights the importance of considering survival and reproduction when estimating species' ecological niches as well as the benefits of incorporating physiological data when evaluating species distributions.

19-6 THOMPSON, Z.*; KOLB, E.M.; HIRAMATSU, L.; CADNEY, M.; GARLAND, JR., T.; Univ. of California, Riverside, Univ. of Southern California; zthom002@ucr.edu

High-running mice have reduced incentive salience for a sweet-taste reward

Animals tend to seek activities that are rewarding, either psychologically or physically, and avoid those that are not. Although much is known about the reward system in mammals, questions remain, especially concerning the comparison of behavioral rewards. To what extent can one rewarding behavior substitute for another? How does the strength of a reward influence its ability to substitute for another reward? In humans and rodents, some rewarding substances have been shown to partially substitute for other rewarding substances or behaviors, but this substitution is not always reciprocal. To explore whether physical activity can be subject to "reward substitution," female mice from a selective breeding experiment for high voluntary wheel-running (HR mice) and their control counterparts (C) were allowed access to wheels along with sweet solutions as a potentially competing reward (saccharin, Sweet

N Low, Equal, Splenda, sucrose). Fluid consumption and wheel running were measured daily. Home-cage activity (without access to wheels) was measured for a different generation of mice that had access to the same sweeteners (analyses are in progress). Wheel running was not statistically affected by exposure to the artificial sweeteners. Sucrose significantly elevated wheel running in C but not HR mice. Fluid consumption increased in a dose-dependent manner with saccharin, sucrose, Sweet N Low, Equal, and Splenda. HR mice had a significantly smaller increase in fluid consumption with the artificial sweetener blends as compared with C mice, despite running ~2.6-fold more than C. These results suggest that HR mice have a reduced incentive salience for artificial sweeteners and this is likely attributable to the stronger competing reward of wheel running that has evolved in these lines.

3-5 THOMPSON, JT.*; LAVALVA, SM; LOIACONO, MM; Franklin and Marshall College; joseph.thompson@fandm.edu
A multi-function muscle in squid

Some striated muscles are multi-functional; i.e., they are able to serve several different roles during locomotion and movement, including acting as motors, brakes, struts, or springs. We discovered a multi-function muscle, the nuchal retractor, in the comparatively simple muscular system of a cephalopod mollusc. Synchronized measurements of head movement and muscle activation revealed that while the mitochondria-poor nuchal retractor muscle fibers were activated only for head retractions that occurred during escape jet locomotion, the mitochondria-rich muscle fibers served three roles during escape jets: as motors to assist in head retraction, as struts to stabilize head position briefly during changes in swimming direction, and as brakes to control the head extensions that followed an escape jet. The nuchal retractor demonstrates that multi-functionality is not restricted to the muscles of animals with jointed skeletal support systems, and also provides a relatively simple model in which to investigate the physiology of multi-function muscles.

108-3 TIFT, M.S.*; ST. LEGER, J; LUEKER, T; PONGANIS, P.J.; Scripps Institution of Oceanography, UCSD, SeaWorld Parks and Entertainment; mtift@ucsd.edu

Natural carbon monoxide production in marine mammals

Carbon monoxide (CO) is typically thought to be an exogenous gas that has toxic properties from binding tightly to the oxygen-carrying heme proteins (i.e. hemoglobin and myoglobin). However, the recent discovery of 1) heme degradation leading to endogenous carbon monoxide production, and 2) therapeutic properties from low concentrations of CO has shed new light on the gas. The most promising therapeutic potential has been attributed to CO reducing injuries associated with ischemia-reperfusion events (e.g. inflammation, apoptosis and cell proliferation). Due to the increased heme protein stores (hemoglobin and myoglobin) and ischemia-reperfusion events associated with the dive response in diving animals, we investigated endogenous CO levels in the breath (ppm CO) and blood (% carboxyhemoglobin - COHb) of four species of cetaceans (Bottlenose dolphins, short-finned pilot whales, killer whales and beluga whales) and two pinniped species (northern elephant seals and Hawaiian monk seals). Our findings show that animals with the most elevated heme protein stores (elephant seals, monk seals and beluga whales) have exhaled CO levels (23ppm, 6ppm and 7ppm, respectively) that mimic those seen in human cigarette smokers (> 6 ppm). However, only the elephant seal displayed elevations in blood CO with values as high as 17.6% COHb (5.8X values seen in chronic cigarette smokers). The high values seen in the elephant seals are likely due to elevated erythrocyte turnover in a species with the highest mass specific mammalian blood volume and hemoglobin concentrations. We suggest that these natural elevations in CO potentially serve to protect the animals against injuries related to consistent ischemia-reperfusion events associated with a lifestyle of breath-holding and the dive-response.

39-6 TILDEN, A.R.*; CHRISTIE, A.E.; WRAY, C.; REYNOLDS, C.J.; PARTRIDGE, J.C.; COLFORD, B.R.; SUNDERLAND, D.K.; SUTANDI, A.; WISE, D.L.; Colby College, University of Hawaii at Manoa, Jackson Laboratory; artilden@colby.edu

Expression and characterization of eight timeless gene paralogs in *Daphnia pulex*

With increasing availability of crustacean transcriptome data and a few currently available sequenced genomes (*Daphnia pulex* and *Daphnia magna*), we can now study the crustacean circadian system in this group more fully with regard to the TIM-PER/CYC-CLK transcription-translation feedback loop. Our prior studies have shown that crustaceans possess predicted orthologous genes and transcripts for all of the core and ancillary clock component proteins known in *Drosophila* and other arthropods. Interestingly, *Daphnia pulex* - known for its high degree of general gene duplication - possessed numerous copies of a *timeless* (*tim*) gene homolog, versus a single copy in *Drosophila*. We selected for further study the 8 paralogs with statistics that were predictive of potential homology. Transcription: *Daphnia pulex* were collected at 3 hr intervals over a 24 hr LD period. Using qPCR with primers designed uniquely for each of the 8 *tim* paralogs, we detected transcription of all 8 genes, with variability over 24 hr. Bioinformatics: A manual annotation and curation workflow was used to further predict the likely functionality of the resulting amino acid sequences. This workflow included promoter prediction, refinement of intron/exon borders, functional domain and motif conservation, and 3-dimensional structural prediction using coordinates of well-characterized arthropod homologs. These results suggest that several of the predicted TIM products are functional proteins.

95-7 TOBALSKE, B.W.*; LANE, S.J.; WOODS, H.A.; GUTIERREZ, M.M.; SHISHIDO, C.M.; MORAN, A.L.; Univ. Montana, Univ. Hawaii; bret.tobalske@mso.umt.edu
Structural Support for Gigantism in Polar Sea Spiders (Pycnogonida)

Polar gigantism is common among diverse oceanic invertebrates, but the underlying mechanisms responsible for this phenomenon are not well understood. Temperate species are small in size, whereas those in the poles and at great depth are often huge. Sea spiders (Pycnogonida) are particularly interesting as they do not have specialized organs for metabolic gas exchange, so their respiration must occur *via* diffusion across their cuticle. We hypothesized that gigantism in sea spiders has evolved under the constraint of a trade-off between the need for a thin cuticle to facilitate diffusion and the need for mechanical support of the body. To begin to test this, we undertook the present scaling study in a comparative context ($n = 32$ species, 5 orders of magnitude in mass). We used micro-computed tomography (μ CT) to measure cross-sectional anatomy of limb segments, and we used standard photography to measure external morphology. Departures from geometric similarity in cross-sectional anatomy were consistent with our hypothesis that gigantism in sea spiders is associated with proportional thinning of the cuticle. For the femur, scaling exponents relative to body mass were: area (0.54), thickness (0.23) and polar moment of area (1.12). In contrast, external morphology (length, diameter) scaled according to predictions of geometric similarity. Large species exhibited apodemes running the length of limb segments that likely aid with structural support. Some large genera (*Colossendeis* and *Pallenopsis*) featured long, thin limbs (aspect ratio > 20), whereas others (*Decalopoda*, *Dodecalopoda*) shared similar aspect ratios with smaller taxa (< 10). Ongoing field studies around McMurdo Station, Antarctica, should reveal the ecological and behavioral consequences of these differences among giants. NSF PLR- 1341485.

69-2 TIVEY, T.R.*; WAIANUHEA, L.K.; WEIS, V.M.; Oregon State University; tiveyt@onid.orst.edu

Host Cell Division and Symbiont Population Dynamics in the Symbiotic Anemone *Aiptasia* sp.

The cnidarian-dinoflagellate endosymbiosis relies on the cellular coordination of its two partners, algal symbionts and the host cnidarian cells that contain them. We examined the effect of nutritional status and symbiotic state on host cell proliferation in the sea anemone *Aiptasia* sp., and its resident algal symbionts *Symbiodinium* clade B1, a model system for coral-dinoflagellate symbiosis. Anemones under three different symbiotic conditions: symbiotic, aposymbiotic (without symbionts) and colonizing (aposymbiotic animals being re-colonized with algae) were treated and stained with S-phase marker 5-ethynyl-2'-deoxyuridine (EdU), late G2/M-phase marker phospho-histone H3 (Ser10), and Hoechst dye. In symbiotic anemones, host cell replication and division was lowest at night and peaked in the late afternoon. Symbiotic and aposymbiotic anemones had similar division rates, though starvation led to increased proliferation of primarily mucocytes. Starvation also had a positive effect on symbiont proliferation but not host cell division during onset of symbiosis. Our results suggest that changes in host cell cycle and proliferation are basic cellular responses to environmental flux and symbiont status.

49-2 TOBLER, M.*; KELLEY, J.L.; Kansas State University, Washington State University; tobler@ksu.edu

Using comparative transcriptomics to identify mechanisms of adaptation in livebearing fishes inhabiting toxic, hydrogen sulfide rich springs

Freshwater springs discharging water riched in toxic hydrogen sulfide (H_2S) belong to the most inhospitable aquatic habitats, and few organisms have been able to persist in these extreme environments. Yet, over a dozen lineages of poeciliid fishes have colonized and thrive in sulfide springs, providing an opportunity to study mechanisms of adaptation and the role of convergent evolution in animal diversification. We used comparative transcriptome analyses in three sulfide spring lineages of *Poecilia mexicana* and matching reference populations from non-sulfidic habitats to test hypotheses about mechanisms mediating tolerance to H_2S toxicity. Elevated tolerance to environmental H_2S could be driven by three mechanisms: (1) Modification of the integumentary system that reduce the flux of environmental H_2S into the body. (2) Increased capability to maintain H_2S homeostasis despite continuous flux from the environment through increased detoxification or decreased endogenous production. (3) Modification of toxicity targets that make individuals more inert to adverse consequences caused by elevated endogenous concentration. Results indicate that about 150 genes are consistently up- or down-regulated across all three population pairs. Functional annotation of shared differentially expressed genes indicate consistent up-regulation of genes associated with H_2S detoxification and sulfur excretion. Consistent with H_2S ' role in generating oxidative stress and interfering with mitochondrial function, we also found up-regulation of antioxidant pathways as well as differential expression of genes associated with energy metabolism.

39-2 TOMANEK, L.*; GARLAND, M. A.; STILLMAN, J. H.; HARMS, L.; California Polytechnic State Univ. San Luis Obispo, San Francisco State Uni. San Francisco, Alfred-Wegener Institute for Polar Research; ltomanek@calpoly.edu

Multi-stressor proteomics: responses to simultaneous emersion, low pH and temperature stress

We analyzed the proteomic responses of gill tissue of the spider crab (*Hyas araneus*) and the intertidal porcelain crab (*Petrolisthes cinctipes*) to simultaneous emersion, pH and temperature stress. Both species showed a decrease in tyrosine metabolism, while simultaneously changing the abundance of lectins and serine proteases, which are thought to lead to the conversion of pro-phenoloxidases (including hemocyanin) to phenoloxidases. These catalyze the synthesis of quinones and melanin from tyrosine. Quinones are involved in the sclerotization of the arthropod cuticle and both species showed abundance changes in a number of cuticle proteins. The porcelain crab also showed changes in the abundance of proteins that are involved in the excretion of ammonium, and thus the excretion of proton equivalents, across the gill tissue. This response to low pH was dependent on the immersion/emersion and temperature conditions animals experienced. Changes in the abundance of proteins involved in the urea cycle might indicate that it too is involved in the excretion of bicarbonate ions and thus protons. Low pH also decreased the abundance of chaperones of the endoplasmic reticulum. In general, crustacean gill tissue changed a number of proteins involved in cuticle structure which may affect the passive ion transport properties of the apical side of the gill epithelium. These changes were accompanied by changes in the active transport of ammonium and the urea cycle (funded by NSF EF-1041227).

51-5 TRACY, CR*; MCWHORTER, TJ; CHRISTIAN, KA; GIENGER, CM; WEBB, GJW; MANOLIS, SC; California State University Fullerton, University of Adelaide Roseworthy, Charles Darwin University, Austin Peay State University, Wildlife Management International; ctracy@fullerton.edu

Old guts leak less: ontogeny of paracellular absorption of carbohydrates by saltwater crocodiles

Passive, paracellular transport of small, water-soluble nutrients can be an important pathway for nutrient absorption, particularly for small, flying vertebrates. This has been hypothesized to be an efficient way to overcome the combined constraints of high-energy demands, reduced gut size, and fast digesta passage faced by small flying vertebrates. However, young saltwater crocodiles also show high paracellular absorption, despite being neither small nor flying. We hypothesized that fast-growing juvenile crocodiles may also rely on high paracellular absorption to fuel the energy demands of growth. Fractional absorption (bioavailability) of metabolically-inert carbohydrate probes decreased with probe size, as expected, and fractional absorption of both arabinose (absorbed only paracellularly) and 3-O-methyl D-glucose (absorbed by both mediated and paracellular transport) decreased with body mass across four size/age classes of saltwater crocodiles ranging from 250 to 33,000g. The higher paracellular absorption in small crocodiles may suggest that the pattern of reliance on high paracellular absorption is not limited to small flyers, but is more general, whereby any vertebrate with high energy demands should rely on energetically-cheap paracellular absorption to fuel growth, survival, or other energetic expenses.

74-3 TOWNSEND, J.P.*; SWEENEY, A.M.; University of Pennsylvania; townj@mail.med.upenn.edu

Organized Water: Addressing the Paradoxes of Acellular Bodies in Ctenophores

In the genomic era, we know that the earliest-branching animal phyla include ctenophores, sponges, and cnidarians. Intriguingly, these animals all share bodies that are more amorphous, acellular materials by volume than they are living cells. Ctenophores perhaps the first-branching extant metazoan taxon are primarily composed of a voluminous hydrogel called the "mesoglea" that is derived from the extracellular matrix of the thin epithelium that surrounds it. We report here that this gel is far from simple, but has sophisticated material properties. First, it behaves as a non-Newtonian fluid that is also self-healing. It is also molecularly crowded, with a viscous fluid phase and very slow diffusion of sub-micron beads. Paradoxically, while the gel appears "full" to diffusing particles, it looks "empty" to light, with a refractive index almost identical to seawater and vanishingly low concentrations of proteins or sugars. How can a structure be "empty" to light, yet otherwise exhibit these sophisticated properties? Further, what do these material properties teach us about the bodies of the earliest animals? We will present results on the biochemical constituents of ctenophore mesoglea, their spatial organization within the gel, and on the viscoelastic, shear-hardening properties of this enigmatic tissue in the context of the animals' development and ecophysiology.

57-4 TRAVERS, M*; SCHIEBEL, P; GOLDMAN, D; CHOSET, H; Carnegie Mellon, Georgia Tech; mtravers@andrew.cmu.edu

Limbless Locomotion Control in Unstructured Terrains

We are interested in uncovering the fundamental elements that enable limbless locomotors to move in unstructured terrestrial environments. This is challenging because while it is possible to observe the changing shapes of biological limbless locomotors as they move, we know little about the underlying mechanisms that govern their motion. Motivated by this difficulty, this work uses observations of biological behaviors to make hypotheses about the dominant type of control strategies employed by different species of snake locomoting in unstructured environments. Based on these observations, we developed a locomotion control framework that provided the ability to freely change low-level parameters as well as sensing modalities of a model system, a physical snake-like robot. This freedom in selecting how to implement the robot's control method gave us the ability to effectively hypothesize about and switch between different neurological control architectures. Furthermore, implementing the different architectures on the robot and comparing the results to data from the biological snakes grounded the hypotheses in the physical world. Initial results show that we are able to capture many of the salient kinematic features exhibited by the biological snakes using somewhat simple force control schemes, as well as that compliant force-based controllers in general far outperform stiffer position-based approaches. We thus believe that using a force-based control framework as the basis for generating and comparing further data from the model system to the biological systems will lead to a deeper understanding of how limbless systems move. The physical nature of this understanding will be more intuitive and ultimately more valuable than simply observing or using reduced models to represent biological systems alone.

52-2 TRICAS, T.C.*; BOYLE, K.S.; Univ. of Hawai'i, Honolulu; tricas@hawaii.edu

Butterflyfish sound communication on noisy coral reefs - divergence in acoustic behavior and auditory systems

Fish produce context-specific sounds during social communication, but it is not known how the acoustic behaviors and auditory systems in fishes have evolved in noisy coral reef environments. Butterflyfishes (family Chaetodontidae) are speciose and prominent members of coral reefs and show a diversity of close affiliative social behaviors. At least two sound production mechanisms exist in the bannerfish clade, and additional mechanisms in the *Chaetodon* clade which is distinguished by anterior swim bladder horns and the laterophysic connection (LC). Some *Chaetodon* species share the head bob acoustic behavior with the bannerfishes, which along with other sounds in the 100-1000 Hz spectrum, are likely adequate to stimulate the ear, swim bladder or LC of a receiver fish. In contrast, only *Chaetodon* species produced the tail slap sound, which involves a 1-30 Hz infrasound pulse that can stimulate the receiver's ear or lateral line at close distances, but not the swim bladder or LC. *Chaetodon* species are more sensitive to sound intensities from 100-1000 Hz than the forcepsfish, *Forcipiger flavissimus* (which lacks swim bladder horns and LC), and also have an extended hearing range up to 2000 Hz that are due to their divergent sensitivity to sound pressure mediated by the swim bladder horns. Coral reef ambient noise levels in the hearing spectrum of *Chaetodon* vary in amplitude and frequency with depth at their territory locations in the field, and appear to differentially degrade the transmission of sound types used by *Chaetodon* for communication. Thus both the close social affiliations common among butterflyfishes and the evolution of the swim bladder horns in *Chaetodon* facilitate their short-range acoustic communication.

86-5 TULENKO, F.J.*; MASSEY, J.L.; DAVIS, M.C.; Kennesaw State University, University of Colorado-Boulder; ftulen1@kennesaw.edu

HoxD expression in the fin-fold compartment of Paddlefish and Catshark: Implications for the evolution of gnathostome paired appendages

How paired fins gave rise to limbs during the invasion of land is one of the compelling questions in vertebrate evolution. This morphological transition involved several key changes in appendage anatomy, including the loss of the fin-fold and dermal skeleton, and an elaboration of the distal endoskeleton to form an autopod with digits. *HoxD* cluster genes are active during both fin and limb development, and over the last two decades, have been the focus of much work aimed at gaining insight into the evolutionary origin of limb-specific morphologies. Here we characterize the expression of *HoxD* genes, as well as the cluster-associated genes *Evx2* and *LNP*, in the paddlefish *Polyodon spathula*, a basal ray-finned fish. Our results demonstrate a collinear pattern of nesting in early fin buds that includes *HoxD14*, a gene previously hypothesized to be isolated from global *Hox* regulation. Additionally, we show that in both *Polyodon* and the catshark *Scyliorhinus canicula* (a representative chondrichthyan) late phase *HoxD* transcripts are present throughout the fin-fold mesenchyme and co-localize with *And1*, a component of the fin-fold actinotrichia and dermal skeleton. These new data support an ancestral role for *HoxD* genes in patterning the fin-fold compartment of jawed vertebrates, and call for a reassessment of current models of fin/limb evolution. Furthermore, these data fuel new hypotheses about the evolution of cluster regulation and the potential downstream differentiation outcomes of distinct *HoxD*-regulated compartments.

