***43.1*** ABBOTT, E.M.*; MARSH, R.L.; ASTLEY, H.C.; AZIZI, E.; ROBERTS, T.J.; Brown Univ., Northeastern Univ., Brown , Brown ; *Emily_Abbott@brown.edu*

***The celebrated jumping frogs of Calaveras County: how far can a frog really jump?***

True performance limits, as defined by maximal physiological function, can be difficult to identify. Estimating maximal performance often relies on subjective criteria, and may be hindered by limited sample size, time, and variability in behavior. Our interest in the maximal jumping performance of frogs led us to the 82nd annual Calaveras County Jumping Frog Jubilee, where large numbers of frogs (*Rana catesbeiana*), standardized rules, numerous trials and competitors' years of experience improves the chance of measuring true maximal performance. We used an HD camcorder to record a sequence of three jumps for each competing bullfrog. The jumping stage was calibrated using a large grid and a perspective de-distortion algorithm (estimated error = ± 1cm). During the three-day competition, we recorded and analyzed more than 3,000 jumps from nearly 1,000 individuals. The distributions of jump distances revealed the influence of competitors' expertise. Frog jumping "professionals", who bring their own frogs and compete annually, elicited jumps that were skewed to long distances. The jump distances produced by "civilians" using rental frogs provided by the organizers were shorter and followed a normal distribution. The longest jump distance recorded was 2.20 m, almost twice as far as published estimates for this species (1.29 m, Zug 1978). Peak power outputs during the longest jumps were higher than 850 (W/kg muscle mass), and total muscle work exceeded 50 J/kg. These values challenge the notion that semi-aquatic ranids are relatively poor jumpers due to functional trade-offs between swimming and jumping. The results of this study demonstrate the potential limitations of quantifying maximal performance in a laboratory setting. Supported by NSF grant 642428 to TJR.

***12.11*** ACOSTA, W.*; SCHUTZ, H.; DLUGOSZ, E.M.; MEEK, T.H.; HANNON, R.M; KEENEY, B.K.; RADOJCIC, B.E.; MACIEL, R.C.; GARLAND, T., Jr.; Univ. of California, Riverside; *wacos001@student.ucr.edu*

***Food Choice in Mice Selectively Bred for High Voluntary Wheel Running***

The human obesity epidemic is growing and many studies are trying to decipher the underlying causes. One main hypotheses emphasizes consumption of a "Western diet" (high in fat and sugar) in combination with a lack of physical activity. We are examining lines of mice bred for high voluntary wheel running (HR lines) in this context. Our previous studies show that mice from the 4 replicate HR lines run, on average, 2.5-3.0-fold more revolutions/day than those from 4 non-selected Control (C) lines, they eat more, have lower body fat, higher endurance capacity, and higher maximal oxygen consumption. In addition, HR females given a high-fat diet while housed without wheel access were unique in that they consumed greater amounts of food, increased home-cage activity, and did not gain weight (Vaanholt et al. 2008 Int. J. Obesity 32:1566-1575). Recently, we have found that providing a Western diet (Harlan Teklad TD.88137 Western Diet, 42% kcal from fat), as opposed to standard chow (Teklad Rodent Diet (W) 8604 14% kcal from fat), can increase daily wheel running by up to 50% in HR males, while having little or no effect on C males (T. H. Meek, J. C. Eisenmann, and T. Garland, Jr., unpublished). The purpose of the present study was to compare dietary choice (Teklad 8604 versus 88137), wheel running, and home-cage activity of HR and C mice when housed with wheel access. We used two experimental groups of mice. The first was tested for two days following the 6-day period of wheel access used to choose breeders in the routine selection protocol. The second was acclimated to wheel access for ~2.5 weeks prior to testing, and was also monitored for home-cage activity. Supported by NSF IOB-0543429.

***71.2*** ADAMS, R.A.*; SNODE, E.; Univ. of Northern Colorado, Greeley; *rick.adams@unco.edu*

***Do vespertilionid bats have a third wing?***

Although the uropatagium of vespertilionid bats is well known for its use as an insect catchment during foraging, the inter-femoral membrane has been largely ignored as an active contributor to flight mechanics. Indeed, the uropatagium is often referred to as a morphological feature that predominately increase drag during flight and is therefore of reduced size in species that exhibit high-speed flight morphology. With the use of high-speed video, we put forth a new interpretation of the uropatagium and its participation in flight dynamics by showing how this membrane is used in a remarkable way to contribute thrust during takeoff. We define this contribution to be Tail-Assisted-Induced-Lift or TAIL. The employment of this technique is manifested fully during more difficult takeoffs, but the timely use of this skill while foraging is readily conceivable.