41-2 TRINH, R. C.*; LAIDRE, M. E.; University of California, Berkeley, Dartmouth College; fish.r.awesome@gmail.com

Niche constructed shells are built for locomotion: enhanced mobility, in the sea and on land, by terrestrial hermit crabs

Species vary enormously in their locomotory ability. For shell-bearing organisms, like hermit crabs and gastropods, locomotion may be strongly constrained by the architectural properties of shells, which represent 'dead weight' that must be carried wherever the organism travels. Here we contrasted movement behavior in the wild, across three shell-bearing species: marine gastropods (*Nerita scabricosta*), marine hermit crabs (*Calcinus obscurus*), and terrestrial hermit crabs (*Coenobita compressus*). All three species use the same shells (originally derived from gastropod *N. scabricosta*); but only terrestrial hermit crabs architecturally remodel these shells through niche construction, creating lighter weight, more portable homes. We hypothesized that niche constructed shells are built for locomotion and therefore would facilitate enhanced travel by terrestrial hermit crabs, relative to the other two species, which use unremodeled shells. In field experiments, we released individuals of all three species into both marine and terrestrial environments, tracking their movement for 20 min. Both in the sea and on land, terrestrial hermit crabs traveled significantly further than either of the other two species, with displacements of over 50 m. In contrast, marine hermit crabs and gastropods showed no difference in displacement, and never exceeded 2 m from their starting point. Additionally, terrestrial hermit crabs traveled significantly further when starting on land vs. in the sea; whereas marine hermit crabs and gastropods showed no difference between environments. Terrestrial hermit crabs thus attain superior mobility using niche constructed shells, which are arguably more adaptive to a highly mobile life style on land in which resource availability is spatially unpredictable.

S5-6 TUNSTALL, P; RAPKIN, J; GAGE, M; HUNT, J; HOUSE, C.M.*; University of Exeter, Penryn, University of East Anglia, Norwich; C.M.House@exeter.ac.uk

A ROLE FOR STABILIZING SEXUAL SELECTION FOR THE EVOLUTION OF MALE AND FEMALE GENITALIA IN A FLOUR BEETLE (*Tribolium castaneum*)

Male genitalia are recognised as being the most diverse morphological structures in the animal kingdom. There is also evidence of complexity in female genitalia suggesting that female genitalia are also subject to strong selection yet studies of the evolution of genitalia have largely neglected to investigate this variation. The main hypotheses that have been proposed to explain the elaboration of male and female genital morphology include the lock and key and sexual selection hypotheses. These contrasting hypotheses make different predictions about the form of selection on genitalia but all predict the co-evolution of female genital morphology or sensory traits that interact with male genital morphology. We use multivariate selection analysis to describe the form of selection on male and female genitalia in the red flour beetle *Tribolium castaneum* that is imposed during mating and test for a correlation between male and female genital structures. Moreover, if sexual selection is an important driver of genital diversification the strength of this correlation should reflect the intensity of sexual selection on male and female genital structures that interact. We investigate the effects of elevated and relaxed sexual selection on the coevolution of male and female genitalia using experimental evolution lines of *T. castaneum*. We show that stabilizing sexual selection tends to drive the evolution of male and female genital morphology to a fitness peak. Our study also suggests that female genitalia may select on variation in aspects of male genitalia, supporting the notion that studies of male and female genitalia are important for our understanding of the evolution of animal genitalia.

62-6 TWEETEN, K.A.*; MORRIS, S.J.; St. Catherine University; katweeten@stkate.edu

Flow Cytometry for Analysis of DNA Ploidy in *Lumbriculus*

Variations in DNA ploidy have been observed in *Lumbriculus*, a freshwater oligochaete, as well as in other annelids. Interpretation and application of experimental results using these animals may be impacted as ploidy levels affect protein expression, reproductive behavior and response to stressors. Ploidy is typically determined by chromosome spreads, a time-consuming and inefficient method. We adapted flow cytometry protocols used on vertebrates and plants to determine ploidy levels in *Lumbriculus*. Worms were from an Environmental Protection Agency lab, Aquatic Foods, and natural habitats. To isolate nuclei, *Lumbriculus* homogenates were filtered to remove cell debris and centrifuged through density gradients. Nuclei were recovered, treated with RNase, and stained with propidium iodide. Flow cytometry of the labeled nuclei showed *Lumbriculus* from natural habitats in Minnesota and Iowa were diploid. Populations from natural habitats in California were highly polyploid as were the EPA and Aquatic Foods worms. Flow cytometry results were verified using chromosome spreads, confirming that flow cytometry provided a rapid, reliable way to determine *Lumbriculus* ploidy levels. We anticipate that this method could readily be applied to analysis of DNA content in other annelids. To further compare the populations, proteins in worm homogenates were subjected to isoelectric focusing gel electrophoresis. Distinct protein profiles were seen; one was shared in common by the diploid worms, the other was characteristic of polyploid populations. Diploid worms could also be distinguished from polyploid worms based on differences in hemoglobin linker proteins, modes of reproduction, and metabolic rates. The results further support classifying the diploid and polyploid forms of *Lumbriculus* as different species.

75-5 URBAN, D.J.*; ANTHWAL, N.; TUCKER, A.S.; SEARS, K.E.; Univ. of Illinois at Urbana-Champaign, King's College London; durban2@illinois.edu

An Earful of Jaw, Then and Now: Insights from Evolutionary Developmental Biology

During synapsid evolution, postdentary elements in the reptilian jaw transitioned into the middle ear of mammals. Though this astounding change is well documented in the fossil record, questions regarding the developmental sequence that drove the ossicular transition still remain. At birth, modern marsupials possess a very reptilian jaw joint with functional articulation between the articular and quadrate. These elements will later become the malleus and incus, respectively, of the middle ear. This entire transition occurs postnatally, and represents a natural system for comparison with the fossil record. We utilized *Monodelphis domestica* as a model organism, and traced the development of ossicular structures as they separate from the jaw and fully incorporate into the middle ear. Micro-CT scans throughout development and three-dimensional reconstructions show decreasing size and rearward movement of ossicles are false illusions created by continued growth and expansion of the surrounding skull elements. Cryosections and immunohistochemistry reveal separation of Meckel's cartilage from the malleus occurs at postnatal day 20 and is facilitated by apoptosis. Additionally, laser capture microscopy and RNA sequencing identify differential gene expression at the time of separation and breakdown of the connecting Meckel's cartilage. The morphological changes are facilitated by an upregulation of cartilage resorption genes paired with simultaneous downregulation of proliferative genes. Finally, marsupial developmental stages were compared with the known fossil record of early mammals exhibiting transitional forms of the definitive mammalian middle ear in order to resolve the question, in this instance, of whether ontogeny is truly recapitulating phylogeny.

27-5 UHRIG, E.J.*; FRIESEN, C.R.; BLAKEMORE, L.A.; LUTTERSCHMIDT, D.I.; MASON, R.T.; Oregon State University, University of Sydney, Portland State University; uhrige@science.oregonstate.edu

Influence of an acute immune challenge on reproductive investment and hormone levels in male red-sided garter snakes, *Thamnophis sirtalis parietalis*

Reproductive activities and immune functions are energetically costly and frequently exhibit tradeoffs. When a pathogen is encountered, immune activity may increase at the expense of reproduction, or reproductive investment may be maintained at the expense of immunity. As the endocrine system influences both reproduction and immunity, tradeoffs are often hormonally-mediated. While immune-reproductive tradeoffs have been widely studied in taxa with associated breeding patterns, few studies have investigated such tradeoffs in dissociated breeders where gametogenesis and peak sex steroid hormone levels occur outside the breeding season. In the current study, we investigated immune-reproductive tradeoffs in a dissociated breeder with well-studied reproductive behaviors and physiology: the red-sided garter snake (*Thamnophis sirtalis parietalis*). During the breeding season, we injected male snakes with lipopolysaccharide (LPS) or saline. LPS, a bacterial endotoxin, elicits an immune response, but is non-pathogenic. Following treatment, we conducted mating trials and collected blood samples for hormone analyses. Our results indicate that LPS-treated males substantially reduce reproductive investment as indicated by decreased courtship and mating success. LPS-treated males that mated produced smaller copulatory plugs than control males, but sperm counts were unaffected by treatment. The immune-reproductive tradeoff appears to be hormonally-mediated as LPS-treated males had elevated corticosterone and depressed androgen levels. Our results show that dissociated breeders are not free from tradeoffs, although the nature of the tradeoff may be influenced by their breeding pattern.

57-2 USHERWOOD, JR.*; HUBEL, TY; The Royal Veterinary College, London; jusherwood@rvc.ac.uk

Scaling of power and work accounts for scaling of animal posture, and walking and running mechanics from toddler to adult.

Larger terrestrial animals tend to support their weight with more upright limbs. This makes structural sense, reducing the loading on muscles and bones, which is disproportionately challenging in larger animals. However, it does not account for why smaller animals are more crouched; instead, they could enjoy relatively more slender supporting structures or higher safety factors. Here, an alternative account for the scaling of gait and posture is proposed. If the costs of locomotion are related to the volume of active muscle, and the active muscle volume required depends on both the work and the power demanded during the push-off phase of each step (not just the net positive work), then the disproportional scaling of requirements for work and push-off power are revealing. Animals with shorter legs and briefer push-off periods are challenged to provide the power (not the work) required for push-off. This can be ameliorated by having disproportionately long push-off periods, accounting for the crouched stance of small animals. We find that many aspects of gait kinetics and kinematics scale with speed and size in humans in a manner consistent with minimizing muscle activation required for whichever is more demanding between mechanical work and power: spreading the duration of muscle action reduces activation requirements for power, at the cost of greater work demands. The gaits of small children, and the greater deviation of their mechanics from work-minimising strategies, may be understood as appropriate for their scale, not merely as immature, incompletely developed and energetically sub-optimal versions of adult gaits.

35-5 VAN BREUGEL, F*; DICKINSON, M; Caltech; floris@caltech.edu

Mysterious diving flies of Mono Lake

In late summer, the shores of Mono Lake, California, are bustling with small flies, *Ephydra hydropyrum*, which dive under water inside small air bubbles to feed. After returning to the surface, the flies pop out of the highly alkaline water and fly away completely dry. Despite Mark Twain's charismatic description of them in 1872, we still do not understand how these tiny flies are able to perform this remarkable feat. We have begun to probe the underlying biophysics of this phenomenon using a combination of highspeed video, micro force measurements, and simple surface chemistry manipulations. Like many insects, *Ephydra* are covered in waxy coatings and small water repellent hairs. This adaptation allows insects such as the water strider to glide across the surface of ponds by floating on cushions of air trapped by microscopic hairs on their legs. In order to crawl underwater, however, *Ephydra* must overcome these strong surface tension forces that are 10-20 times their body weight. Specially adapted claws on their tarsi allow them to crawl through the air-water interface on the surface of Mono Lake's tufa formations. Once satiated and ready to return to the air, they must come free of the water without wetting their wings, which would attach them helplessly to the water surface where they would quickly succumb to predation. Here, the high surface tension forces help them escape the water by gently catapulting the flies free of the surface so they can safely take flight. Making a safe exit, however, requires that they break their bubble right side up, which they accomplish through actively controlling their ascent with their legs. In addition to understanding the most critical adaptation of this key species, determining the physics underlying their behavior may find applications in waterproofing materials and amphibious technologies.

98-2 VAN SANT, M.J.*; OUFIERO, C.E.; Cameron University, Towson University; mvsant@cameron.edu

Repeatability and Variation in Cutaneous Water Loss at Different Times of Day and Temperatures in *Sceloporus consobrinus*

Although reptiles have likely evolved mechanisms to reduce cutaneous water loss (CWL), this remains the main route of evaporative water loss in many species. Despite the importance of CWL to reptiles few studies have quantified the amount of variation in this trait, including its relation to temperature and diel variation. We measured CWL and calculated the skin's resistance to water loss (R_s) of twenty male *Sceloporus consobrinus* collected from southwestern Oklahoma in 2014 and 2015. The goals of this study were to determine 1) how rates of CWL and R_s are affected by temperature, 2) how rates of CWL and R_s vary throughout the day and 3) the repeatability of CWL within a sampling period. To determine the effect of temperature we recorded three measurements of CWL on the dorsal and ventral side, surface temperature, room temperature and relative humidity at 24°C and 35°C on separate days using a Delfin vapometer. We also measured the same parameters on each lizard three times over seven hours while they behaviorally thermoregulated in their enclosures. We found that 1) lizards at 35°C had lower CWL and higher R_s than lizards at 24°C, but there was a lack of repeatability for both traits across temperatures. We also found 2) a difference in CWL and R_s at different times of the day with inconsistent repeatability measures. Lastly, we found 3) significant repeatability of CWL and R_s within each measuring period as measured by the intraclass correlation coefficient. The lack of repeatability across certain times of day and at different temperatures suggests to us that lizards may be using physiological mechanisms such as altering peripheral blood flow to reduce rates of water loss when in a desiccating environment.

109-4 VAN HEUKELEM, L.D.*; SMITH, C.M.; Univ. of Hawaii i at Manoa; laurendv@hawaii.edu

Can we control invasive algal abundances with a native herbivore, in mixed stands of native/invasive algae?

Tropical island ecosystems and their human residents depend on the multiple stable-state reef community that provides food, protection from storms and income via tourism. Worldwide, overfishing and eutrophication via urbanization of nearby lands have led to record losses of coral dominated reefs. On so-called urban reefs, impacts of eutrophication push algal growth rates above rates of herbivore grazing. In most cases, few grazers or their guilds are left. Such appears to be the case for the Waikiki reef region, where the marine plant community is dominated by the invasive species *Acanthophora spicifera*, *Avrainvillea amadelpha*, and *Gracilaria salicornia*. In an effort to identify ways to restore this reef to a better balance, feeding preferences of the native urchin *Tripneustes gratilla* were examined to establish feeding preferences on native vs. introduced seaweeds found in the Waikiki region. Urchins were placed in tanks with continuous flow and offered a pair-wise combination of a native and an invasive algal species over a 24 hour period at the Anuenue Fisheries Research Center. In total, 15 urchins were used and three replicate runs were conducted between Oct. 25th and Nov. 15th, 2014. In most cases, the urchins grazed the invasive species *A. spicifera* and *G. salicornia* more readily than native species with the exception of native *Microdictyon setchellianum* and *Gracilaria cornopifolia*. Future work will include caging experiments in areas of mixed plant assemblages to test the outcomes of our previous studies. Such tests are important to validate the use of urchins as biocontrol agents for regions with mixed native and invasive algal assemblages.

104-5 VANDENBROOKS, JM*; ARTHUR, K; GSTREIN, G; Midwestern University; jvandenbrooks@midwestern.edu

Using confocal imaging to understand the effect of atmospheric oxygen on insect respiratory systems

Recent geochemical models suggest that oxygen has varied from 12% to 31% over the last 500 million years. These changes in atmospheric oxygen would have had multiple effects on the physiology and evolution of organisms living at that time. We have hypothesized that the unique tracheal respiratory system of insects may have made them uniquely susceptible to changes in atmospheric oxygen. Previously, we have shown that as some insects increase in body size, their tracheal system increases at a faster rate and may eventually limit the maximum body size of insect species. We have also shown that rearing oxygen is inversely correlated with tracheal diameters in several groups of insects. However, a limit of these studies has been a focus on only the larger tracheae that drive the bulk flow through the system. Here we use confocal imaging to look at the effect of rearing oxygen on the smallest component of the respiratory system - the blind ended tracheoles. We reared *Drosophila melanogaster* under three different oxygen concentrations (12%, 21%, and 31%) that match the variation seen over geologic time. We imaged the tracheal and tracheolar network taking advantage of their auto-fluorescent properties and used these images to reconstruct high resolution 3D models of the respiratory system. We then measured tracheal and tracheolar diameters and characterized the network branching properties of the flight muscle in *D. melanogaster* reared under the three oxygen levels. We have identified effects of rearing oxygen on the density of tracheoles, tracheolar diameters, and branching patterns. All of these have major impacts on oxygen delivery and may be a major driver in the modulation of insect body size by atmospheric oxygen.

22-6 VANDEPAS, LE*; AMEMIEA, CT; University of Washington, University of Washington, Benroya Research Institute;

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Chitin distribution in the anemone *Nematostella vectensis*, a species lacking hard skeletal structures

Chitin is an abundant biopolymer comprised of repeating N-acetylglucosamine molecules which is used in building hard structures such as arthropod exoskeletons, annelid chaetae, and the endoskeletons of some corals. Our lab's recent finding that chitin is endogenously produced in vertebrates suggests that this biopolymer may serve many additional roles in biology. The distribution of chitin and its role in the physiology, anatomy, and development of the anemone *N. vectensis* (which lacks a hard endo- or exoskeleton or other overt hard structures) are not known, despite the fact that a *bona fide* chitin synthase gene was recently described in this species. We used affinity histochemistry to show that the tubules of some cnidae in *N. vectensis* are chitinous. We also demonstrate that treatment with diflubenzuron, an active ingredient in common aquaculture pesticides, stunts regeneration in *Nematostella* in a dose-dependent manner. These results suggest an expanded role for chitin in cnidarians that is not morphologically structural.

124-5 VASQUEZ, M.C.*; MARTINEZ, D.A.; LUQUIN, M.G.; TOMANEK, L.; California Polytechnic State University, San Luis Obispo; *mcvasque@calpoly.edu*

Proteomic responses of two mussel congeners to hypo-salinity, aerial heat and sirtuin inhibition: a multiple-stressors approach

Understanding physiological tolerances of marine organisms to environmental stress is key to predicting species adaptability in a changing global climate, and when investigated, is most accurate under a multiple-environmental stressor approach. Congeners of the intertidal mussel genus *Mytilus* vary in their physiological tolerances to environmental stress. *M. galloprovincialis*, an invasive species from the Mediterranean, is overall more stress tolerant and can withstand elevated heat exposure, but it is vulnerable to hypo-salinity, while the native Pacific coast *M. trossulus* is more tolerant to hypo-saline conditions but vulnerable to heat stress. Recent findings suggest that sirtuins, a group of NAD⁺ dependent deacetylases, influence the environmental stressor tolerances in these two mussel species. Therefore, the purpose of this study was to investigate the combined effect of hypo-salinity and aerial heat stress on the proteome of *M. galloprovincialis* and *M. trossulus* while also investigating the role of sirtuins in influencing stress tolerance. Mussels were acclimated to tidal and circadian cycles for 3 weeks after which mussels were exposed to fully factorial combinations of salinity (34 or 29 ppt), aerial heat (18 or 32°C) and sirtuin inhibition (+/- suramin and nicotinamide) over the course of a 6 h high tide and 6 h low tide event. Gill tissue was collected after each stress exposure and following a 6 h recovery in control conditions (34 ppt, 18°C and no sirtuin inhibition). A preliminary analysis suggests that the congeners differ widely in how molecular chaperones of the endoplasmic reticulum respond to the combined exposure to heat and hypo-salinity.

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Incorporating short-term temporal variability into model projections of performance and population dynamics.

Over the past two decades ecological theoreticians have begun to incorporate environmental attributes such as temperature into the classical models that underpin a variety of ecological processes and systems. However, as a starting point, much of this work has focused on the impact of altering the static environment as a proxy for climate warming and other gradual change. Although this approach has yielded important insight, it has largely ignored the role of environmental variability at the shorter-term time-scales that maintain ecological systems in a non-equilibrium state. Using a series of simple theoretical models I demonstrate how the different statistical moments (e.g. mean, variance, skewness, etc.) can impact the performance of a population, its risk of extinction and various aspects of its population dynamics. Coupling this information to a well-studied set of 38 ectothermic insects and other more recently collected dataset on thermal performance, I demonstrate that the interaction between the mean and variance of future climate is the most important factor driving population performance and extinction risk. This work highlights the importance of considering short-term fluctuations in temperature when making predictions about the risk of altered climatic conditions. Yet, it also highlights important gaps in our knowledge that link short-term variation to the fundamental rates that govern population dynamics.

64-5 VATS, A*; PRASAD, P; PANDEY, C; RAJA, S V; SANE, S P; National Centre for Biological Sciences, Bangalore, Indian Institute of Science, Bangalore; *amritanshv@ncbs.res.in*

Sensory cues affecting mound building behavior in termites

Termites of the species *Odontotermes obesus* are found widely in India and their presence is visible due to the large over-ground mounds that they build across the landscape. These mounds house the entire colony, which includes the queen, worker and soldier termites, and the brood. In addition, the termites also farm a specific variety of fungus which is commensal with the termites, and may help them break down the cellulose-rich food. The precise function of the mound architecture is the subject of some debate, and it has been argued that its structure serves physiological functions such as thermoregulation for the entire colony, or gas exchange. If the mound structure indeed serves an important function, then we hypothesized that termites must have the ability to sense and repair any breaches in their mound architecture. A small breach in the mound wall is quickly detected by the worker class and repaired. This behavior is consistent and provides us with an assay to investigate various phenomena pertaining to mound building, investigate the sensory cues involved, and measure the response to external environmental factors and soil conditions. Here, we describe a method of measuring this behavior, and develop various assays that exploit this behavior to gain insights into the sensory cues used by termites. We also present a mathematical model for the mound repair behavior, and show that although worker termites do not possess well-defined eyes, they are capable of sensing luminosity via some light-mediated extra-ocular mechanism.

121-6 VEA, IM*; TANAKA, S; SHIOTSUKI, T; JORAKU, A; TANAKA, T; MINAKUCHI, C; Nagoya University, National Institute of Agrobiological Sciences, National Institute of Agrobiological Sciences; *isabelle.vea@gmail.com*

Role of the Juvenile Hormone in establishing extreme sexual dimorphism in scale insects (Hemiptera: Coccoomorpha)

Scale insects are important plant pests with a peculiar post-embryonic development leading to an extreme sexual dimorphism. The wingless juvenile-like adult females result from traditional hemimetabolous development, whereas males develop through neometaboly, a type of metamorphosis including quiescent non-feeding stages where wings and other adult features develop. The latter is reminiscent to complete metamorphosis and its understanding would provide insights into the evolution of holometaboly. Our study aimed at examining the potential role of the juvenile hormone (JH) in this sexual dimorphism and wing development in males. We assessed the expression profiles of genes involved in JH signaling pathway during male and female development of the Japanese mealybug, *Planococcus kraunhiae* (Kuwana) (Pseudococcidae). Quantitative RT-PCR of JH receptor and partner *Methoprene-tolerant* and *Taiman*, as well as early response genes *Krüppel-homolog1* and *Broad* showed notable differences, especially during the embryonic stage and from the middle of the second-instar nymph, when males and females start to differentiate. JH analogue treatment on male quiescent stages allowed to identify the *Broad* copy and isoform involved in JH signaling. Our results suggest that JH may play a role in the sexual differentiation in mealybug post-embryonic development.

124-1 VELOTTA, J.P.*; JONES, J.; WOLF, C.J.; CHEVIRON, Z.A.; University of Montana, Governors State University; *jonathan.velotta@gmail.com*

Mechanisms of adaptation to cold-hypoxia in high altitude deer mice: the role of non-shivering thermogenesis

For small mammals living at high altitude, aerobic heat generation (thermogenesis) is essential for survival during prolonged periods of cold, but is severely impaired under conditions of hypobaric hypoxia. Recent studies in the deer mouse (*Peromyscus maniculatus*) have revealed adaptive enhancement of thermogenesis in high (4350 m)-compared to low (430 m)-altitude populations under hypoxic cold stress, an enhancement that is driven by greater aerobic performance of muscles used in shivering, and upregulation of associated O₂ diffusion and utilization pathways. To more fully understand the mechanistic basis of adaptive enhancement of thermogenesis in high altitude deer mice, we investigated the role of non-shivering thermogenesis (NST) in brown adipose tissue (BAT), which can account for up to 75% of total thermogenic performance in rodents. To do so, we measured NST and characterized BAT transcriptional profiles of high- and low-altitude deer mice that were 1) wild-caught and acclimatized to their native altitude, and 2) born and reared at low-elevation. We found that NST performance is enhanced in wild-caught high altitude deer mice, a difference that is associated with upregulation of genes involved in several hierarchical pathways at BAT: differentiation and proliferation of brown adipocytes, vascularization of BAT, metabolism of fatty acids, and the regulation of uncoupling protein 1 expression. Constitutive between-population differences in expression of hemoglobin and heme synthesis genes were detected in wild and lab-reared mice. Our results suggest that both plastic and genetic mechanisms make important contributions in the adaptation to the twin stressors of cold and hypoxia at high altitude.

69-1 VELASCO, B.; CELA, B.; FIELDS, P. A.*; Franklin and Marshall College; *peter.fields@fandm.edu*

Biochemical assessment of the coral-dinoflagellate symbiosis: Enzymes of each partner show evidence of adaptation to different thermal regimes

Tropical reef-building corals obtain most of their energy in the form of reduced carbon provided by endosymbiotic algae (dinoflagellates of the genus *Symbiodinium*). However, during times of physiological stress, for example high temperature, corals can expel their symbionts in a process termed bleaching, which often is fatal to the coral. Bleaching events have become more common in the past few decades, and have been associated with a number of anthropogenic impacts, including rising sea surface temperatures. However, the causes of the breakdown in the symbiosis are still poorly understood. We hypothesize that a contributing factor is a difference in adaptation temperature between the partners, which would be apparent in differences in temperature-dependence of enzyme kinetics. We are attempting to determine the optimal physiological temperature range of each member of the symbiosis by sequencing and expressing common metabolic enzymes and measuring kinetic parameters (K_m , k_{cat} , Arrhenius activation energy), to determine whether enzymes from these taxa have similar functional responses across a physiologically realistic range of temperatures. In addition, we are comparing enzymes from *Symbiodinium* clades C and D, the latter of which may be more resistant to bleaching than the former. Our initial results indicate that coral (*Acropora millepora*) and *Symbiodinium* clade C glyceraldehyde-3-phosphate dehydrogenases (GAPDHs) indeed are adapted to different thermal regimes, with the coral enzyme having greater sensitivity to temperature, evidenced by a higher Arrhenius activation energy and a more rapid increase in K_m and k_{cat} as temperature increases.

3-4 VELTEN, B. P.*; RAMENOFKY, M.; WELCH, JR., K. C.; University of Toronto, University of California, Davis, University of Toronto, Scarborough; *brandy.velten@mail.utoronto.ca*
Alterations of pectoralis myosin heavy chain expression as White-crowned sparrows prepare for and complete spring migration

Migratory birds undergo a variety of physiological changes to support long distance flight. Numerous studies have focused on the shifting metabolic demands and fuel utilization of avian flight muscle during migration, however, relatively few focus on how birds may morphologically meet the dynamic mechanical challenges of migratory flight. Myosin is a protein integral to muscle function, and the contractile properties of muscle are strongly linked to the isoforms of myosin present within fibers. In this study, we examined the expression of myosin heavy chain (MHC) in the pectoralis of the migratory white-crowned sparrow (*Zonotrichia leucophrys gambelii*), using SDS-PAGE electrophoresis and western blots. Flight muscle samples were collected over three life history stages: February - winter condition, April - spring departure on wintering grounds, and May - spring arrival on breeding grounds. MHC expression changed substantially throughout the 3 stages. Overwintering birds expressed a single novel MHC isoform that does not match isoforms previously identified in the muscles of the domestic chicken. At spring departure, MHC expression included two isoforms: the novel isoform and one similar to the chicken adult fast isoform. Finally, at spring arrival, the MHC isoforms found in April specimens remained present but the relative proportions of the two isoforms differ with a higher percentage of the adult fast isoform (34.6% to 57.1%). To the best of our knowledge, this study is the first time a change in pectoral MHC isoform expression has been observed in avian species and may represent a specific adaptation for long distance, migratory flight. Further, this change, if present in other species, may provide a useful diagnostic tool to monitor changes in avian migratory status.

38-6 VERDES, A.*; GORSON, J.; MEHR, S.; GRUBER, D.; HOLFORD, M.; Graduate Center, City University of New York, SUNY College, Old Westbury, New York, Baruch College, City University of New York, Hunter College, City University of New York; *averdes@gradcenter.cuny.edu*

Diversity and Molecular Characterization of the Bearded Fireworm Venom

Certain annelid lineages use venom for predation or defensive purposes. Amphinomids (Amphinomida, Annelida), more commonly known as fireworms, constitute a group of marine polychaetes characterized by having defensive calcareous chaetae that break off upon contact and deliver an inflammatory substance, which can cause skin irritation and a painful burning sensation. However, a venom producing tissue has not been identified and knowledge on fireworm venom is scarce, with only one known active toxin, complanine, isolated from *Eurythoe complanata*. To date, neither complanine, nor any other potential toxic components of fireworm venom have been characterized on a molecular level. Here we use next-generation sequencing to analyze the transcriptomic profile of *Hermodice carunculata* body tissue and identify for the first time putative venom toxins in this species. A great diversity of transcripts coding for putative peptide toxins and venom-related proteins are expressed in *H. carunculata* transcriptome. These transcripts represent a variety of toxin classes that have been repeatedly recruited into animal venoms, including C-type lectins, Kazal domain protease inhibitors, Gigantoxin-like neurotoxins and Ryncolin-like peptides. Interestingly, several identified transcripts have specific domains homologous to the snake three-finger toxin (3FTx) and appear to be unique to *H. carunculata*. While proteomic and functional studies are needed to confirm the putative *H. carunculata* toxins identified, our results suggest that venom has also convergently evolved in fireworms, which use effective and complex venoms to deter predators.

129-5 VINAUGER, C.*; LAHONDÈRE, C.; LUTZ, E K; LOCKE, L T; RIFFELL, J A; Univ. of Washington, Seattle, Univ. of Washington; *vinauger@uw.edu*

Olfactory learning in the vector mosquito *Aedes aegypti*

Olfactory learning in blood-feeding insects, such as mosquitoes, could play an important role in host preference and disease transmission. However, standardized protocols allowing testing of their learning abilities are currently lacking, and how different olfactory stimuli are learned by these insects remains unknown. Using a Pavlovian conditioning paradigm, we trained individuals and groups of *Aedes aegypti* mosquitoes to associate an odorant conditioned stimulus (CS), with a blood reinforced thermal stimulus (unconditioned stimulus; US). Results showed that the success of olfactory conditioning was dependent upon the CS and that mosquitoes' ability to learn could interfere with the action of the insect repellent DEET. Results demonstrated that pre-exposure and the presence of DEET in the CS reduced the aversive effects of DEET. In addition, using cold-shock treatments and a protein synthesis inhibitor the nature of the formed memories was explored. Together, these results show that learning is a critical component in odor responses in *Ae. aegypti*, and provide the first evidence for the functional role of different memory traces in these responses.

S9-5 VICKERS, MJ*; ARNOLDI, JF; HART, S; SCHWARZKOPF, L; Centre national de la recherche scientifique, James Cook University, James Cook University; *vickers.mathew@gmail.com*

Individual heterogeneity in thermoregulatory behaviour under strict thermal regimes in a tropical skink.

Ectotherms leverage environmental temperature variability in both space and time to thermoregulate behaviourally. Increasingly, we are aware that spatial and temporal variability as well as mean temperature are important: we know that two habitats with the same mean and variance in temperature are not necessarily equal, but how to evaluate this inequality in terms of space and temperature use, and body temperature achieved is still being explored. The spatial and temporal distribution of resources, such as temperature, allow habitat partitioning and niche realisation, and understanding this thoroughly will be important in our understanding of how organisms share the available space, and hence our predictions of how organisms will be affected by climate change. We conducted an experiment using two thermal arenas with 250W of light arranged as either one single patch or five separate patches. We monitored the movements of two sympatric heliothermic skinks in each arena. Using ergodic theory, we ask whether individuals use the same space in the same way, whether they achieve the same limit distribution of body temperature, and at the same rate, and whether this distribution is distinct from expected as estimated by a null model.

119-6 VOLKEL, SL; VOLKEL, Shea; NOAA Hollings Scholarship Program, NMFS NEFSC Maine Field Station, Orono, ME, National Oceanic and Atmospheric Administration (NOAA) , University of North Carolina at Wilmington; *shea.volkel@noaa.gov*

Fish distribution during smolt migration in the Penobscot Estuary, ME

Estuaries are complex and dynamic ecosystems. The Penobscot Estuary is particularly important because it harbors a suite of imperiled diadromous fish species. In order to properly manage these populations, it is imperative to understand their distribution and ecology. My study focuses on May because endangered Atlantic salmon migrate seaward then. Successful emigration of these smolts is important to the population's overall fitness. One potential way to increase the likelihood of migratory success (survival) is to decrease their risk of predation. Assuming that predators in this system are generalists, overall smolt predation may be reduced by having a larger selection of alternative prey (other fish species). We hypothesize that diadromous fish abundance is increasing as a result of recent (2012-2013) dam removals. To explore this hypothesis, I used hydroacoustic methods to characterize the distribution patterns of alternative prey (TL=10-30 cm). I found that peak fish abundances occurred in the mid-estuary, especially during mid-May, and depth distribution patterns varied weekly. By understanding these seasonal, longitudinal, and vertical distribution patterns, I explored potential interactions of other fish populations as prey buffers to emigrating smolts.

36-3 VOLTZOW, J.; Univ. of Scranton, PA;
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The origin of Darwin's metaphor of the wedges

In the first edition of *On the Origin of Species* Darwin used what is known as "the metaphor of the wedges" to illustrate how competition between species might serve as a driving force for natural selection. A careful reading of Darwin's notebooks, letters, manuscripts, and publications indicate that this striking image appears and disappears multiple times in the body of his writings from his geological descriptions through the transmutation notebooks and eventually to the *Origin*. I propose that the magnificent vistas of the Andes that Darwin viewed as he crossed the cordilleras during the *Beagle* expedition were the original inspiration for this imagery and that his experience there had a profound impact on his later work. Thus this metaphor represents an important link between Darwin's early geological observations and his development of the theory of evolution by natural selection.

23-6 VON DASSOW, Y.J.; Duke University, Beaufort, NC;
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Not dead yet: survival of embryos in highly desiccated intertidal egg masses

Desiccation is a potential problem for all life stages of intertidal animals, particularly early stages that are not capable of moving around a habitat. A common benthic reproductive strategy is to encase eggs in gelatinous masses during development. Because egg masses vary hugely in shape, size, and attachment method, they vary in desiccation resistance. The opisthobranch gastropod *Haminoea vesicula* attaches its flat, ribbon-shaped egg masses to a variety of benthic substrata. In False Bay, San Juan Island, Washington, USA, *H. vesicula* has a behavioral adaptation to prevent benthic egg masses from desiccation: adults preferentially lay egg masses on seagrass or other substrata in tide pools. However, individual masses and clumps of masses can detach and drift due to current movements. In False Bay, the worst-case scenario for desiccation involves a single egg ribbon stranded on a dry sand bar between tide pools, where it is exposed to full sun and wind for the duration of low tide (approximately 6 hours, maximum sediment temperature of 35°C in summer). Regardless of location, the egg mass will eventually be rehydrated by the incoming tide. I deployed egg masses of different ages under these field conditions. After rehydration, older embryos (spinning stages) showed higher rates of survival than newly-laid embryos (<24 hours old), but for both stages the survival rates were frequently over 25%. In the laboratory, up to 25% of embryos survived in egg masses that had lost approximately 70% of their weight after desiccation under lamps. Although many surviving embryos in both experiments appeared unhealthy, these data show that egg mass stranding is not necessarily fatal to embryos. The embryos may be able to survive a far greater range of conditions than they normally encounter, compensating for their lack of ability to move.

33-5 VON DASSOW, M; Duke Univ. Marine Lab;
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The echinoid blastula: linking biomechanics to development-environment interactions

The response of hatched sand dollar blastulae to salinity variation presents a simple case study of how biomechanics can influence the sensitivity of morphogenesis to environmental variation. The formation of a hollow blastocoel cavity, surrounded by a cell layer, is an important developmental event in diverse taxa. Salinity variation occurs in many habitats, and drives changes in cell size. Mechanical coupling between cellular and non-cellular parts of the embryo will control how such cell size changes affect embryo shape and proportions. I compared effects of salinity on the blastocoel to predictions for hypothesized mechanisms of blastocoel expansion and size control. The blastocoel-to-cell volume ratio decreased with salinity-driven cell swelling. This indicates that non-cellular components of the embryo are mechanically important. However, it is inconsistent with models in which the matrix layer surrounding the embryo (the hyaline layer) resists expansion with a yield stress (i.e. plastic deformation models). Hatched blastulae resisted isotropic compression by high molecular weight osmolytes, indicating that the blastocoel can exert pressure to support the cellular and hyaline layers. All observations were consistent with models in which blastocoel forces are balanced by elastic hyaline stiffness and/or cell stiffness. These models predict that salinity-driven cell swelling will alter blastocoel pressure. Because increased blastocoel pressure can inhibit invagination of the endoderm during gastrulation, I hypothesize that the physics of blastocoel expansion modulates effects of salinity on the sensitivity to gastrulation defects. Because successful gastrulation is necessary for survival of subsequent developmental stages, this might influence selection on the mechanism of blastula expansion.

12-1 VORIS, A; ANDERSON, EJ; GARBORG, CS; FLAMMANG, BE*;
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Using image motion enhancement to uncover the mechanics of remora adhesion

Remoras are fishes well known for their ability to stick to other marine organisms, but the mechanics of their adhesion is not well-understood. Attachment of a remora to a surface is a rapid action often concealed by the adhesive disc coming into contact with the host surface. We recorded video of remoras attaching, detaching, repositioning, and sliding on a clear surface and used Eulerian Video Magnification (EVM) to amplify motion of the disc that was not visible otherwise. EVM analyzes color variation over time in a video sequence and resolves a frequency of amplification that matches the frequency of variation. We found that the four different behaviors were characterized by distinct lamellar motion patterns and regionalization of disc action. Regionalization of the disc motion is likely important to maximize water expulsion during attachment and to permit repositioning of the disc without fully detaching.

125-1 VOYLES, J*; PEREZ, R; ROLLINS-SMITH, L; RICHARDS-ZAWACKI, C; University of Nevada, Reno, Vanderbilt University, University of Pittsburgh; jvoyles@unr.edu
Seasonal patterns in innate immune effectiveness against *Batrachochytrium dendrobatidis*

Amphibians are declining worldwide and are currently regarded as one of the most threatened classes of vertebrate animals. Many of these declines are due to the disease chytridiomycosis, which is caused by the fungal pathogen, *Batrachochytrium dendrobatidis* ("Bd"). In many parts of the world, infection patterns and disease dynamics of chytridiomycosis exhibit seasonal fluctuations. Previous studies have primarily focused on seasonal temperature effects on Bd (i.e., how temperature can limit Bd growth), while few investigations have focused on seasonal shifts in host immune responses. We conducted seasonal (wet and dry) post-epidemic surveys in 2013-2014 in two populations of the Common Rocket Frog (*Colostethus panamensis*), a species known to be susceptible to chytridiomycosis. We sampled for the prevalence and intensity of the pathogen (Bd), recorded microhabitat temperatures and collected skin secretions to test for the efficacy of host immune defenses (Anti-microbial peptides; AMPs) across seasons. We found clear seasonal patterns in the ability of the AMPs to inhibit Bd growth in laboratory challenge experiments. Specifically, the AMPs collected from *C. panamensis* during the dry seasons were more effective at inhibiting Bd growth than those collected during the wet seasons and predicted host infection status better than microhabitat temperatures. These results suggest that seasonal differences in immune effectiveness against Bd may be playing an important role in seasonal disease dynamics in chytridiomycosis.

11-6 WAGNER, M*; CARTER, C; GALINDO, D; SWEET, E; LAKE, E; COOPER, W.J.; Washington State University; michel.wagner@wsu.edu

The role of thyroid hormone in the development of the functional morphology of feeding in the zebrafish

Many thousands of fish species possess mechanically dynamic feeding mechanisms that employ protrusion of the upper jaw. This motion is driven by the downward rotation of the mandible during mouth opening. Such functional integration between the upper and lower jaws requires the morphological integration of these structures. An immense number of fishes metamorphose from a distinct larval stage into a juvenile stage. It is after this metamorphosis that jaw protrusion typically appears. Since metamorphosis is strongly associated with a sharp increase in thyroid hormone levels, we sought to investigate the role of the thyroid hormone thyroxine (T4) in establishing jaw integration in the zebrafish (*Danio rerio*). To this end we examined two genetically modified lines: transgenic fish in which the thyroid gland can be ablated at a chosen stage; and the mutant line *opallus*, which has elevated levels of T4 (hyperthyroid treatment). We compared the cranial morphology and feeding kinematics of hyperthyroid fish with transgenic fish in which the thyroid gland had been ablated (hypothyroid treatment), non-ablated transgenic fish (control) and two strains of wild-type zebrafish (AB and TL). We found that manipulating T4 levels had a strong effect on both craniofacial morphology and feeding kinematics. Upper jaws were highly reduced in hypothyroid fish and they exhibited little to no protrusion. They were forced to rely heavily on hyoid driven suction feeding. Hyperthyroid fish tended to have enlarged lower jaws, but exhibited less pronounced changes in feeding kinematics. Feeding by hypothyroid fish more closely resembles that of pre-metamorphic zebrafish. This preliminary data suggests that T4 may play an important role in establishing the functional integration of fish jaws.