***15.8*** ADAMS, N*; CAMPANALE, J; GRAVEM, S; MALLICOAT, A; MALLONEE, M; California Polytechnic State University, San Luis Obispo, ; *nadams@calpoly.edu*

***Long-term exposure of adult purple sea urchins, Strongylocentrotus purpuratus, to sunlight protects embryos from ultraviolet radiation***

Purple sea urchins, *Strongylocentrotus purpuratus*, were reared on controlled algal diets with or without exposure to natural solar ultraviolet radiation (UVR) in flow-through aquaria at the Cal Poly Center for Coastal Marine Sciences Pier Facility to identify whether we could alter the accumulation of mycosporine-like amino acids (MAAs) in their tissues and whether subsequent eggs and embryos from UV-exposed or MAA-enriched adults varied in resistance to UVR. *S. purpuratus*, were exposed to one of four solar UVR-MAA diet conditions as follows: 1) –UVR –MAA, 2) –UVR +MAA, 3) +UVR –MAA, 4) +UVR +MAA from October 2007 to February 2008. Each batch of experimental eggs was analyzed for MAA content using HPLC to determine whether there was a correlation between the amount of delay and the concentration of MAAs in eggs. Embryos resulting from the fertilization of remaining eggs were either exposed to or protected from a 60-minute exposure to UVR. All embryos exposed to UVR experienced a delay in mitosis. Delays in division did not correlate with the MAA concentration of each batch of eggs (ANOVA, linear regression, $P>0.05$). Nevertheless, the concentration of MAAs was considerably lower in these eggs than in previous studies with green sea urchins. Embryos from +UVR adults experienced significantly shorter amount of delay, both in percent and minutes, than those from UV-protected adults ($P<0.05$). There was no difference in delay due to the diet of adults and there was no interaction in cleavage delay between adult UV-treatment and MAA diet. These data indicate that adult sea urchins exposed to sunlight transmit some protective effect to their eggs and embryos.

***72.5*** ADDISON, B*; RICKLEFS, RE; KLASING, KC; Univ California Davis/Deakin Univ, Univ Missouri-St Louis, Univ California Davis; *brianne.addison@gmail.com*

***Testing the maternal immune imprinting hypothesis using direct manipulation of yolk antibodies.***

Ecoimmunology is a growing hot topic, and maternal effects on immunity are of increasing interest to ecologists and in human medicine alike. Immunological imprinting by maternally derived antibodies has been proposed to have both positive and negative consequences for offspring immunity in early and adult life. Using laboratory Japanese quail, we developed a novel method of directly manipulating yolk antibodies of neonates, and then followed individuals through a series of immune challenges until they were of reproductive age. Our method of directly injecting purified antibodies into the yolk sac of newly hatched chicks successfully elevated the plasma titres of specific anti-KLH IgY in neonates, to levels comparable to offspring of vaccinated hens. This allows us to test whether differences in neonatal anti-KLH IgY affect immunity at the juvenile and adult stages of life, and whether vaccination has effects on immunity independent of the effects of antibodies. We found little evidence for an effect of maternal antibodies on juvenile stage immune response, in contrast to results from previous studies. Adult immune response was also independent of neonatal IgY titres, and surprisingly only weakly predicted by previous antigen exposure. We found no evidence of carryover effects of yolk-derived antibodies on adult immunity. Our study employs new methodology for investigation of maternal antibodies and presents results suggesting that further studies of maternal effects on immunity will require careful consideration of the numerous ways maternally derived yolk components can impact the different types of immune response.

***72.7*** ADELMAN, J.S.*; WIKELSKI, M.C.; HAU, M.; Princeton University, Max Planck Institute for Ornithology; *jsadelma@princeton.edu*

***Latitudinal Differences in Sickness Behaviors and Fever: From Patterns to Mechanisms***

While immune responses often differ among closely related species and populations, the physiological mechanisms underlying these differences remain unknown. We need to understand such mechanistic differences to determine how and where selection acts to shape differences in immune function. Free-living song sparrows (*Melospiza melodia*) along the western coast of North America exhibit differences in sickness behaviors (lethargy, in particular) and fever that vary inversely with latitude. In this study we brought sparrows from two populations along the west coast (Southern California and Washington) into captivity to determine 1) whether these population differences persist in a common-garden environment and 2) if so, what physiological signals underlie such differences. As in free-living song sparrows, injection of lipopolysaccharide (LPS), a non-pathogenic antigen that mimics bacterial infection, decreased locomotor activity and increased body temperature in all birds. Also consistent with free-living birds, treated birds from Washington recovered normal activity and thermoregulation significantly faster than did birds from California. Moreover, Washington birds exhibited lower circulating levels of the pro-inflammatory cytokine Interlukein-6 than did Californian birds. Results on cytokine mRNA expression and circulating levels of corticosterone, which can diminish sickness behaviors and fever, will also be presented. Our results suggest that the differences in immune responses among wild song sparrows cannot be explained by current environmental conditions alone and may reflect evolutionary changes. Moreover, they show that differences in pro-inflammatory cytokine pathways may play a crucial role in shaping variation in immune function among wild vertebrates.