101-8 WACKER, D.W.*; KHALAJ, S.; JONES, L.J.; CHAMPION, T.; DAVIS, J.E.; MEDDLE, S.L.; WINGFIELD, J.C.; UW Bothell, Seattle U, Radford, U of Edinburgh, UC Davis; dwacker@uw.edu
Dehydroepiandrosterone (DHEA) Heightens Aggression and Increases Androgen Receptor and Aromatase mRNA Expression in the Brain of a Male Songbird

Dehydroepiandrosterone, or DHEA, is a testosterone/estradiol precursor, associated with avian aggression. Male song sparrows (*Melospiza melodia morphna*) show high aggression during breeding and non-breeding when circulating DHEA levels are also high, as compared to low aggression and low DHEA levels during molt. When artificially elevated, DHEA increases aggression in male song sparrows in the field and laboratory. We previously demonstrated that androgen receptor and aromatase mRNA expression are higher during breeding and/or non-breeding in brain regions associated with social behavior, but DHEA's potential role in mediating these changes remained unclear. Here, non-breeding male song sparrows were captured and held in the laboratory on short days (8L:16D). Birds were implanted with subcutaneous DHEA-filled or empty (control) implants for 14 days. DHEA implants increased circulating DHEA and testosterone levels, and aggression, as assessed by a laboratory-based simulated territorial intrusion. Brains of DHEA-implanted birds showed higher aromatase mRNA expression in the preoptic area (POA) and higher androgen receptor mRNA expression in the periventricular nucleus of the medial striatum (pvMSt) and the ventromedial nucleus of the hypothalamus (VMH). These experimental increases in androgen receptor and aromatase mRNA expression are largely consistent with previously reported seasonal increases associated with naturally elevated DHEA levels. This suggests that DHEA may facilitate seasonal increases in aggression in male song sparrows by up-regulating steroid signaling/synthesis machinery in a brain region-specific fashion.

S10-3 WAINWRIGHT, P.C.; Univ. of California, Davis; pcwainwright@ucdavis.edu

The ecology and evolution of organismal innovation

Innovations in functional morphology, physiology and biochemistry are thought to be a major force in shaping evolutionary patterns, with the potential to drive adaptive radiation and influence the evolutionary prospects for lineages. But the evolutionary consequences of innovation are diverse and usually do not result in adaptive radiation. What factors shape the macroevolutionary impact of innovations and can we predict what kinds of innovation will lead to diversity as opposed to those that result only in greater specialization? I present a framework for studying biological innovations in an evolutionary context. Innovations are discrete changes in functional mechanisms that enhance organismal performance. But because of the ubiquity of trade-offs in functional systems, enhanced performance on one axis often occurs at the expense of performance on another axis, such that many innovations result in more of an exchange of performance capabilities, rather than an expansion. Innovations may open up new resources for exploitation and their macroevolutionary consequences depend heavily on the adaptive landscape around these novel resources. I survey 12 innovations in the feeding mechanism of labrid fishes, an exceptionally successful and trophically diverse group of reef fishes, and explore their consequences for performance, patterns of resource use, and macroevolution. All of the innovations provide performance enhancements and result in changes in patterns of prey use. But 11 of 12 are associated with ecological specialization and only one has promoted further ecological diversification. Because selection acts on the specific performance enhancement and not on the evolutionary potential of an innovation, those that enhance diversity are rare. Thus the macroevolutionary potential of innovations depends critically on the interaction between the performance enhancement and the ecological opportunity that is exposed.

95-1 WAINWRIGHT, DK*; LAUDER, GV; Harvard University; dylan.wainwright@gmail.com

Three-dimensional structure of tuna scales: novel trabecular design and hypothesized function

Tunas have an area of enlarged scales behind the gill opening called the corselet. We find that these scales are not only larger in length and height, but also in thickness compared to scales more posterior on the body. Fish scales are normally a single ossified plate, but tuna corselet scales appear as hollow scales, with ossification on the top and bottom as well as ossified struts in the middle. This bizarre morphology looks similar to trabeculated bone, and has not been previously described in the literature. In this study we examine tuna scales using μ CT scans of scale patches from different areas on the bigeye tuna (*Thunnus obesus*). The thickened scales occur mostly on the anterior part of the body, on corselet and cheek areas, and small but thickened scales also occur on the tail. These thickened tail scales may be for helping to shape and stiffen the keels on the tail of tuna. Scales elsewhere on the body do not show the thickened morphology. Cheek and tail scales are modified into elongate, spindle-like shapes, although cheek scales are an order of magnitude larger than cheek scales. Scales are embedded under epidermis over the corselet and perhaps the entire body, allowing the surface of the tuna to be smooth despite the large scales. We hypothesize that the function of these corselet scales may have to do with heat conservation.

47-5 WALDROP, LD*; KHATRI, S; MILLER, LA; Univ. of California, Merced, Univ. of North Carolina at Chapel Hill; lwaldrop@ucmerced.edu

A tale of two antennules: the odor-capture organs of marine and terrestrial crabs show specific adaptations to their own fluid environments

Odor capture is a first step and an important part of olfaction by which odors (chemical signals) are brought into contact with an animal's chemosensory organs. For marine crabs, odor capture begins by flicking antennules bearing arrays of chemosensory hairs back and forth. This motion drives water in a periodic flow-no flow pattern within the array called 'sniffing,' which relies heavily on a range of flicking speeds, hair sizes and spacings, and the properties of water. Terrestrial hermit crabs flick their antennules in air, which has different physical properties than water, with morphologically different hair arrays and a loss of flow between the hairs during flicking. Here we examine whether the morphological changes between a marine crab (*Callinectes sapidus*) and terrestrial hermit crabs (*Coenobita rugosus*) confer a performance advantage in terms of odor capture in their native fluid environments through computational simulations of antennule flicking. We find that the sniffing of marine crabs outperforms the non-sniffing flow patterns of terrestrial hermit crabs in water but not in air, where terrestrial crabs capture several times the available fraction of odor concentration. Furthermore, the size of the odor filament also plays a role, wider filaments enhances odor capture for terrestrial crabs which flick for longer duration. Terrestrial hermit crabs also experience intermittency in continuous odor filament despite not sniffing. Our results suggest that sniffing may only be important where molecular diffusivities are low relative to the organ's size and speed or contained within an internal structure.

14-7 WAKELING, JM*; ROSS, SA; Simon Fraser University; wakeling@sfu.ca

Scaling of muscle contractile properties depends on the inertial mass within the muscle

During contraction, muscles must do internal work to deform their tissue and in particular to overcome the inertia of the individual elements within the muscle. However, the contribution of the internal mass within a muscle to the mechanical output of that muscle has only rarely been studied. As muscle size increases the inertial load will increase in proportion to the muscle mass, yet the force available to accelerate that mass will increase with the cross-sectional area of the muscle or muscle fibres. Thus, there should be a scaling effect of this inertial cost to contraction with a higher specific cost when progressing from single fibres to whole muscles, and similarly from small muscle to large muscle. A similar effect should be seen across different activation levels because the force available within the muscle increases with activity, even though the inertial load would remain the same. Here we use a dynamic, multi-element Hill-type muscle model to understand the effects of the inertial mass within the muscle on its contractile performance. The results show that the maximum strain-rate of a muscle (negative during contraction) is slower for large muscles but increases at higher activation. The curvature of the force-velocity relation increases for large muscles but decreases at high activations, even when the fibre-type of the muscle is held constant. Faster fibre-types appeared more sensitive to size and activation than did the slower muscles. This study highlights how estimates of the intrinsic speed of muscle fibres will be under-estimated when measured from whole muscles, and how the contractile performance of muscles from larger species may be reduced even when they contain the same fibre-types as muscle from smaller species.

4-1 WALKER, B.G.*; HASKINS, J.W.; SPIZOUCCO, F.A.; Fairfield University; bwalker@fairfield.edu

Seasonal Variation and Correlation between Corticosterone and the Antioxidant Uric Acid During Stress in the Northern Cardinal (*Cardinalis cardinalis*)

Glucocorticoids modify metabolism in order to mount a response to stressors. In passerines, this response is affected by a combination of seasonal changes, life-history events, and environmental factors. Knowing the connection between stress hormones and metabolism is fundamental in understanding normal seasonal physiological changes. We evaluate seasonal variation in the acute corticosterone stress response of Northern Cardinals (*Cardinalis cardinalis*) and if this response correlates with the antioxidant marker uric acid. Baseline corticosterone, δ_{10} CORT, and total stress response were significantly different between seasons. For all three corticosterone measurements (baseline, δ_{10} CORT, and total) birds captured in summer consistently had the lowest values while spring birds had the highest. The difference in corticosterone between spring and summer may reflect a physiological reduction of stress response meant to protect the investment in eggs/chicks being reared in the summer. High corticosterone in the spring may result from breeding and nesting during a period of abundant resources and mates in which nest abandonment due to an acute stressor is less costly. Plasma uric acid, an end product of protein metabolism with known antioxidant effects, was monitored to test for a correlation between corticosterone induced stress and metabolic activity. While plasma uric acid significantly decreased over 60 minutes independent of season, there was no significant correlation with corticosterone. We conclude there are physiologically relevant seasonal fluctuations in corticosterone in the Northern Cardinal and an indirectly related decrease in uric acid during acute stress.

S4-9 WALKER, Marquis T.*; RUPP, Alan; WENG, Shijun; BERSON, David M.; HATTAR, Samer; MONTELL, Craig; University of California, Santa Barbara, Johns Hopkins University School of Medicine, Fudan University, China, Brown University; mtwalker@jhmi.edu

A mouse homolog of *Drosophila* RDGB functions in ipRGC dim light activation

Mammals have three major classes of photoreceptor cells in the retina, rods, cones, and intrinsically photosensitive retinal ganglion cells (ipRGCs). Both rod and cone photoreceptors are located in the outer retina and transduce light-activated signals through the retina to retinal ganglion cells (RGCs). ipRGCs are a heterogeneous subset of RGCs that form the principal conduit for retinal input to brain regions that control non-image forming functions, such as pupillary light reflex and circadian photoentrainment. Under bright light conditions ipRGCs are directly activated by their invertebrate-like photopigment, melanopsin. In dim light which is unable to activate melanopsin, ipRGCs receive input from rod and cone pathways. RdgB2 is a mammalian homolog of a phosphoinositide transfer/exchange protein that functions in *Drosophila* phototransduction and is expressed in the retinal ganglion cell layer of the retina. The expression pattern of RdgB2 suggests that it might function in the melanopsin-dependent activation of ipRGCs. Surprisingly, RdgB2^{-/-} mice have normal pupillary light reflex and circadian photoentrainment in bright light, but show a defect in both behaviors in dim light. We have found that the RdgB2 protein was not expressed in ipRGCs, but instead in a subset of GABAergic amacrine cells. RdgB2-positive amacrine cells provide inhibitory feedback onto bipolar cells, which is essential for maintaining bipolar cell response amplitude. We have provided the first evidence of RdgB2 function in the mammalian retina and have shown that it is required to transduce rod-driven input to ipRGCs for activation in dim light.

41-6 WARKENTIN, KM*; COHEN, KL; CUCCARO DIAZ, J; GUELL, BA; JUNG, J; Boston University, Universidad de los Andes, Bogota, University of California, San Diego; kwarken@bu.edu

Development of embryo behavior: hatching mechanisms, performance, and decisions in red-eyed treefrogs

Arboreal embryos of *Agalychnis callidryas* hatch prematurely to escape danger, but early hatching increases larval mortality. We examined the ontogeny of embryo responses to hypoxia and physical disturbance, which cue hatching during flooding and predator attacks. Hypoxia-cued hatching began before disturbance-cued hatching, prior to the appearance of large hatching gland cells that mediate rapid escape in attacks, or a vestibuloocular reflex that indicates otic mechanoreception. Using scanning electron microscopy and *in situ* hybridization probing for hatching enzyme mRNA, we found a second hatching gland cell type that appears earlier in development; these likely mediate the first hypoxia-cued hatching but largely disappear before spontaneous hatching. We video-recorded hypoxia-cued hatching of embryos at different stages to examine decisions and performance. After flooding, embryos first changed position many times, using movements like those used to orient in oxygen gradients in eggs in air. With development, this oxygen-seeking behavior decreased, consistent with the lower risk of mortality outside the egg. Embryos then performed hatching-specific movements. Development improved hatching speed and success; less developed embryos made smaller holes in the membrane, suffered greater body compression squeezing out, and their movements were less effective in propelling them from the capsule. Capsules collapsed around embryos that did not immediately enter their initial hole, allowing fluid to leak. More developed embryos digested additional holes in the membrane to escape, but younger ones sometimes remained trapped.

S9-7 WANG, G; Max Plank Institute for Developmental Biology; george.wang@tuebingen.mpg.de

Tempcycles: R tools for exploring the ecological consequences of temperature cycling, with examples from plants.

There is a growing appreciation for the biological importance of temperature variability. However, there are few computational tools to facilitate investigations of the ecological consequences of varying temperatures. Here, I introduce Tempcycles, a collection of R tools to facilitate modelling temporally varying temperatures in thermal ecology. Included are tools to measure the cyclical components of a temperature history, generate temperature patterns with specified cycling, and apply these patterns to reaction norms to predict ecological outcomes and generate testable hypotheses. I demonstrate the utility of Tempcycles by addressing several developmental and phenological questions in plants.

128-2 WARNE, RW*; CATENAZZI, A; Southern Illinois University; rwarne@siu.edu

Maternal nutrient transfer in pouch brooding Marsupial frogs

Amphibians exhibit a stunning diversity of reproductive modes ranging from aquatic larvae to terrestrial, direct developing metamorphs. Marsupial frogs display one intriguing reproductive mode in which females carry eggs adhered to their dorsum until metamorphosis. In some marsupial frog species, the developing embryos are entirely enclosed in a well-vascularized, sealed dorsal brooding pouch. While anurans are generally all considered to be oviparous with lecithotrophic eggs (i.e. the embryo receives no nutrition other than yolk), the extensively vascularized membrane of the marsupial frog (*Gastrotheca excubitor*) brood pouch suggests that there may be opportunities for nutrient transfer. We used carbon (13C) and nitrogen (15N) stable isotopes to track nutrient allocation in gravid marsupial frogs, and to test if there is maternal nutrient transfer to developing embryos. Through feeding gravid marsupial frogs insects labeled with a 13C labeled fatty acid and a 15N labeled amino acid, we found that embryos and maternal tissues all exhibited significant increases in d13C and d15N values. These results suggest that in addition to gas exchange, the vascularized membrane of the marsupial frog brood pouch also provides a means for maternal nutrient transfer.

92-4 WARNER, D.A.*; IVERSON, J.B.; MILNE-ZELMAN, C.; MITCHELL, T.M.; REFSNIDER, J.M.; BODENSTEINER, B.; JANZEN, F.J.; Auburn University, Earlham College, Aurora University, University of Toledo, Iowa State University; daw0036@auburn.edu

Geographic Variation in Temperature-Dependent Sex Determination in a Widespread Reptile, the Painted Turtle (*Chrysemys picta*)

Species that occur across broad geographic ranges often experience substantial variation in ambient temperature. Because temperature is critical to many biological functions, how different populations have adapted to local thermal environments has been an important question in evolutionary biology. This is particularly important in species with temperature-dependent sex determination (TSD), whereby developmental temperature has a direct impact on the primary sex ratio, and hence population demographics. We used the painted turtle (*Chrysemys picta*) to assess how TSD is adjusted across widespread populations that experience different climates. Specifically, we test hypotheses derived from a long-standing theoretical framework that primary sex ratios under TSD are adjusted through changes in the sex determining response of embryos to incubation temperature and/or maternal nesting behavior. Lab experiments aimed at quantifying sex-determining reaction norms across seven populations (Illinois, Minnesota, Kansas, Nebraska, New Mexico, Idaho, Oregon) provide little evidence that populations differ in how developmental temperature affects offspring sex ratio; pivotal temperatures were approximately 28 C across all populations. Thus, TSD may be adjusted across populations via maternal nesting behavior. To address this, we have collected field data on nest microhabitat (e.g., nest temperature, overstory cover, depth) and the timing of nesting at six of our study sites. These data will provide a comprehensive understanding of how long-lived taxa with TSD accommodate geographic variation in temperature, and how they may adjust to predicted climate change scenarios in the future.

75-4 WEBSTER, NB; University of Alberta; nwebster@ualberta.ca

Bridging pattern and process: How do snails grow shell sculpture? Mollusc shells are a prime example of "endless forms most beautiful" and exhibit many diverse and complicated patterns. Shells are formed by the mantle, which lines the opening of the shell (aperture), secreting the necessary components for biomineralization. Great strides have been made in recent years in understanding the molecular processes involved in secreting the calcium carbonate shell. The patterns of shell shape and sculpture have been modeled extensively, but whether these models reflect the biological reality is unclear. Nothing is known about how the process of shell secretion is modified to yield different patterns of shell sculpture. Here I study: What aspects of the mantle changes to produce different shell sculpture? *Nucella ostrina* has plastic shell sculpture, varying from strong spiral ribs to a smooth shell. The ability to produce ribs arises from a single gene, two allele polymorphism. Examining the mantle of ribbed and smooth snails using histology, TEM, 3d reconstructions, histochemistry, and *in situ* hybridizations, I show that simple changes in the dimensions of the mantle epithelium correlate with ribs in the shell. Alternative hypotheses such as ultrastructural changes in the epithelium were tested and rejected. Thus shell ribbing is formed by a corrugated mantle epithelium; in a rib, the region secreting shell material is longer, producing a thicker shell than the intervening inter-rib regions, while a smooth shell has a smooth-edged, uniform mantle. These results support general conclusions from the modelling literature that relatively few parameter changes can account for many of the diverse shell shapes seen in molluscs. Furthermore this work is a first step in understanding how snails grow shell sculpture, and can be built upon to explain more elaborate and diverse forms.

65-6 WATTS, HE*; CHOPRA, JK; ASINAS, CE; HAHN, TP; RAMENOFISKY, M; Loyola Marymount University, Los Angeles CA, University of California, Davis; hwatts1@lmu.edu

Behavioral and physiological changes associated with a migratory life history stage in a facultative migrant

Most research on migration has focused on obligate migrants. In contrast, facultative migrants, whose movements are less predictable in timing and direction, have received much less attention. We used captive pine siskins (*Spinus pinus*), nomadic and irruptive migrants, as a model to investigate facultative migration. Wild-caught birds were held on naturally changing photoperiods; their behavior was recorded and patterns of fat deposition were measured. Captive pine siskins exhibited periods of migratory restlessness (MR) similar to that described in obligate migrants. Night activity was characterized by jumping and rapid wing flapping. As in obligate migrants, pine siskins exhibited a period of quiescence prior to the onset of night activity. We also found that the expression of MR varied across the year, with night activity being highest during the spring and summer. Finally, the expression of MR was associated with increases in fat deposition. Overall, our results indicate strong similarities in the behavioral and physiological changes associated with migration in facultative and obligate migrants. Furthermore, our findings suggest that migratory behavior in this species is driven, at least in part, by seasonal mechanisms.

36-6 WEGENER, JE*; MULDER, KP; PRINGLE, RM; KARTZIEL, TR; LOSOS, JB; KOLBE, JJ; University of Rhode Island, Kingston, University of Porto, Portugal, Princeton University, NJ, Princeton University, NJ, Harvard University, Cambridge, MA; johanna_wegener@my.uri.edu

Relative contribution of genetic and ecological factors to morphological differentiation in island populations of *Anolis sagrei* Morphological differentiation among populations can be influenced by a number of evolutionary mechanisms, including gene flow, genetic drift and adaptation to local environmental conditions. Island systems are ideal to study underlying mechanisms of morphological differentiation, because gene flow is limited and populations may be largely independently evolving units. We sampled male and female brown anoles (*Anolis sagrei*) from 16 island populations near Staniel Cay in the Bahamas. To test what factors drive morphological differentiation among populations, we measured seven morphological variables of body size and shape, genotyped 10 microsatellite loci, collected structural microhabitat use data (i.e., perch height and diameter) and estimated population densities. We found significant morphological differentiation among island populations and between males and females. These differences could not be explained by variation in structural habitat use, geographic distance, or genetic distance (Fst). High genetic differentiation and signatures of genetic bottlenecks suggest that founder effects might be an important initial driver of morphological differentiation. We found that head length and injury rate in both males and females increase with population density, suggesting that competition might play a role in some aspects of morphological differentiation. Population densities can change rapidly over time and more work is needed to determine if morphological traits respond to these changes.