***24.4*** ADOLPH, S.C.*; DAVIS, A.R.; FEDEROWITZ, M.; PETERSEN, J.; Harvey Mudd College, University of California, Berkeley; *adolph@hmc.edu*

***Stochastic Population Dynamics of a Desert Lizard***

Desert organisms experience highly variable precipitation, which can strongly affect reproduction and therefore population dynamics. In the viviparous desert night lizard (*Xantusia vigilis*), Zweifel and Lowe (1966) found that fecundity is highly correlated with the previous winter's rainfall. We used Zweifel and Lowe's demographic data to construct a rainfall-dependent population model. A simple matrix model with (a) constant, age-independent survival rate and (b) fertility rates that increase linearly with rainfall predicted the historical data very well. We combined this model with historical rainfall data to simulate long-term stochastic population dynamics. Although litter size only varies from 0 to 3 in this species, population size could fluctuate substantially due to random runs of either wet or dry years. The resulting long-term stochastic population growth rate corresponded to an average annual growth rate of $\lambda = 0.97$, not appreciably different from a stable average $\lambda = 1.0$. A simplified (non age-structured) stochastic model relating annual rainfall to $\lambda$ captured the essential behavior of the age-structured model. We used our model to explore climate change scenarios by modifying the historical rainfall distribution. $\lambda$ increased linearly with mean rainfall but was relatively insensitive to changes in the variance of the rainfall distribution. Finally, we revisited Zweifel and Lowe's Mojave Desert field site in two different years — an extremely wet year and an extremely dry year — to obtain additional demographic data on these lizards. Our samples, taken more than 50 years after their pioneering study, confirmed the strong dependence of fecundity on rainfall.

***65.4*** AIGLER, S.R.; STOCK, D.W.*; University of Colorado, Boulder; *David.Stock@Colorado.edu*

***Reversal of dorsal pharyngeal tooth loss in the zebrafish through over-expression of ectodysplasin***

The irreversibility of the loss of complex structures has been considered a “law” of evolution, and explained as the result of the degeneration of genes required for their development. Little empirical evidence is available for such degeneration, however, and the extensive pleiotropy of developmental regulatory genes calls its likelihood into question. The reduction of dentition in the lineage leading to the zebrafish, *Danio rerio*, provides an opportunity to investigate the developmental and genetic changes associated with the loss of complex structures. Teeth in the zebrafish, as in other members of the order Cypriniformes, are restricted to a single pair of bones, the fifth ceratobranchials of the ventral, posterior pharynx. Reduction of dentition to this state occurred through the loss of teeth from the oral cavity and dorsal pharynx over fifty million years ago. Among the candidate causes of cypriniform dentition reduction is modification of the signaling ligand ectodysplasin. This gene has been shown by others to be necessary for pharyngeal tooth development in the zebrafish, and we found through comparative analyses that loss of its expression is associated with cypriniform dentition reduction. To test whether reversal of this expression loss represents a potential mechanism for the re-evolution of lost teeth, we used transgenic methods to express ectodysplasin ubiquitously and continuously throughout zebrafish development. Although such over-expression failed to restore oral dentition, it resulted in the appearance of dorsal pharyngeal teeth, which have been missing from cypriniforms for a similar period of time. This result suggests that, at least in the case of meristic systems, long absent structures have the potential to reappear through surprisingly simple genetic changes.

***27.1*** ALMEIDA, Suellen*; IRSCHICK, Duncan J.; Univ. of Massachusetts, Amherst; *salmeida@cns.umass.edu*
***Evaluating the affects of climate change on larval locomotor performance in Ambystoma maculatum***
Variation in temperature has a profound effect on many aspects of animal physiology and whole-organism performance. For example, temperature can affect many physiological variables such as metabolic rate, digestion rate, and the effectiveness of muscular performance among other physiological processes. As climate change becomes more unpredictable it is fundamental to comprehend how organisms will react in relation to temperature-related stress and how temperature affects whole organism performance, as these traits are often crucial to survival. Here, we investigate how increased developmental temperature affects development and locomotion in spotted salamanders (*Ambystoma maculatum*). We collected eggs of spotted salamanders from the western Massachusetts area, and maintained both the eggs and the resulting larvae in two different temperature regimes (15°C and 20°C) until the larvae had reached four weeks of age. The 15°C group was the control group, since a temperature of 15°C is similar to the natural developmental temperature these animals are exposed to in the wild, whereas the experimental temperature of 20 °C was significantly higher than what they would normally experience, but could be relevant for ponds that experience warming. We tested how this alteration of developmental temperature affected both the rate and progress of development, and the burst speed of larvae. We found profound effects of increased developmental temperature on the overall speed and progress of development, and some instances of impaired performance.