109-6 WEINNIG, A.M.*; WILLIAMS, G.C.; HAYZELDEN, C.; California Academy of Sciences, San Francisco State University; alexismweinnig@gmail.com

X-Ray Microanalysis and the Axial Elemental Composition in Alcyonacean Octocorals (Anthozoa, Octocorallia)

Octocorals are among the most abundant and diverse organisms in the ocean. These animals are present in every ocean and can be found from the intertidal zone (0 m) to abyssal depths (over 6000 m). Gorgonians are octocorals with a solid, internal axis. There are three axial types that differentiate gorgonians: scleraxonians, holaxonians, and calcaxonians. This study analyzed the variation in axial chemical composition within these three gorgonian axis types with x-ray microanalysis, by using quantitative energy dispersive x-ray spectrometry (EDS). EDS successfully quantified the elemental composition of eleven gorgonian octocoral axes. Scleraxonian elemental composition showed significant similarity and suggests that, based specially on axial elemental composition, scleraxonians comprise a unified group. However, holaxonian and calcaxonian elemental compositions were significantly different within each group and thus do not represent concise grouping by axis type.

22-2 WEISBLAT, D.A.*; CHO, S.J.; WATSON, Q.D.; YOO, S.; Univ. of Calif., Berkeley, Chungbuk National Univ.; weisblat@berkeley.edu

Wnt signaling and cell fate specification in a grand-parental stem cell lineage of the leech

Elongation via a posterior growth zone (PGZ) is a common feature of bilaterally symmetric embryos. In many taxa, the PGZ involves an ill-defined combination of cell movements and/or divisions. By contrast, the PGZ in clitellate annelid embryos, e.g., the leech *Helobdella austinensis* consists of five pairs of lineage-restricted stem cells (teloblasts). Typical stem cells undergo "parental interactions"--the self-renewing cell generates the same type of differentiating progeny at each division. In leech PGZ, three pairs of teloblasts undergo such divisions. Remarkably, however, the teloblasts generating ventral and dorsal ectoderm (N and Q lineages, respectively) exhibit "grand-parental iterations"--that is, each N and Q teloblast gives rise to two different types of progeny in exact alternation (nf & ns; qf & qs blast cells, respectively). A priori, the differences between adjacent cells in the N and Q lineages could arise from a flip-flop mechanism in the teloblast, or by interactions among initially equipotent blast cells. We can distinguish the two types of cells in each grand-parental lineage by differences in the timing and symmetry of their first mitoses, roughly 50-60 hours after their birth from the teloblast. To distinguish between the two general mechanisms of blast cell differentiation, we seek to identify genes that are differentially expressed before the blast cells divide. The evolutionarily ancient Wnt signaling pathway is involved in the PGZ of many embryos. We have found differential expression of mRNAs encoding one Wnt ligand (*Hau-wnt16a*) and one putative Wnt modulator (*Hau-sfrp2*) of pre-mitotic f and s blast cells in the N lineage. *Hau-sfrp2* but not *Hau-wnt16a* is differentially expressed between the f and s blast cells of the Q lineage.

51-6 WELCH, KC*; OTÁLORA-ARDILA, A.; HERRERA M., LG; FLORES-MARTÍNEZ, JJ; Univ. of Toronto Scarborough, Univ. Nacional Autónoma de México; kwelch@utsc.utoronto.ca

The cost of digestion in the fish-eating Myotis (*Myotis vivesi*)

Flying vertebrates, such as bats, face special challenges with regards to the throughput and digestion of food. On the one hand, as potentially energy-limited organisms, bats must ingest and assimilate energy efficiently in order to satisfy high resting and active metabolic demands. On the other hand, the assimilation of nutrients must be accomplished using a digestive tract that is, compared with that of similarly sized non-flying vertebrates, significantly shorter. Despite these competing demands, and the relative breadth of dietary diversity among bats, little work has been done describing the cost of digestion, termed 'specific dynamic action' (SDA). Here, we provide the first systematic assessment of the SDA response in a bat, the fish-eating myotis (*Myotis vivesi*). Given the shorter digestive tract and the relatively higher resting and active metabolic rates of bats in general, and based on anecdotal published evidence, we hypothesized that the SDA response in fish-eating myotis would be dependent on meal size and both significantly more brief and intense than in small, nonflying mammals. In agreement with our hypothesis, we found that the peak metabolic rate during digestion, relative to rest, was significantly higher in these bats compared with any other mammals or vertebrates, except for some infrequently eating reptiles and amphibians. Additionally, we found that the magnitude and duration of the SDA response were related to meal size. However, we found that the duration of the SDA response, while generally similar to reported gut transit times in other small bats, was not substantially shorter than in similarly sized non-flying mammals.

76-4 WERNER II, LC*; ESSNER, JR, RE ; WILLIAMS, JB;

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Physiological Responses to Freezing in the Mountain Tailed Frog, *Ascaphus montanus*

The Mountain Tailed Frog, *Ascaphus montanus* is a cryophile that is associated with permanent mountain streams in the Northwestern United States. Although unknown, adults likely overwinter in the fast moving streams, but to do so they would need to survive extended bouts of subzero temperatures. Previous work has described the frog's ability to supercool to low temperatures and survive freezing. The purpose of this study was to determine tissue level indicators of freeze tolerance, namely cryoprotectant concentrations and wet mass. Winter acclimated frogs cooled from 2°C at 0.2°C h⁻¹ and then held at -1°C until they spontaneously froze or had a small ice chip placed on their back to inoculate freezing after 3 days. After being held at -1 °C for seven days, they were then removed, double pithed and the gracilis and gastrocnemius muscles, heart, and liver were removed on ice. Water content of the liver was determined after a portion of the tissue was blotted dry, weighed and dried in an oven at 60 C°. Water content significantly increased after freezing. Urea and Glycerol concentration were below detectable limits of the assay. Glucose concentrations did not change in response to freezing but were elevated compared to acclimatized individuals of other species. Based on the known literature and previous work it seems that this species can survive in high sub-zero temperatures found in its aquatic environment. These data suggest that the frogs may survive freezing in conditions likely found in their stream habitat and may use a combination of supercooling and freeze tolerance to overwinter.

88-2 WESTERMAN, E.L.*; KRONFORST, M.R.; University of Chicago; ewesterman@uchicago.edu

Nature and nurture: The genetics of visual attraction in *Heliconius* butterflies

The genetics of assortative mating has long fascinated biologists, however identifying genes responsible for variation in mate selection has proven difficult due to the complexity of the mate selection process. Here we take advantage of next generation sequencing technology and variation in male preference for a single visual trait in *Heliconius cydno* butterflies to identify genes associated with visual attraction. We identify SNPs perfectly associated with a visual attractant, a white or yellow band on the forewing. We then identify SNPs associated with life-long male preference and initial male preference for white- or yellow- banded females. Life-long preference in *H. cydno* is polygenic and influenced by genes associated with neurodevelopment and neuron function. Initial courtship preference is associated with a small set of candidate genes that influence neurodevelopment and gene expression during development. None of these four genes are also highly associated with life-long preference. The loci of large effect for the preferred trait, the forewing white/yellow color band, are not loci of large effect for mate preference, though they are associated with visual preference, and have a small, simple dominant/recessive effect on the trait. Our results suggest that variation in initial attraction can be driven by a small number of genes with large effect, and that the genes influencing evolutionarily important behaviors such as mate selection may change throughout an individual's lifetime.

32-2 WHELAN, N.V.*; KOCOT, K.M.; KOHN, A.B.; MOROZ, T.P.; MUKHERJEE, K.; WILLIAMS, P.; MILLS, C.E.; PAULAY, G.; MOROZ, L.L.; HALANYCH, K.M.; Auburn University, University of Queensland, University of Florida, University of Florida, University of Washington; nwhelan@auburn.edu
Phylogenomics resolves relationships among major Ctenophora lineages

Ctenophora is the sister group to all other extant animals. However, relationships among ctenophore lineages are poorly understood. In particular, only limited molecular phylogenetic studies on ctenophores have been conducted. Furthermore, these studies conflict with morphology-based hypotheses, especially in regards to the placement of species lacking tentacles. Robustly resolving relationships among ctenophore lineages will be essential for understanding the evolution of ctenophore body plans. We sequenced 16 new ctenophore transcriptomes and combined these with ten publicly available ctenophore transcriptomes to assemble a phylogenomic dataset of Ctenophora. Orthology determination resulted in a primary data set of 306 genes and over 80,000 amino acid positions. Maximum likelihood analyses on a partitioned dataset using RAxML recovered a well-supported phylogeny. In agreement with recent phylogenetic hypotheses, two higher-level Ctenophora groupings, Lobata and Cydippida, were recovered non-monophyletic. *Euplokamis*, rather than tentaculate beroids, were recovered sister to all other extant ctenophores, supporting previous genetic evidence that tentaculate ctenophores are derived. Tentaculate species included here formed a monophyletic derived clade. Benthic species in the order Platyctenida (i.e. *Coeloplana*, *Vallicula*) were monophyletic. The enigmatic, semi-benthic species *Lobatolampea tetragona* was recovered at the base of a clade containing *Ocyropsis*, *Cestum*, and *Bolinopsidae* spp. The transcriptomic-based approach used here has resulted in a robust picture of ctenophore relationships, and our findings indicate that the traditional higher-level classifications should be revised.

7-4 WEY, TW*; VRANA, PB; MABRY, KE; New Mexico State University, University of South Carolina; tina.vey@gmail.com
Monogamous *Peromyscus* species show higher attraction to social and novel stimuli

Social monogamy is often associated with increased within-pair social behaviors, but little is known about associations between mating system and behaviors in non-mating contexts. Behaviors across ecological contexts are often correlated due to shared selective pressures or underlying mechanisms. We hypothesized that monogamous species would exhibit both different average behaviors and different behavioral syndromes from non-monogamous species. We compared multiple behaviors of monogamous and non-monogamous *Peromyscus* species using lab-reared wild-type stocks. We predicted that monogamous species would show both greater social attraction (to same-sex conspecifics) and greater attraction to novelty in general (exploration), whereas we did not expect activity or boldness (response to risk) to differ by mating system. We further predicted that the direction or strength of behavioral correlations would differ by mating system, due to differing selective pressures on social behaviors. As predicted, monogamy was associated with increased social attraction and attraction to novelty, but not with activity or boldness. Social attraction was correlated with exploration and boldness correlated with activity, but these correlations did not differ with mating system. Thus, mating system variation in *Peromyscus* appears to be also associated with average differences in non-mating behaviors; monogamous species were more attracted to novel conspecifics and to novelty in general. The mechanisms underlying these behaviors seem to be conserved across species, as the correlation structure did not differ with mating system. Notably, we still found significant behavioral variation between species with the same mating system and among individuals within species.

93-1 WHITAKER, DL*; ZAGERMAN, SL; Pomona College; dwhight.whitaker@pomona.edu

The efficient flight of *Ruellia ciliatiflora* seeds

The fruits of *R. ciliatiflora* launch disk shaped seeds that travel at speeds over 10 m/s with a rotation rate that exceeds 1 kHz. By analyzing the trajectories of these seeds with a high speed camera we have learned that they fly with significant lift and almost no drag. To understand the mechanism for this remarkable behavior we create 3D printed models of these seeds to test in a flume or tow tank with particle image velocimetry. The results of these analysis should shed insight into the mechanism by which the seeds are able to use air to generate a lift that exceeds its weight while not producing significant drag on the projectile. The results from these studies should also help to guide future work on the comparative analysis of flights among the Acanthaceae, which has over 2000 species with exploding fruits that grow in a wide range of ecosystems.

86-6 WIJESANA, N.M*; SIMMONS, D.K.; MARTINDALE, M.Q.; Whitney Laboratory for Marine Bioscience; naveenw@whitney.ufl.edu

The heart-field specification gene regulatory network kernel was in place in the cnidarian-bilaterian ancestor

Gene regulatory networks (GRNs) consisting of functional linkages between regulatory genes and their cis-regulatory modules determine the development of animal body plans. Given the hierarchical nature of organ development that starts with the specification of a field of cells followed by the patterning of its morphological features and terminal differentiation, the GRNs regulating these processes are also hierarchical. Thus, subcircuits regulating early specification, referred to as "kernels" of the GRN have more pleiotropic effects and are evolutionarily constrained compared to subcircuits responsible for subsequent fine-scale patterning and terminal differentiation. Studies of heart development in bilaterians have led to the identification of an evolutionarily conserved hierarchical GRN, consisting of interconnections between upstream signaling pathways that direct cardiac cell fate, myogenic transcription factors and their downstream target genes. To better understand the evolutionary origins of the heart specification GRN, we looked at the regulation and function of components of the bilaterian heart GRN in the anthozoan cnidarian, *Nematostella*. Morpholino mediated knock down of *NvBMP 2/4*, a key upstream regulator of the bilaterian heart-field specification kernel, resulted in the down regulation of *NvNkx2-like*, *NvHAND2* and *NvGATA* in developing gastrodermis, all components of the bilaterian heart GRN kernel. This indicates to the presence of an ancestral heart-field specification kernel in the endomesoderm of the non-bilaterian *Nematostella*. Targeted functional experiments focused on these components and their downstream targets will provide a detailed understanding of the heart GRN kernel in *Nematostella* and the origins of heart development in metazoans.

16-2 WILCOXEN, TE*; WROBEL, ER; SEITZ, J; NUZZO, JT; Millikin University, University of Georgia, Illinois Raptor Center, Illinois Raptor Center; twilcoxen@millikin.edu

Prevalence of antibodies against Avipoxvirus, Aspergillus, and West Nile Virus in birds of prey from Central Illinois.

There are many pathogens known to infect birds of prey, but many reports of the prevalence of such pathogens involve only birds displaying severe symptoms. Avipoxviruses are a diverse group of viruses that are known pathogens across avian taxa. Severe pox symptoms include lesions on featherless areas of the body and respiratory distress, but little is known about the asymptomatic prevalence of this virus in free-living bird populations. *Aspergillus* is an opportunistic fungal pathogen that occurs naturally in grasses and can become concentrated in agricultural products such as hay bales. Aspergillosis is a known cause of death for birds of prey in otherwise stressful situations and in birds of prey hunting near barns and hay fields, but again, little is known about how often raptors are exposed to *Aspergillus* and to what extent the raptors develop adaptive immune responses against the pathogen. West Nile Virus has been studied in free-living bird populations to a much greater extent, and has also been implicated in many bird deaths, but many individual birds also tolerate West Nile Virus and become reservoirs for the pathogen. The purpose of this study was to determine the rate at which birds of prey in Central Illinois are exposed to these pathogens and subsequently produce IgY against the pathogens. Using indirect ELISAs, we found that antibody prevalence was far greater than the prevalence of symptoms for each pathogen. We also found species-specific differences in prevalence for different pathogens that largely reflect differences in habitats, behaviors, and overall niche occupancy of different species. Overall, our findings reveal important disease dynamics in understudied groups of birds.

71-2 WILCOX, SC*; CLARK, CJ; Univ. of California, Riverside; swilc002@ucr.edu

Flight performance and sexual differences in black-chinned hummingbirds (*Archilochus alexandri*)

Locomotor performance is important for animals, especially hummingbirds, which catch mobile prey, avoid predators, defend territories, and perform aerial courtship displays. Using black-chinned hummingbirds (*Archilochus alexandri*) we investigated the relationships of three flight-performance assays (i.e., weight-lifting vertical flight, top-speed flight in a wind tunnel, and maneuvering flight through a string maze), the effect of sex, and the repeatability of these measures. We found no significant relationships among the three flight-performance assays. Males and females differed significantly in morphology, and weight-lifting performance, but not in top-speed flight performance or flight through a string maze. We show that the weight-lifting and top-speed flight measures are highly repeatable. We submit that our assay for maneuverability was insufficient, in our system, to detect expected differences in maneuvering flight given the dissimilarities in morphology between the sexes. Although our flight-performance assays have been proposed as proxies for power output, our results suggest these performance measures are independent of one another.

S10-10 WILGA, Cheryl*; DINIZ, Stephanye; STEELE, Preston; TUTU, Elizabeth; SUDARIO-COOK, Jordan; GALLOWAY, Katherine; University of Alaska Anchorage, University of Rhode Island; cwilga@uaa.alaska.edu

Laboratory studies: ontogeny of feeding mechanics in sharks: morphology and cartilage strain

Dusky smoothhound sharks inhabit shallow inshore waters where they forage for crustaceans, with crabs comprising the largest dietary item by percentage and volume. They mature relatively rapidly, within 2-4 years of age, and having molariform teeth are well adapted for feeding on durophagous prey. Whether a dietary change occurs over this relatively short period is unknown. Shape change over ontogeny was analyzed using geometric morphometric analyses of the mandibular and hyoid arch cartilages in twenty-four individuals spanning most of the size range (32-116 cm TL). Mechanical stiffness, Poisson's ratio, and percent mineralization were quantified in the same individuals. Geometric morphometric analyses show that while some shape changes occurred, the jaw and hyoid elements remain largely isometric over ontogeny. In most elements, cross-sectional area and percent mineralization increases with size as expected, leading to consistent strain, and thus stress over ontogeny. Poisson's Ratio decreases with % mineralization over ontogeny in the mandibular elements, but not the hyoid arch elements. Young's Modulus increases in some elements over ontogeny with increasing mineralization, but remains consistent in others. An inflection point exists in the stress-strain curve that may indicate mechanical property changes of tesseræ-ligament interactions during compression.

48-1 WILLIAMS, TD*; FOWLER, MA; Simon Fraser Univ., Burnaby, Springfield College, MA; tdwillia@sfu.ca

Can we detect a physiological signature of cost of reproduction?

Increased investment in current reproduction can have a negative influence on survival to, or future fecundity of, a subsequent breeding attempt. Life-history theory predicts that current and 'residual' reproductive value should be balanced at each time point to maximise fitness. Thus, experimental manipulations of current reproductive investment (e.g. brood size manipulation) are required to demonstrate 'costs of reproduction'. Although cost of reproduction (and other trade-offs) must have a physiological basis, few experimental studies include comprehensive physiological analysis, and the physiological basis of reproductive costs remains poorly understood. We handicapped female European starlings (*Sturnus vulgaris*) using wing-clipping, and compared foraging behaviour, breeding productivity and physiology with control females. We obtained repeated measurements of biomechanical traits (mass, wing length, wing area) and 13 physiological traits during incubation and chick-rearing of 1st and 2nd broods; this included measures of oxidative stress, muscle damage, metabolic regulators, immune function, aerobic capacity, and intermediary metabolism. We used behavioural observations and radio-telemetry to obtain information on foraging behaviour of the same individuals (nest-visit rate, flight distances). Wing-clipped females continued to "work hard" with similar provisioning rates compared with control females, but had lower current breeding productivity and lower survival, i.e. they appeared to show a clear cost of (increased) reproductive effort. We will use our physiological data to test hypotheses about the mechanistic basis of individual variation in a) workload ability (e.g. provisioning rate, flight distance, breeding productivity), and b) costs of workload (breeding failure, return rate, future fecundity).

62-5 WILLIAMS, J.*; DAVID, A.; PHELAN, K.; WHITFORD, T.; Hofstra University, Clarkson University, East Stroudsburg University; biojdw@hofstra.edu

Regenerative capacity of the invasive polychaete *Marenzelleria viridis* (Annelida: Spionidae) and first documentation of parasitism by trematodes in its native range

Marenzelleria viridis is a spionid polychaete native to the east coast of North America that has been introduced into northern European waters. The objective of this study was to examine the regeneration capacity and parasitism of *M. viridis* from Long Island, New York. In the field, 7% of the worms exhibited regeneration. In the laboratory, worms were ablated at the 10th-50th chaetiger and their regeneration documented. Anterior morphogenesis was similar to previous studies on spionids, with wound healing, blastema formation, and differentiation of segments occurring within 14 days. The number of segments replaced was equal to the number removed for up to 10 segments but up to 17 segments were replaced when higher numbers were ablated. The impact of salinity on regeneration was tested in worms cultured at five salinity treatments (0-24ppt). All specimens cultured at 5-24ppt successfully completed regeneration whereas 75% of specimens cultured at 0ppt died. Salinity did not effect regeneration time but did effect the percentage of chaetigers regenerated (highest at 15ppt). During examination of *M. viridis* from the field, putative trematode cysts were discovered in their body cavity. DNA barcoding confirmed the presence of three species of trematodes. Brown bodies were also recovered from worms and molecular testing confirmed the presence of trematodes, indicating an immune response leading to encapsulation. This is the first confirmation that trematodes use *M. viridis* as a second intermediate host. Future research should explore regeneration and the role of *M. viridis* in trematode life cycles, particularly in its non-native range.

111-1 WILLIAMS, K. A.; Ohio University; williak5@ohio.edu
Linking reproductive success to individual behavioral and environmental variation?

Parents face trade-offs between providing resources for the development and survival of their offspring and acquiring resources for their own survival. Nesting birds must maintain incubation temperatures adequate for embryonic and nestling development while also providing food resources for nestlings and meeting their own energetic needs. Habitat quality including the availability of food may alter parental time and energy budgets. Individual differences in behavior may result in variation in the acquisition and allocation of resources. This study examines how individual behavioral strategies of resource acquisition and allocation in female hooded warblers *Setophaga citrina* are related to the abundance and availability of food in the environment, to the resources provided to offspring and to offspring growth and survival. Markov model analysis of individual behavior transition matrices yield multivariate estimates of individual behavior variation that can be used together to test hypotheses about how individual variation in behavioral strategies (combinations of behaviors used) and environmental conditions affect variation in offspring condition and survival. This study provides insight into how mothers acquire and allocate time and resources between survival and reproduction under different environmental conditions and the effect of these trade-offs on offspring growth and survival.

63-1 WILLIAMS, CD*; SPONBERG, S; IRVING, TC; DANIEL, TL; Univ. of Washington, Georgia Inst. of Tech., Illinois Inst. of Tech; cdave@uw.edu

Cross-bridge cross-talk between force generation and radial lattice spacing

Within muscle, actin and myosin filaments are arranged in a highly regular lattice. Force generation depends on actin-myosin cross-bridge formation which in turn depends on myosin diffusing across and bridging filament gaps. Alterations in filament lattice spacing change cross-bridge binding probability, and thus the force muscle generates. When large numbers of cross-bridges attach or detach as during maximal activation, it is likely that lattice spacing changes. An open question looms: does this feedback between force generation and binding regulation take place only in the most extreme of circumstances, or is it present during everyday activation? We use real-time X-ray diffraction measurements of lattice spacing, combined with work loops activated at various phase offsets to provoke altered binding timing (and thus possible altered lattice spacing regulation) within *Manduca sexta* flight muscle. Preliminary analysis shows that, contrary to a set of existing assumptions, lattice spacing varies within each work loop's length oscillation by 0.5 nm. This is sufficient to alter maximal force production by up to 20% under conditions of maximal activation. What is even more interesting is that not only does lattice spacing vary with length, but the alteration of cross-bridge recruitment by changes in activation phase within the work loop modulates the length-lattice spacing relationship, retarding or advancing length change by 7% of cycle duration. This work was supported by ARO Grants W911NF-13-1-0435 and W911NF-14-1-0396.

59-4 WILLIAMS, C.M.*; SZEJNER, A.; MORGAN, T.S.; SUNNY, N.E.; MCCUE, M.D.; HAHN, D.A.; Univ. of California, Berkeley, Univ. of Florida, Gainesville, Kansas State University, St Mary's University; cmw@berkeley.edu

Extreme low temperatures remodel metabolic physiology and life history in *Drosophila melanogaster*

Living in cold regions is associated with two primary challenges: 1) increased frequency and severity of low temperature exposure which can induce mortality and curtail opportunities; and 2) a short and on average cool growing season, in which it is difficult to complete development and grow to large adult size in a timely fashion. Elevational and latitudinal clines in cold hardiness have traditionally been attributed to the former evolutionary driver, while parallel clines in metabolic rates, growth rates, and development times have been attributed to the latter. Here, we show that adaptation of *Drosophila melanogaster* to acute low temperature exposure induces increased growth rates, metabolic rates, and increased rates of catabolism and anabolism. In addition, cold-adapted flies have greater metabolic plasticity, and maintain metabolic homeostasis more effectively during cold exposure leading to faster recovery times. We suggest that selection pressures imposed by acute low temperature exposure may be an under-appreciated force leading to the development and maintenance of elevational and latitudinal clines in metabolic traits.

52-7 WILLIS, M.A.*; MILLIGAN, J.M.; COX, A.S.; MAKOWSKI, E.; Case Western Reserve University, Shaw High School; maw27@case.edu

Odor distribution, locomotor behavior and sensor arrangement interact to structure plume tracking behavior in the moth *Grapholita molesta*

The structure of the odor tracking behavior of flying or swimming animals arise from: (1) changes in flows and odor plumes resulting from environmental differences, (2) differences in the odor inputs of animals flying or swimming rapidly vs. walking slowly through their environments, or (3) different control rules used whether walking or flying. It has been proposed that insects walking slowly along zigzags in the boundary layer use spatial cues by comparing across their bilaterally symmetrical antennae, while insects flying rapidly through plumes in free stream flows may 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 change their mode of locomotion. Studies of male oriental fruit moths, *Grapholita molesta*, transitioning 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 one antenna removed change from symmetrical zigzag tracks identical to flying males, to walking tracks that loop toward their intact antenna (left or right). Sometimes walking in loops can result from loss of contact with odor and has been interpreted as a local search behavior. To resolve whether the looping tracks of one antenna males resulted from a switch from temporal to spatial odor comparisons or the moths had initiated a local search after losing contact with the plume we removed the odor source during plume tracking walking. This work was supported by NSF grant IOS-1121498.

52-1 WILLIS, KL*; CARR, CE; University of Maryland; kwillis@ou.edu

Sound Localization in Turtles

The experiments described are designed to give insight into how binaural hearing evolved. Modern neuroanatomical tract tracing techniques were used to understand the connections among the auditory nuclei in the brain stem of the Red Ear Slider Turtle. Turtles have brain stem nuclei that are connected in the same pattern as the other reptiles, including birds. These nuclei are nucleus angularis (NA), nucleus magnocellularis (NM), nucleus laminaris (NL), superior olive (SO), and torus semicircularis (TS). The auditory nerve bifurcates to NA and NM. NM projects bilaterally to NL. NL and NA project bilaterally to TS, and SO projects contralaterally to TS. Using an in vitro with attached periphery physiology preparation, neurons were characterized by best frequency response, threshold, phase locking. Best frequencies ranged from 100 to 700 Hz. Thresholds were typically around 70 dB SPL. Phase locking vector strength varied, depending on whether the unit recorded was single or multi. Binaural neurons (NL) were additionally characterized by interaural time difference (ITD) sensitivity and phase interactions. These neurons were shown to have a small range of interaural time difference sensitivity responses. The range of ITD tuning curves measured are within a reasonable physiological range for the turtles' head sizes 200us or less to the left or right. These data demonstrate that turtles have the neural substrates and information necessary for some navigation based on auditory cues. Given that the sounds must be relatively loud, auditory cues are likely not the primary mode for navigation. Although the evolutionary position of testudines is not yet resolved, close study of testudine anatomy and physiology can provide insight. It is most likely that testudines share their most recent common ancestor with the archosaurs and we hypothesize that testudines likely reflect the ancestral condition of auditory processing for the archosaur clade.

117-6 WILSON, RS*; NIEHAUS, AC; CAMERON, SF; HEINIGER, J; CLEMENTE, C; CHARTERS, J; University of Qld, University of the Sunshine Coast; r.wilson@uq.edu.au

Costs of too much sex: declines in performance for an Australian carnivorous marsupial across their intensive mating season

The northern quoll (*Dasyurus hallucatus*) is a medium-sized (approx. 1 kg) predatory marsupial previously common across the entire top-end of Australia. It is the largest known semelparous mammal in the world, which means mating 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. In contrast, females live for two to three years and their die-off occurs after the young are weaned - which is around four months after the mating season. In this study, we explored how eight different dimensions of whole-animal performance varied across the intensive mating period for male and female northern quolls within a 125ha area on Groote Eylandt in remote northern Australia. We assessed the running acceleration, sprint speed, jumping power, biting force, manoeuvrability, motor control, gripping strength and endurance for individual quoll across the mating season. We expected the performance of males of high quality to be high throughout the breeding season while those of poor quality to rapidly decrease across the mating period. In contrast, we expected changes in the performance of females to be dependent on their age, with older females experiencing rapid declines due to the intensive attention from males within the population.

126-8 WINDSOR, R.L.*; FOX, G.A.; BOWMAN, R.; University of South Florida, Archbold Biological Station; *rwindsor@mail.usf.edu*
Structural Color Variation in the Florida Scrub-jay (*Aphelocoma coerulescens*): The Effects of Environmental Conditions on Feather Ultraviolet Reflectance

Ornamental traits function as signals to conspecifics, indicating status, fitness, condition, etc. However, elaborate ornaments are costly to produce and maintain, and honest-signaling theory predicts that only high quality individuals are able to produce exaggerated ornamental displays. Variation in ornamentation can be genetic or from environmental sources. In birds with structural coloration, plumage variation results from differences in energy allocated to feather growth due to environmental conditions during molt, and is an honest signal of condition since birds with large energy budgets can invest more in feather development. However, little is known about the consistency of ornamental signals throughout an individual's lifetime, or more specifically, how signals differ between different plumages. Florida Scrub-jay (*Aphelocoma coerulescens*) juveniles are sexually dimorphic in the ultraviolet (UV) range, and UV brightness predicts social dominance, but not adult reproductive fitness. We combined observational and experimental approaches to test how environmental conditions and stress interact to affect structural coloration in Florida Scrub-jays across molts. We collected feathers from the same individuals in pre-basic (juvenile) and basic (adult) plumages and examined the effects of increased stress by administering corticosterone to yearlings during their first basic molt. Because most Florida Scrub-jays breed at 2-3 years of age, we also evaluated how consistency and relative brightness of UV coloration affected probability of breeding. Florida Scrub-jays are a Threatened species, and as their habitat continues to decline and degrade, it is important to understand how environmental changes affect plumage and reproductive fitness.

8-7 WOFFORD, S.J.*; LAPLANTE, P.M.; MOORE, P.A.; Bowling Green State University, BGSU; *swofford1@gmail.com*
Sniffing out the competition: Examining the role of chemical signals in same sex and mixed sex crayfish contests

Information obtained from the surrounding environment allows organisms to reduce uncertainty and influences behaviors with direct or indirect fitness consequences. Information plays a vital role in agonistic encounters with conspecifics. While contests enable the establishment of hierarchies that can provide exclusive or primary access to resources, the value of that resource should outweigh energy and time costs used to obtain it. This "cost-benefit analysis" or assessment strategy can be performed by gathering information about one's own state (e.g. fighting ability, energy stores), about the resource (e.g. quality, availability), and (potentially) about an opponent (e.g. relative strength, size). Limited studies of female and mixed sex fighting behavior have shown that males and females differ in their fighting strategies. Some studies suggest that these differences lie in the source of information driving motivation in these contests. In order to elucidate mechanistic differences in the decision making paradigm (i.e. assessment strategy) used by males and females during contests, we compared the use of a quantifiable signal over different types of contests. Male and female crayfish (*Orconectes rusticus*) were injected with a fluorescent dye and then paired with a contestant of the same or opposite sex. The dye was used to visualize urine released from the individuals, a chemical signal with numerous implications for crayfish behavior. Contest videos were analyzed for the type of assessment strategy in use as well as any differences in the timing or duration of signal release. In line with expectations based on previous studies, we found that males and females appear to differ in assessment strategy. We also found that males and females use the signal of interest (urine) differently during agonistic contests.

79-5 WINTERS, GC*; KOHN, AB; LAUX, R; STERN, N; BOSTWICK, C; DI COSMO, A; HOCHNER, B; MOROZ, LL; Whitney Lab, Dept of Neuroscience U. Florida, Whitney Lab, U. Florida, Humbolt State U., Hebrew U. Jerusalem, U. Naples Federico, McKnight Brain Institute, U. Florida; *gabrielle.winters@gmail.com*

Molecular organization of *Octopus* brains: First insights into unique memory center signaling

Cephalopod molluscs (*Octopus*, cuttlefish, squid, *Nautilus*) have independently evolved neural circuitry that controls stereotyped and learned behaviors whose complexity rivals that of many mammals. The Vertical Lobe (VL), a functional analog to the mammalian hippocampus, is unique to cephalopods and mediates spatial memory and visual discrimination. We used RNA-seq/transcriptome profiling, and anatomical validation using *in-situ* hybridization to identify and map candidate cephalopod memory molecules. We identified 17,841 transcripts in the VL and found 12,379 (69.4%) appear to be cephalopod-specific, while many memory related signal molecules were not identified in the VL transcriptome. These data suggest that cephalopods used a distinct subset of genes and signaling molecules (SM) to form memory circuits. Previously, we identified the neuropeptide complement in the *Aplysia* genome, and found 22 homologs in *Octopus* VL. We mapped the expression of 17 of these conserved neuropeptides and two of them, TkP and WhP, localize to the VL circuit. WhP is expressed in the cell bodies of the MSF, where the afferent tract to the VL begins, and TkP localizes to cell bodies of each VL gyrus. Next, we used computational predictions and manual annotation to identify putative SM in the VL. We identified four cephalopod-specific abundant transcripts, one of which (IRP) maps to cell bodies in the VL. Two others are highly expressed in *Octopus* brain, but absent in the ancestrally branching *Nautilus* CNS. This expansion of novel SM in the VL circuit is likely a key feature of cephalopod memory systems, implying extensive parallel evolution of cephalopod brains. Supported by NSF, NIH & NASA

61-2 WOLF, BO*; MCKECHNIE, AE; MCWHORTER, TJ; GERSON, AR; SMITH, EK; TALBOT, WA; SMIT, B; WHITFIELD, M; O'NEIL, JJ; Univ. New Mexico, Albuquerque, Univ. Pretoria, South Africa, Univ. Adelaide, South Australia, Univ. Massachusetts, Amherst, Univ. New Mexico, Albuquerque, Univ. Port Elizabeth, South Africa; *wolf@unm.edu*

Heat stress, climate change, and the thermoregulatory performance of desert birds

We studied thermoregulatory performance of summer-acclimatized wild birds to heat stress in the deserts of Australia, North America and South Africa. We measured evaporative water loss (EWL), resting metabolic rate (RMR) and body temperature (T_b) continuously using ramped temperature profiles with increasing air temperatures in 40+ species, which included 10 orders with body size ranging from 7- 450g. We estimated the heat tolerance limit (HTL) for each species by measuring T_b , EWL and RMR and activity when exposed to air temperatures ranging from 30-64°C. We found that birds from the orders Columbiformes (pigeons and doves) and Caprimulgiformes (nighthawks and nightjars) had the highest HTLs and were able to thermoregulate at air temperatures as high as 60°C. Perching birds (Passeriformes), in contrast, showed a much more limited capacity for thermoregulation at high air temperatures and exhibited HTLs near 50°C. We found that HTLs appear to be driven by the primary pathway of evaporative heat loss, where birds that evaporate water from the skin or have a well-developed gular apparatus were most effective at heat dissipation at high air temperatures. Body size was also a critical factor in determining the capacity of a species to tolerate high temperatures. This work greatly expands our knowledge of avian tolerance to heat and provides insights into how rapid warming and more intense heat waves may change avian distributions and community structure.

22-4 WOLL, S.C.*; PODRABSKY, J.E.; Portland State University, Portland; scwoll@pdx.edu

Insulin-like Growth Factor Expression in Annual Killifish Embryos

Cellular proliferation during multicellular development is a highly regulated process that relies on different signaling factors being produced at the proper time, in the proper concentrations, and the presence of appropriate receptors. The mechanisms responsible for cell cycle arrest associated with developmental arrest are not completely understood in any species, but a wealth of evidence points to the importance of insulin-like growth factors (IGFs) signaling in regulating entrance into metabolic dormancy. *Austrofundulus limnaeus*, an annual killifish, is uniquely suited to address the complex relationship between IGFs and developmental arrest. The embryonic development of *A. limnaeus* has been well-defined and contains a unique developmental arrest, called diapause, that can be experimentally induced or avoided through manipulation of environmental conditions. Whole-embryo IGF protein levels were quantified using competitive ELISA assays. Embryos entering diapause exhibited reduced levels of IGF-I protein compared to embryos that do not enter diapause. This differential expression of IGF-I protein suggests a role for IGF-I in the regulation of diapause. Thus, we have examined the mRNA expression patterns of proteins involved in IGF signaling during early development in both developmental trajectories using Illumina RNAseq. By studying the function and regulation of IGF signaling during development in a diversity of species I hope to improve our understanding of development and ageing, and how IGF dysregulation can lead to uncontrolled or cancerous growth.

50-1 WOODIN, SA*; BERKE, SK; WETHEY, DS; Univ. of South Carolina, Siena College; woodin@biol.sc.edu

The ecology and biogeography of *Diopatra biscayensis* (Fauchald): Kristian's last description

Kristian, like myself, loved polychaetes. Of all the polychaetes in the world, Kristian quite rightly thought that *Diopatra* was the most wonderful. He was always willing to think about them, no matter how twisted your perspective. *Diopatra biscayensis* is the last *Diopatra* that Kristian Fauchald described. I suspect he did it as a favor, and because he loved them, and it was an opportunity to annoy the ghost of Fauvel. When first discovered, *D. biscayensis* was thought to have a continuous distribution from Aracachon in southern France to the Brittany peninsula. More recent work has revealed its distribution to extend south as far as San Vicente de la Barquera, on the northern coast of Spain (Arias and Paxton 2015). Fascinatingly, *D. biscayensis* also has a discontinuous population more than 500 km beyond its northern limit in the Bay of Biscay. *D. biscayensis* achieves densities of over 500 m⁻² and builds an emergent tube with a L-shaped tubecap with abundant decoration. The southernmost populations are denser than those in the north but with a smaller maximal size. This pattern is repeatable over years, interesting, but unresolved as to causal agent. If *Diopatra* continues to expand its distribution northward with ocean warming, it may become a major player in determining infaunal shallow water communities on the Atlantic coast of Europe.

24-5 WOMACK, M.C.*; CHRISTENSEN-DALSGAARD, J.; HOKE, K.L.; Colorado State University, Fort Collins, University of Southern Denmark, Odense M; mollywo@rams.colostate.edu
Better never than late? Convergent loss of late-forming ears in toads

Anurans have outer and middle ear structures to transmit airborne sound from the environment to their inner ear sensory cells. Yet, many bufonid (true toad) species have independently evolved earlessness, the lack of middle and outer ear structures, despite the importance of acoustic communication in most toad mating systems. Our work aims to determine why middle and outer ear structures are so evolutionarily labile in the Bufonidae family by comparing hearing and morphological data of eared and earless bufonid species within a phylogenetic context. We show that the middle and outer ear structures form very late in the development of toads and take many months past metamorphosis to become fully functional. Adult earless species are typically less sensitive to acoustic stimuli at high frequencies and more sensitive to low frequency vibrations compared to eared toads. The skulls of earless species neither lack other skull bones nor are less ossified than skulls of eared species. We conclude that extratympanic hearing pathways buffer the hearing consequences of tympanic ear loss, and we discuss roles for heterochrony and directional selection in shaping the evolutionary lability of ear structures.

S12-5 WOOLLEY, S M; Columbia University; sw2277@columbia.edu

Insights gained from comparative approaches to studying vocal communication

Social communication is a strong selective pressure on brain evolution; the exchange of information between individuals is crucial for fitness-related behavior such as mating. At the species level, brains of signal senders and receivers are likely to be functionally coordinated. We study vocal behavior and auditory processing in multiple species of estrildid finches whose species-specific songs differ dramatically in their spectral and temporal features. Our goal is to understand how species identity and experience interact to shape behavior and the neural systems that subserve communication. Male finches learn to produce acoustically complex songs that are both species-specific and unique to an individual. Song learning occurs during a developmental critical period and depends on auditory processing. Both sexes rely on central auditory processing to recognize species-specific and individual songs. I will present our studies of song acoustics, auditory perception, song learning and the neural coding of sound that provide insight into: 1) relationships between species-specific communication signals and the neural coding of those signals in sensory systems; and 2) effects of social learning on the development of communication behavior and cortical processing of communication signals.

4-6 WORD, K.R.*; WINGFIELD, J.C.; Univ. of California, Davis; krlizars@ucdavis.edu

Measuring Allostatic Load: Heart rate and corticosterone in free-living and captive wintering Gambel's white-crowned sparrows

The model of allostatic load describes a functional role for the stress response in moderating energetic optimization and tradeoffs in a capricious environment. As such, it predicts a direct relationship between energetic costs incurred by environmental fluctuations and the endocrine mediators of allostatic processes, particularly glucocorticoids. Heart rate telemetry was used to examine effects of environmental conditions on energy budgeting in outdoor-captive and free-living Gambel's white-crowned sparrows (*Zonotrichia leucophrys gambelii*). Baseline corticosterone was measured at the beginning (both groups) and end (captive only) of each trial. Weather, and particularly environmental temperature, influenced heart rate in both groups. In captive birds, heart rate was significantly predicted by an interaction between ambient temperature and subsequent baseline corticosterone levels. Implications of these subtle interactions for the allostatic load framework and the evolution of stress physiology will be discussed.

16-1 WRIGHT, R.M.*; KENKEL, C.D.; BAY, L.K.; MATZ, M.V.; The University of Texas at Austin, Australian Institute of Marine Science; rachelwright8@gmail.com

Colony-specific responses to bacterial challenge in the coral *Acropora millepora*

The randomness of coral disease dynamics suggests that differences in individual coral's susceptibility may be a major factor influencing mortality rates in a population. Understanding the cellular mechanisms responsible for these differences could lead to the development of much-needed tools to forecast coral disease risks. Here, we compared global gene expression profiles of individual corals challenged with a bacterial pathogen to reveal molecular signatures correlated with disease outcome. We measured mortality rates for eight adult colonies of *Acropora millepora* from two Great Barrier Reef populations after bacteria challenge with putative coral pathogens, *Vibrio* spp. Significant difference in mortality between colonies was associated with differential gene expression in response to the bacterial challenge, but not with immune responses at the protein level. Genes associated with growth and defense against oxidative stress were upregulated in corals that survived bacterial challenge relative to those that did not. Conversely, surviving corals downregulated genes associated with signal transduction and metalloendopeptidase activity. These susceptibility-associated genes can become biomarkers to evaluate coral disease risk in nature, since their expression in an individual informs us of their likely disease outcome.

83-1 WORTHINGTON, AM*; JURENKA, RA; KELLY, CD; Washington State University, Iowa State University, Université du Québec à Montréal; amy.marie.worthington@gmail.com
Mating to acquire ejaculate-derived compounds that confer fitness benefits

Resources provided by males that increase female fecundity after mating are considered to be the driving force of high female mating rates, yet often, species in which females do not receive these benefits still experience increased fitness from mating frequently. One hypothesis suggests that females receive male-derived substances within the ejaculate that boost survival or offspring production. If these materials are limiting to females and require continual renewal via mating, they could offer a functional mechanism linking high mating rates to increased fitness. Mated female Texas field crickets have stronger immune systems than virgin females and females with higher mating rates are significantly more fecund. These positive effects of frequent mating, however, only take place when females receive an ejaculate containing testes-derived components. Here, we investigate the sexual transfer of prostaglandin E₂ (PGE₂), an important hormone-like mediator of insect reproduction and immunity. We demonstrate that PGE₂ indeed originates from the testes and is stored within the female sperm storage organ after mating. Also as predicted, PGE₂ is quickly depleted within one week of mating, but its presence can be maintained at high quantities and for prolonged periods of time by remating. Our results support the hypothesis that high female mating rates increase the amount and availability of PGE₂ throughout the breeding season, which might explain the positive relationships between female mating rate, fecundity, and immune function if PGE₂ is mediating investment in these important life-history traits after mating.

18-5 WRIGHT, N.A.*; STEADMAN, D.W.; TOBALSKE, B.W.; WITT, C.C.; Univ. of Montana, Missoula, Univ. of Florida, Gainesville, Univ. of New Mexico, Albuquerque; nataliestudiesbirds@gmail.com

A new island rule for birds: evolution toward flightlessness

Island birds have evolved flightlessness at least a thousand times. Each instance involved dramatic shape changes via the reallocation of mass from the forelimbs to the hindlimbs. The adaptive energy savings of this near elimination of costly flight muscles can only be realized by species that need not fly to forage and in the absence of terrestrial predators. The majority of island birds, however, retain flight. We hypothesize that these volant island species also reduce their investment in the flight apparatus, inducing a qualitatively similar but more subtle shape change. We examined shifts in the relative investment in forelimbs versus hindlimbs in 366 bird populations from 80 islands across the Pacific and Caribbean. We found that island-restricted volant species evolved smaller flight muscles than their continental relatives, with the degree of reduction greatest on islands of low species diversity. The decrease in flight muscle size was accompanied by an increase in leg length. This evolution along the trajectory toward flightlessness occurred in island bird populations from all nine families studied. We tested how reduced flight muscles and longer legs affect take-off performance in birds on the small, depauperate island of Tobago. We found that birds on Tobago had slower maximum velocity and maximum acceleration during take-off relative to conspecifics on the larger island of Trinidad. Initiation of wingbeats occurred later during take-off in populations on the island of Tobago. Lower predation pressures on small, species-poor islands likely permit the slower take-off velocities that result from island birds' reduced flight muscles. These predictable morphological changes may explain why volant island birds are particularly vulnerable to introduced predators.

58-5 WROBEL, E.R. *; WILCOXEN, T.E. ; GALEWSKY, S.; SRINIVASAN, S.; HORN, D. ; University of Georgia, Millikin University, Millikin University ; ewrobel@uga.edu

Prevalence and health impacts of avian pox and conjunctivitis in a community of wild songbirds

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. Birds often gather at bird feeders in large densities, creating an increased likelihood of disease transmission around these resources. Over a three-year period, we surveyed individuals from nine species of birds for the presence of two different pathogens that can have a serious impact on the overall health of birds: the pathogenic bacteria, *Mycoplasma gallisepticum* (a causative agent 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. We used both field identification of pathological symptoms and molecular techniques to identify pathogens. We found severe symptoms to be more common in feeder-using birds than in songbirds at sites without feeders. Songbirds hosting these pathogens showed greater heterophil to lymphocyte ratios, lower total antioxidant capacity, and were in overall worse body condition. PCR analysis was also utilized to detect either pathogen in birds that may have been infected but not showing visual symptoms of disease. Overall, this study reveals important disease dynamics associated with bird feeding activities in a community of free-living birds.

55-7 WYNEKN, J*; SALMON, M; HAMANN, M; WHITING, S; Florida Atlantic University, Parks and Wildlife, Western Australia, Parks and Wildlife, Western Australia; jwynekn@fau.edu
Shape Change in Neonate Sea Turtles: Spines, Keels, Points, and "Hockey Pucks"

Sea turtles hatch on oceanic beaches, enter the surf and then migrate to offshore nursery areas. Hatchlings are small and defenseless; predators take many. They reduce vulnerability by migrating at night, growing rapidly, and enhancing the protective function of the shell through changes in shape, spination, and sharp edges. We focus how those modifications differ among species during early growth. We compared changes in shape among loggerheads (*Caretta caretta*), Kemp's ridleys (*Lepidochelys kempii*), green turtles (*Chelonia mydas*), and flatback turtles (*Natator depressus*). Flatbacks (F), which are closely related to green turtles (G), uniquely remain in predator-rich continental shelf waters; other species are oceanic as small juveniles. They return to coastal waters when larger/less vulnerable. Ridley (R) and loggerhead (L) turtles are more closely related to one another than to flatbacks and green turtles. These "R-L" and "G-F" groups have similarities and differences in development of defensive structures and behavior. All showed allometric shell growth, increasing in width faster than length, a modification that should decrease vulnerability to gape-limited predators. Shape change was more extreme in G-F ("hockey puck" shaped) than in the R-L, and most pronounced in flatbacks. Shell spination was pronounced in the R-L group. G-F shell surfaces remained smooth with sharp serrated margins that are more pronounced in flatbacks than in green turtles. Differences were correlated with behavioral contrasts in how the turtles avoid predators. R-L reduce detection by minimizing movement; G-F escape by fleeing rapidly. The two groups evolved different anti-predator strategies that are manifested by differences in how they grow, morphology and behavior.

89-4 WU, J.N*; SHI, G.Y; REN, J; HU, D.L; GE, S.Q; 1. Key Laboratory of Zoological Systematics and Evolution, Chinese Academy of Sciences, Beijing, PR China. 2. George W. Woodruff School of Mechanical Engineering, and School of Biology, Georgia Institute of Technology, Atlanta, GA, USA. 3. Department of Automotive Engineering, Tsinghua University, Beijing, PR China. 1. Key Laboratory of Zoological Systematics and Evolution, Chinese Academy of Sciences, Beijing, PR China. 2. George W. Woodruff School of Mechanical Engineering, and School of Biology, Georgia Institute of Technology, Atlanta, GA, USA. 1. Key Laboratory of Zoological Systematics and Evolution, Chinese Academy of Sciences, Beijing, PR China; 791396787@qq.com

A flea beetle jumps like a coin flips

When we flip a coin, we expect a 50 percent chance of it landing on heads. But not with the flea beetle. Flea beetles live in a maze of leaves and other vegetation. To escape predation, it can jump over 20 body lengths, turning up to 20 somersaults in the process, similarly to the way we toss a coin. Surprisingly, the beetle lands on its feet 90 percent of the time. We perform high-speed videography with landing platforms of varying orientation. We hypothesize beetles use a vision-based control law during their flight trajectory, opening their wings to varying their drag in mid-flight so that they stick a perfect landing, every time.

2-3 XU, NW*; DABIRI, JO; Stanford University; nicolexu@stanford.edu

How pacemaker numbers affect swimming behavior in jellyfish

An understanding of the locomotive control mechanisms in *Aurelia aurita*, a species of scyphomedusae, can potentially enable more efficient biomimetic medical tools and decrease the energy consumption of aquatic vehicles. Scyphomedusae are radially symmetric invertebrates comprising a flexible bell and subumbrellar coronal muscle that contracts to provide motive force. To swim, eight pacemakers along the bell margin activate the motor nerve net, which innervates the muscle ring. Jellyfish primarily swim vertically but can achieve more complicated motions by activating select pacemakers, which generates torque by time delays of traveling wave propagations and asymmetrical separation of vortices. Because *A. aurita* can survive with different numbers of pacemakers from natural mutations or injuries, two fundamental questions are why scyphomedusae have eight pacemakers and whether this tetrasymmetry found in all jellyfish is advantageous under certain swimming conditions. Through computational modeling and observation, we investigate whether there are optimal numbers of pacemakers to coordinate straight swimming, sharp turning, and/or smooth turning; and how these might change at various Reynolds numbers.

66-7 YANG, P.*; LAMARCA, M; HU, DL; Georgia Institute of Technology; peijyang@gatech.edu

The intestine is a blender

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 human health, the physics of digestion remains poorly understood. In this study, we ask a simple question: what sets the frequency of intestinal contractions? We measure the frequency of intestinal contractions in rats, as a function of distance down the intestine. We find that intestines contract radially ten times faster than longitudinally. This motion promotes mixing and, in turn, absorption of food products by the intestinal wall. We calculate viscous dissipation in the intestinal fluid to rationalize the relationship between frequency of intestinal contraction and the viscosity of the intestinal contents. Our findings may help to understand the evolution of the intestine as an ideal mixer.

104-1 YAP, K.*; HARRIS, K.C.; KIM, O.; WILLIAMS, T.D.; Simon Fraser University; knyap@sfu.ca

Individual variation in physiological effects of training for increased foraging effort in zebra finches, *Taeniopygia guttata*.

It has long been assumed that a key determinant of reproductive success in birds is the quality of parental care and, consequently, increased foraging effort associated with rearing chicks. Some, though not all, studies have shown that parental effort, as measured by provisioning rate, can affect reproductive output although individuals appear to have considerable plasticity regarding provisioning rate, suggesting that perhaps individuals vary in the cost they pay for provisioning chicks at a higher rate. However, little is known about the physiological basis of individual variation in workload associated with foraging effort, or costs associated with high workload. To examine physiological response to increased workload, we experimentally manipulated foraging costs in captive zebra finches (*Taeniopygia guttata*) to examine physiological responses to "training" and high workload. We measured pre-treatment basal metabolic rate (BMR), hematocrit (Hct), and hemoglobin (Hb), and collected plasma samples (n=18 males, 17 females). Then we subjected half of the birds to high foraging cost conditions (HF) and the other birds to control foraging conditions (CTR). We measured BMR and collected plasma samples again at 3 timepoints over 90 days as birds adapted to HF condition. All birds were sacrificed at the end of the experiment to examine longer-term changes in body composition and physiology. Preliminary results showed that HF birds foraged at a higher rate, and that there was no change in BMR, Hct, Hb, pectoral muscle mass and heart mass, in relation to increased workload. Regarding potential physiological cost, HF birds had smaller gut size compared to CTR birds at day 90. To further examine physiological costs induced by high workload, we will analyze measures of oxidative stress and plasma metabolites.

35-4 YAVNO, S.*; HOLZMAN, R; Tel Aviv University and the Interuniversity Institute for Marine Sciences; stanyavno@post.tau.ac.il

What determines the survival of marine fish larvae through the critical period? Effects of the hydrodynamic regime and phenotypic traits

Many species of freshwater and marine fish experience high levels of mortality during early ontogeny. While few experimental studies have identified why larval fish perish, recent research suggests that the hydrodynamic regime restricts their ability to acquire prey, and possibly leads to starvation. In this study, gilthead seabream (*Sparus aurata*) larvae were reared under increasing water viscosities to test the hypotheses that (1) the hydrodynamic regime affects survival through the critical period, and that (2) phenotypic differences among larvae predict survival. Seabream were reared individually, and phenotypic traits of survivors and mortalities were assessed on each rearing day. Survivorship was negatively correlated with viscosity and age, and positively correlated with body size. Additionally, individuals reared under high viscosity exhibited the greatest measures of body depth. Other morphological characteristics that are linked to foraging and locomotion were weak predictors of survivorship, but there was higher morphological variance among mortalities. These data suggest that larger body sizes may be beneficial for overcoming the viscous effects of the hydrodynamic regime during the earliest stages of ontogeny, and that functional, external morphological traits may have a secondary role in determining survival of larval fish.

93-6 YEATON, I.J.*; BAUMGARDNER, G.A.; WEISS, T.M.; NAVE, G.; ROSS, S.D.; SOCHA, J.J.; Virginia Tech; iyeaton@vt.edu

Snakes in a Cube: high-resolution kinematics of gliding in flying snakes

Gliding by flying snakes of the genus *Chrysopelea* is distinguished by complex, three-dimensional body undulations. Undulation may enhance lift, as it places a greater percentage of the body perpendicular to the flow, but it may also be destabilizing, as unsteady aerodynamic forces are constantly redistributed over the body. Quantifying the undulation waveform is therefore necessary to determine the contributions of aerodynamic and inertial effects on stability. However, previous experimental studies under-resolved the undulation waveform during gliding. Here, we report on recent glide experiments for two species of *Chrysopelea* to improve the temporal (6X) and spatial (4X) measurement resolutions of the body, and to provide the first measurements of tail motion. We recorded a total of 97 glides from 7 individuals of *C. paradisi* and 34 glides from 5 individuals of *C. ornata* in a large indoor arena ("The Cube" at Virginia Tech). Snakes were marked with between 12 and 17 landmark points along the trunk and tail, and allowed to jump and glide from a height of 8.5 m. Landmark points were tracked using a 23-camera motion-capture system (179 fps, Qualisys Oqus 500) and two high-speed cameras (500 fps, Photron APX-RS). We reconstructed body posture throughout the glide by fitting arc-length constrained quintic splines to the measured points and calculating the curvature and torsion. *C. paradisi* had better overall glide performance and more uniform lateral undulation than *C. ornata*. Supported by NSF 1351322.

110-2 YEN, J*; HELMS, M; GOEL, A; KHAN, S; TOVEY, CA; WEISSBURG, MJ; Georgia Institute of Technology; jeannette.yen@biology.gatech.edu

Teaching Practices in Biologically Inspired Design

Biologically inspired design (BID) is a powerful and logical bridge to multidisciplinary education. Biologists, engineers and designers face the problem of identifying design criteria, yet each approaches the problem from a unique perspective. Biologists know about a great variety of organisms and the functions they accomplish to survive and reproduce, with an implicit understanding of design principles employed by living organisms. Engineers are experienced in specifying operational design criteria and analyzing desired functionalities. Designers are expert in identifying human challenges, and assessing and improving the applicability, appeal, and usability of a design. Mixing upper level undergraduates majoring in engineering and design with those majoring in biology, we have devised a BID class at Georgia Tech that provides both increased content knowledge in areas relevant to BID as well as practical training in methods and techniques that facilitate the identification and translation of biological principles into solutions for human challenges. Our goals in designing this course are both to facilitate BID and to provide novel practices that enhance current methods in science, technology, engineering, and math education (STEM). Our learning goals include: (1) novel techniques for creative design; (2) interdisciplinary communication skills; (3) knowledge about domains outside of their core training; (4) a uniquely interdisciplinary collaborative process; and (5) application of existing technical knowledge to a new discipline. To share our teaching experience, we present key problems that we encountered and how we addressed them. We also point out where tough student challenges still exist that are in need of attention from the community.

47-2 YEN, J*; PENDER-HEALY, L; HEAPHY, M; Georgia Institute of Technology, Gwinette K12; jeannette.yen@biology.gatech.edu

Trail following by planktonic microcrustacean copepods

The response of precise three-dimensional trail following by the aquatic microcrustacean copepod is a consequence of viscosity-induced attenuation of mixing that enables the persistence of small-scale chemical and hydrodynamic cues. *Temora longicornis*, a coastal marine copepod, and *Hesperodiptomus shoshone*, a high-alpine freshwater lake copepod, exhibit tracking of laminar trails. High-speed videography coupled with high-magnification Schlieren optics enabled us to visualize both the deformation of the trail signal and the propulsive movements of the male copepod, providing the opportunity to examine a guidance system at an intermediate Reynolds number. Males happily followed the trails we made and our observations show clear differences between the marine and freshwater species. Comparative analyses of these two species reveal tracking mechanisms that differ in sensor location with respect to the trail and locomotory kinematics. Copepods perform directed motions that lead them to a stimulus source in the absence of other collimating stimuli. Tracking by the copepod around the trail allows it to have one or numerous sensors inside and outside the trail to facilitate edge detection using spatial sampling. The advantage of this remarkable behavior of following trails fast and accurately is to encounter mates or food patches more frequently, thus contributing to recruitment into the population and transfer of energy up the trophic food web. Precise mate and food finding strategies found for pelagic copepods may be a key adaptation, promoting survival in these open-ocean planktonic populations.

52-4 YOHE, L.R.*; DAVIES, K.; ROSSITER, S.J.; DÁVALOS, L.M.; Stony Brook University, NY, Queen Mary College of London; laurel.yohe@stonybrook.edu

Selection on the sniffer: olfactory receptor evolution shows association with diet

Olfactory receptor genes are the largest family of protein-coding genes in the mammalian genome, and how natural selection has influenced these odorant detectors remains largely unknown. New World Leaf-nosed bats (Phyllostomidae) occupy an enormous range of dietary niches and have evolved a high diversity of sensory adaptations to find food. While previous research has established that the number of functional olfactory receptors is greater in plant-visiting phyllostomids than in insectivorous bats, the molecular evolution of these genes has not been analyzed. To identify and compare olfactory receptor gene sequences across phyllostomids with divergent diets, we generated transcriptomes from olfactory epithelial tissues. We characterized unique sets of receptors shared only among plant-visiting bats, which may have resulted from recent duplications generating new receptors required for identifying plant resources. Several homologous receptors detected in frugivorous and nectarivorous species were nonfunctional in insectivorous species, suggesting plant-visiting bats have undergone strong purifying selection to maintain olfactory receptor function. Concurrently, bats relying on alternative sensory adaptations (e.g. echolocation) may have experienced relaxed selection on homologs. Finally, we tested for diversifying selection in functional orthologous receptors across species and found evidence of several olfactory receptors under positive selection, consistent with the neofunctionalization of receptors for discriminating fruit and flower odors. Our study illuminates how the evolution of olfactory receptors may have opened up novel dietary niches for bats.

101-1 YOUNG, R.L.*; O'CONNELL, L.A.; HOFMANN, H.A.; University of Texas, Austin, Harvard University, University of Texas, Austin; rebecca.youngbrim@gmail.com

Comparative transcriptomics of the monogamous: conserved themes despite independent behavioral evolution

Complex social behavior evolved independently many times, with monogamy as a prominent example. Certain neurochemical and neuroendocrine pathways have ancient origins and likely play vital roles in behavioral regulation across distantly related taxa. We hypothesized that akin to the now established genetic toolkit, as novel behavioral traits arose independently in diverse lineages, similar neural and molecular mechanisms were likely recruited repeatedly. Much progress has been made towards unraveling the genes and regulatory sequences that govern the development and function of brain circuits supporting social behavior in a few species, but much is still unknown. Here we use RNA-seq to compare whole genome gene expression profiles across brains of monogamous and non-monogamous male *Microtus* voles, *Peromyscus* mice, passerine birds, dendrobatid frogs, and cichlid fishes. We find that genes highly up- or down-regulated in monogamous species of one clade also tend to be highly up- or down-regulated in the monogamous species of another clade. Genes with concordant expression patterns across clades were involved in signal transduction and neural development and plasticity. These results suggest that a core network of genes were recruited repeatedly and independently in these convergent evolutionary transitions to monogamy.

127-6 YU, M-Y*; LIEDTK, A.; REVZEN, S.; University of Michigan, Ann Arbor, University of Birmingham; myyu@umich.edu
Trotting horses synchronize their legs during the second half of stance

Horses trot by synchronizing two pairs of legs and alternating support between them. We examined this synchronization by reducing each leg down to a phase oscillator and looking at the dynamics of the coupled oscillators representing a pair of legs that step in synchrony. Our recent work on near simultaneous transitions in hybrid dynamical systems suggested that touchdown may act to synchronize legs without neural feedback, provided legs touch-down independently but lift-off in a coordinated fashion. Using an existing dataset of 5293 strides, from 54 trials with 6 horses (Irish thoroughbred) we tested this hypothesis. We reduced each leg to a phase oscillator, mapped the touchdown and liftoff transition in phase coordinates, and examined the phase coupling for expansion and contraction in various parts of the cycle. Our results showed that while the hypothesized hybrid transition structure was present, touchdowns were associated with a decrease instead of an increase in synchronization. Legs were brought back into synchrony in a continuous region in the second half of stance. We conclude that while the hybrid synchronization effect might be present and active, the only clearly detectable form of synchronization acts continuously during the second half of stance.

123-2 ZANI, P.A.; Univ. Wisconsin-Stevens Point; pzani@uwsp.edu
Life-history trade-offs of lizards in response to drought

Changing environmental conditions, such as drought, can impose life-history trade-offs on animal populations. Over the past several years, drought conditions have influenced the life history of side-blotched lizards (*Uta stansburiana*) in northern Nevada. Ongoing monitoring of lizard populations has revealed that the effects of and recovery from the worst of the drought, which occurred in 2013, may have involved multiple life-history trade-offs. Drought conditions caused a decline in body condition of all lizards, especially females, accompanied by the absence of late-season of egg laying (evidence of a shift from reproduction to survival). This resulted in a marked alteration to the body size distribution of adults. By 2014 when the drought had eased, all lizards were two years old or older. Hence, mean adult body size in 2014 was 7-10% greater than during the drought (~3 mm longer; ~0.7 g heavier) and standard deviation in body size was low. However, the older females, which had dominated the adult breeding population in 2014, were largely absent from the population in 2015, two-years post-drought. I infer from these observations that females first shifted their life history tactics from reproduction (in 2012) to survival (in 2013) then back to reproduction (in 2014). Moreover, because there were relatively few three-year old females in 2015, reproduction by females in 2014 appears to have been at the expense of continued survival by those females. In contrast, the two-year old (and older) males survived the 2013 drought and were able to enter the largest sizes classes post-drought in 2014 and 2015.

62-2 ZAKAS, C*; ROCKMAN, MV; New York University; czl2@nyu.edu

The genetics of developmental transitions: Determining the genetic architecture of development mode in a dimorphic model

How do major transitions in development occur, and what are their evolutionary consequences? Large-scale evolutionary changes, from molecular diversification to speciation, are initially constrained by early developmental program. To understand how genetic variation contributes to variation in development, I use an emerging model system: the polychaete *Streblospio benedicti*. This species is ideal because it produces two distinct offspring types that differ in egg size, early development, and larval morphology. Using genetic crosses, I identify quantitative trait loci (QTLs) for reproductive traits. By extending crosses to the F3 generation, I can map loci associated with egg size and distinguish maternal effects. To contextualize this marker information, I am constructing both the genetic map and the *S. benedicti* genome assembly. I identify regions that differ between larval morphs, and uncover how the dimorphic developmental program is determined on a whole-genome level.

50-2 ZANOL, J.; DA SILVA, T; HUTCHINGS, P*; 1Campus Xerém, Universidade Federal do Rio de Janeiro, Duque de Caxias, RJ, Brazil, Australian Museum; pat.hutchings@austmus.gov.au
Diversity of *Marphysa* (Eunicidae, polychaete) on the Australian coast

Species of *Marphysa* are popular bait for recreational fishing in Australia. Until 10 years ago, they were all considered the same species, *Marphysa sanguinea* (Montagu, 1813). However, *M. sanguinea* is not present in the Australian coast. Instead, at least four *M. sanguinea* like species are present. Of these, two have been described as new species and at least an additional one is undescribed. Also, four other species of *Marphysa* not closely related to *M. sanguinea* have been identified from Australian coastal areas. Such diversity is the result of multiple colonization of the Australian Coast by different *Marphysa* lineages rather than of local diversification and is being explored using both molecular and morphological techniques. We have found three clades based on molecular data, one bearing species with both compound falcigers and spinigers, a second including species with only compound falcigers and the third one of species with only compound spinigers or lacking compound chaetae. The increase in knowledge about the diversity of *Marphysa* species in Australia as well as about the history of this diversity can greatly contribute to more effective conservation measures and exploitation planning of these species by the bait industry.

86-1 ZATTARA, EE*; LINZ, DM; TOMOYASU, Y; MOCZEK, AP; Indiana U, Miami U; ezattara@gmail.com
Postembryonic redeployment of *otd* during adult head formation underlies the developmental evolution of novel head structures in horned beetles

Arthropods are formed by segments whose identities are determined by *hox* genes, but anterodorsal head tissues pose an exception to this rule. The bend-and-zipper model proposes that this region originates by upfolding of anterolateral embryonic primordia, suggesting that its developmental control is separate from its ventral counterpart. This could have facilitated evolution of novel dorsal head structures critical for insect diversification. Such structures are typically absent in the larval head, and instead develop during metamorphosis. Yet nothing is known about how the dorsal head is patterned during postembryonic development or how novel structures have become integrated into this process. We used larval RNAi to investigate if *otd* and *six3*, two embryonic patterning genes, instruct adult dorsal head formation in the flour beetle *Tribolium castaneum* and the morphologically divergent horned beetles *Onthophagus taurus* and *O. sagittarius*. We show that in *Tribolium*, *otd1* and *otd1+otd2* RNAi cause subtle gaps in ventral trunk plates but have no obvious effects in the dorsal head. In contrast, *otd1* and *otd1+otd2* RNAi in *Onthophagus* results in deletion of large portions of ventral trunk plates, and spectacular changes in dorsal head structures, including reduction or deletion of horns, novel patterns of horn formation, and ectopic medial eyes. RNAi of *six3* results in smaller eyes but has no obvious effect on the head in any species. We characterized expression of *otd1*, *otd2* and *six3*, and show that *otds*, but not *six3*, are upregulated in the dorsal head epidermis of *Onthophagus spp.* Our results suggest that embryonic head patterning genes play crucial and previously undescribed roles in specifying the identity of medial epidermal head structures during postembryonic development.

S6-4 ZERA, A.J.; University of Nebraska; azera1@unl.edu
Evolutionary endocrinology of dispersal polymorphism in insects
 Studies of dispersal polymorphic insects have and continue to contribute significantly to the development of evolutionary endocrinology. This talk will briefly summarize key early and current studies, and future directions, with a focus on evolutionary-endocrine studies of wing-polymorphic and phase-polyphenic insects. Classic studies of juvenile hormone (JH) and its regulators in wing-polymorphic *Gryllus* crickets were the first to provide a deep integration of quantitative genetics and endocrinology by estimating, for the first time, key quantitative genetic parameters for endocrine traits in non-domestic animals, showing how artificial selection can modify endocrine function, and identifying genetic correlations between endocrine and important life history traits and trade-offs. Recent detailed studies of JH signaling in *G. firmus* have identified unexpected morph-specific circadian rhythms for both JH titers and global gene expression, sparking an exciting expansion of evolutionary-endocrinology to include chronobiology (circadian rhythms). Recent neuroendocrine studies of locusts are providing detailed information on the mechanisms by which variable environmental signals are transduced via the endocrine system to guide fast-acting phenotypic transformations. These studies are important for understanding the mechanisms underlying adaptive polyphenism- a key topic in evolutionary biology. Finally, the endocrine regulation of morph development has been a longstanding topic in insect evolutionary endocrinology. Classic studies, which have focused primarily on the role of key metamorphic hormones such as JH and ecdysteroids, are being complemented by newer investigations focusing on other hormones, notably insulin-like peptides. These studies collectively provide important insights on how developmental and metabolic pathways are modulated to induce alternate morphs and how the expression of morph-specific traits are regulated during adulthood.

62-1 ZATTARA, EE; Indiana University - Smithsonian Institution; ezattara@gmail.com

Pre-existing developmental capabilities channel the evolution of novel developmental trajectories in annelids

Life-history evolution results from innovation in developmental trajectories enabling lineages to explore and adapt to available ecological niches. Annelids show a wide array of embryonic and post-embryonic developmental strategies to survive and thrive in land and sea. Mapping these strategies to current phylogenies of the phylum suggests that some novel developmental trajectories have evolved independently many times in several clades, while completely absent in others. Agametic reproduction by fission is an example of such a novel trajectory. Annelids have evolved fission numerous times, yet morphogenetic analyses reveal surprising similarities across independent gains. Why does fission present such remarkable developmental convergence? As a case study, I present data from observations of morphogenetic events during regeneration and fission in several species of clitellate annelids spanning at least three independent gains of fission. Post-amputation morphogenesis is mostly similar in all species capable of regeneration, and is characterized by wound healing, local gut de-differentiation, blastema formation, restoration of anterior central nervous system neuropil and longitudinal muscle by elongation of pre-existing tissue, and de novo formation of brain, ventral ganglia and circular muscle. Among fission trajectories, elements shared with regeneration are similar, but novel processes show differences that correlate with separate origins. These data strongly support that fission has evolved by co-opting most of regeneration's developmental trajectory. Furthermore, they suggest that evolution of this novel trajectory is contingent on the pre-existence of good regenerative abilities, and explain the absence of agametic asexual reproduction in annelid lineages with poor regeneration.

63-5 ZHANG, Y.*; SWANSON, D.L.; Univ. of South Dakota; yz0095@auburn.edu

Cross-training in birds: Acute cold and exercise training upregulate similar aspects of fatty acid transport and catabolism in house sparrows, *Passer domesticus*

Summit (M_{sum} = maximum thermoregulatory metabolic rate) and maximum (MMR = maximum exercise metabolic rate) metabolic rates both increase in response to acute cold or exercise training in birds. Because lipids are the main fuel supporting both thermogenesis and exercise in birds, adjustments to lipid transport and catabolic capacities may support elevated energy demands from cold and exercise training. To examine a potential mechanistic role for lipid transport and catabolism in organismal cross-training effects (exercise effects on both exercise and thermogenesis, and vice versa), we measured enzyme activities and mRNA and protein expression in pectoralis muscle for several key steps of lipid transport and catabolism pathways in house sparrows, *Passer domesticus*, during acute exercise and cold training. Both training protocols elevated pectoralis protein levels of fatty acid translocase (FAT/CD36), cytosolic fatty acid binding protein, and citrate synthase (CS) activity. However, mRNA expression of FAT/CD36 and both mRNA and protein expression of plasma membrane fatty acid binding protein did not change for either training group. CS activities in supracoracoideus, leg and heart; and carnitine palmitoyl transferase (CPT) and α -hydroxyacyl CoA-dehydrogenase activities in all muscles did not vary significantly with either training protocol. Both M_{sum} and MMR were significantly positively correlated with CPT and CS activities. These data suggest that upregulation of trans-sarcolemmal and intramyocyte lipid transport capacities and cellular metabolic intensities, along with previously documented increases in body and pectoralis muscle masses and pectoralis myostatin (a muscle growth inhibitor) levels, are common mechanisms underlying the training effects of both exercise and shivering in birds.

122-7 ZHU, R.*; SARAIYA, V.S.; BRANDES, A; LEWIS, G.T.; CARTER, D.J.; WHITE, C.H.; KEMP, T; ZHU, J; BART-SMITH, H; Univ. of Virginia; *rz6eg@virginia.edu*
Investigation of Thunniform Swimming Using Biomimetic Robotics and Particle Image Velocimetry

Thunniform swimming is widely recognized as an efficient method for high-speed long-distance swimmers such as tuna. Previous research has shown that tuna relies on contraction and relaxation of its red muscle to generate angular motion of its large, crescent-shaped caudal fin through its peduncle. However, little research was conducted to investigate the material properties of related tissues and resulting biomechanics. This research project is composed of two parts, first of which is determining mechanical properties of components such as spine joints, tendons, fin rays and cartilage, from which the biomechanics of tuna tail can be better understood. The second part is building a robotic system mimicking a real tuna tail based on previously retrieved information, and testing the system inside a flow tank. With help of Particle Image Velocimetry (PIV), fluid-structure interaction of the biomimetic fin is visualized and data such as swimming speed and power consumption are collected by researchers automatically through the robotic system. The outcome should better explain how the material properties of tuna tail affect performance and efficiency of thunniform swimming.

SI-1 ZIMMER, R.K.; Univ. of California, Los Angeles;
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Keystone species and molecules of keystone significance

Neuroecology unifies principles from diverse disciplines, scaling from biophysical properties of nerve and muscle cells to community- and system-wide consequences of biotic interactions. Here, these principles are used as a common fabric, woven from threads of chemosensory physiology, behavior, and population and community ecology. The 'keystone species' concept, for example, is seminal in ecological theory. Impacts of keystone species are far greater than predicted from their relative abundances or total biomasses. Similarly, select neuroactive, immunoreactive, and biomineralization compounds could function in keystone roles. They are rare/uncommon within natural habitats, but exert strong effects on species interactions at multiple trophic levels. A general theory is developed and mechanisms are proposed that would lead to the expression of molecules of keystone significance. Through convergent evolution, these compounds inform phylogenetically diverse species, initiate major trophic cascades, and structure respective communities in terrestrial, coastal-ocean, open-ocean, and freshwater habitats.

84-6 ZHU, J.*; WHITE, C; SAADAT, M; BART-SMITH, H; University of Virginia; *jzzhu31@gmail.com*

Design and Experimental Study of a Bio-inspired Superficial Flow Sensor

Most aquatic animals such as fish rely heavily on their ability of detect and respond to ambient flows in order to explore and inhabit various habitats or survive predator-prey encounters. Fish utilize neuromasts in their skin surface and lateral lines in their bodies to align themselves while swimming upstream for migration, avoid obstacles, reduce locomotion cost, and detect flow variations caused by potential predators. In this study, a thin film Micro-Electro-Mechanical Systems (MEMS) sensor analogous to a fish superficial neuromast has been designed for flow sensing. Residual stress arises in many thin film materials during processing. Metal and polymer thin film materials with a significant difference in elastic modulus were chosen to form a multiple-layer structure. Upon releasing, the structure rolls into a tube due to mechanical property mismatch. The self-rolled tube can expand or retract, depending on the existence of external force such as flow. An embedded strain sensor detects the deformation of the tube and hence senses the ambient flow. Numerical simulations were conducted to optimize the structural design. Experiments were performed in a flow tank to quantify the performance of the sensor.

15-5 ZINNA, R.*; EMLLEN, D.; LAVINE, L.C.; DWORKIN, I.; Washington State University, University of Montana, McMaster University; *robert.zinna@wsu.edu*

Using RNA-seq to understand the endocrine control of condition-dependent traits.

Across animal species, competition for females has encouraged ever more extreme morphologies. In many cases the condition dependent growth of these structures is mediated by endocrine signals. The insulin signaling pathway has been shown to specifically mediate this growth in horned rhinoceros beetles. In addition, the critical insect hormone juvenile hormone (JH) has been shown play a role in condition dependent growth in this species. Upregulation of JH during horn growth has no measurable effect on horn size, contrary to the effect of this hormone in other beetles. On the other hand, downregulation through RNAi knockdown of the JH receptor *Methoprene-tolerant (Met)* decreased relative horn size. Here we test the hypothesis that partial co-option of downstream members of the JH pathway mediates condition dependent growth of rhinoceros beetle weapons. RNA-seq analysis of developing horn tissue from beetles raised in different nutritional conditions provides support for this hypothesis. Key JH pathway members (such as *Met*) are indeed upregulated in horns from high-condition males. However, members farther downstream (such as *Broad*) do not show differential expression patterns. In comparison, virtually all members of the insulin-signaling pathway show upregulation in high-condition males. This correlates with functional data- RNAi knockdown of the insulin receptor decreases relative horn size to a much larger degree than knockdown of the JH receptor, and accordingly fewer pathway members are upregulated during horn growth in the latter pathway. Our data show that the evolution of endocrine regulation of traits, and the relative importance of their signals, can drive the evolution of even similar structures.

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Endocrine regulation of the weapons of sexual selection

Juvenile hormone (JH) has diverse functions in insects and is critical in the control of plastic phenotypes. Its role in the condition-dependent expression of male beetle weapons is important but not well known. What is known is that JH mediates the condition dependent expression of mandibles in male stag beetles and male dimorphic horns of dung beetles. What remains unknown is how general this JH mediated response to condition is in sexually-selected traits in beetles and how JH interacts with other endocrine pathways to generate an appropriate environmental response. JH is part of a much larger endocrine feedback loop in which ecdysone represses JH. In dung beetles, ecdysone levels negatively correlate with adult horn length. In this study, we tested the hypothesis that JH induces the exaggeration of the elaborate head horns of the Asian rhinoceros beetle, *Trypoxylus dichotomus*. Unlike the stag beetle we found that ectopic application of fenoxycarb significantly delayed pupation time, but had no effect on adult horn size relative to body size. On the other hand, RNAi mediated knockdown of the juvenile hormone receptor Methoprene-tolerant (Met) decreased head horn size, relative to body size. In addition, we found no correlation between titers of ecdysone and adult horn length. Finally, RNAi mediated knockdown of the ecdysone receptor had no effect on adult horn scaling. Our results indicate that endocrine regulation of sexual dimorphisms in beetle weapons has evolved significantly between clades.

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Rediscovery of *Cirolana poissoni* (Paulian and Delamare-Deboutteville, 1956) from Madagascar, with notes on feeding behavior

The Cirolanidae are marine isopods, with some species found in karstic habitats. Several specimens of a *Cirolana* species were recently discovered in southwestern Madagascar in a subterranean freshwater cave, when they were found feeding on humans that entered the water. These specimens were determined to be *C. poissoni*. The original type specimens of the species, found in the nearby Mitoho cave in 1948 and originally deposited in the Museum National d'Histoire Naturelle in Paris, are apparently lost; therefore the present specimens comprise the only extant collection. Very little is known about the biology of the Cirolanidae, and in this study we present notes on the ecology and feeding behavior of *C. poissoni* for the first time. In brief, our findings suggest that *C. poissoni* exhibits active swimming behavior in open waters, with increased activity in low light conditions, and exhibits predatory or scavenging feeding habits, but not cannibalism. One specimen was fed on a volunteer and the feeding process, which occurred for 16 continuous minutes, was documented. Following the feeding bout, the isopod grew from 8.2 mm to 11.4 mm, about 1 mm every ten days, during the study. Other specimens that had a visible blood meal at the time of collection survived for 40 days without any supplementation. Finally, in the cave, alongside these isopods is the largest fossil site in all of Madagascar, containing pristine specimens of extinct Malagasy species (including the giant lemurs) that the scavenging *C. poissoni* may have fed on historically. Blood meal analyses from collected specimens will reveal what other cryptic organisms are currently living in this underwater cave, and the dietary preferences of *C. poissoni*.

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Common measures of innate immune function vary with time of day and sampling protocol in five passerine species

Ecological immunology is a rapidly growing field of study that focuses on understanding variation in immune systems across species and how this relates to species ecology and evolution. Newly developed field methods aimed at studying variation in immune function in a field setting, and within an ecological context, have yielded many insights. Nonetheless, there continues to be much debate regarding the interpretation of field measures of immune function. One important obstacle for field studies of ecological immunology is separating variation in immune function that is related to factors of biological interest from measurement artifacts. For example, there is substantial evidence to suggest that handling stress could introduce variation into measures of immune function, yet no study has examined the impacts of incremental changes in handling times under 30 min on immune measures. Nor has any study examined variation in immune function with time of day, though other physiological measures, including glucocorticoids known to impact immune function, vary with time of day. Here, I use observational field data to test the hypothesis that innate immune function varies with handling stress. Furthermore, I test the hypothesis that innate immune function changes over the course of the day. I show that measures of innate immune function vary with 1) handling stress over short time periods typical of sample collection in the field, and 2) the time of day that an individual is sampled. I discuss these findings from an ecological perspective and end with a summary of the practical implications of these findings for field studies of ecological immunology.