***54.1*** AMEMIYA, Chris T.*; SAHA, Nil Ratan; SMITH, Jeramiah J.; Benaroya Research Institute; *camemiya@benaroyaresearch.org*
***Programmed genome dynamism and its evolutionary cooption in a basal vertebrate***
While trying to understand how genomic rearrangements occur during the diversification of an immune receptor system in the sea lamprey (Petromyzon marinus), we serendipitously discovered unprecedented numbers of cells undergoing double-stranded DNA breaks in many embryonic stages. The meaning of these breakage events was unclear, but when considered with other pieces of data on DNA content and DNA Southern blot hybridization, it became evident that the lamprey undergoes significant DNA losses (rearrangements) during early embryonic development. These rearrangements do not occur in the germline, only the soma. Furthermore we have demonstrated that these rearrangements are tightly regulated, occur very early in development and result in the loss of specific transcribed genes. In this presentation we will discuss the developmental and evolutionary ramifications of this genome dynamism and present a model by which this genomic rearrangement process may be a significant driving force for regulating the genome.

***33.2*** ANDERSON, Philip S. L.*; RAYFIELD, Emily J.; Univ. of Bristol; *Phil.Anderson@bristol.ac.uk*
***The intersection of experiment and theory: using cutting tests and FEA models to understand how teeth fracture food***
Material properties of food items can exert a strong influence on tooth morphology. Previous experimental studies have shown that the morphology of bladed dental tools can have a significant effect on the energy required to cut various biological tissues. We integrate further experimental analyses with theoretical finite element (FE) modeling to explore the relationship between blade shape and food materials. Our aim is to create a strong link between experimental and theoretical data to better understand dental functional morphology. We used a double guillotine testing device to cut biological tissues of varying physical properties (fish muscle and plant materials) and standardized homogenous materials (photoelastic resin and silicone rubber). We measured work to fracture during cutting using tool shapes based on dental morphology. We built FE models that matched the guillotine structure: a test material given the properties of silicone or resin compressed between rigid features shaped like cutting tools. Stress and strain patterns and reaction forces were calculated for a variety of dental tool shapes. Experimental results show that the effects of dental shape are dependent on the physical properties of the materials being cut. Work to fracture measures varied up to 50% depending on tool shape and material used. FE analyses based on photoelastic resin replicate both strain patterns and force values produced by the experiments, allowing us to read the stress and strain values calculated as real. The FE analyses show distinct differences in both the levels and patterns of strain present in test materials cut by different tool shapes. These results show the power of integrating experimental data and theoretical models to approach biomechanical questions.

***101.6*** ANDERSON, C.V.*; DEBAN, S.M.; University of South Florida; *cvanders@mail.usf.edu*
***Effects of temperature on the motor control of chameleon feeding***
Environmental temperature effects muscle contractile velocity and thus constrains the activity patterns of ectotherms. As temperature decreases, performance of muscle-powered movements such as locomotion and tongue protraction decline and hinder prey capture ability. Chameleons do not pursue prey but use ballistic tongue projection to ambush prey. We have shown that their specialized feeding mechanism, which incorporates rapid recoil of collagenous sheaths to power tongue launch, maintains high performance at low body temperature, despite the presumed effects of temperature on muscle dynamics. Tongue retraction performance, which relies on direct muscle power, is strongly affected by temperature. We hypothesize that chameleons maintain high performance at low temperature as a result of minimal thermal effects on peak isometric muscle force and the elastic recoil of collagen. To test an alternative hypothesis that chameleons maintain high projection performance via muscle fibers that can maintain contractile rate performance at low temperature, we imaged *Chamaeleo calyptratus* feeding at 15-35°C with simultaneous electromyographic recordings of the accelerator muscle (ACC) and retractor muscle (HG). We found a $Q_{10}$ <1.1 for elastically powered tongue projection rate and $Q_{10}$ >1.6 for muscle-powered tongue retraction rate. Between 15 and 25°C motor control parameters show $Q_{10}$ >2.0 for muscle times to peak activity and for latencies between muscle activity events and kinematic events. These EMG results suggest that muscle contractile rates for both the ACC and HG show a temperature effect that is typical for muscle. Results thus fail to support the hypothesis that chameleons maintain tongue projection performance by maintaining muscle contractile rate performance at low temperature, and lend support to the elastic recoil model.

***84.1*** ANDERSON, Stuart/P*; GEORGE, Matthew; SWANSON, Brook/O; Gonzaga University; *sanderson@gonzaga.edu*

***Claw force and cuticle strength: Functional morphology of fiddler crab combat***

Crabs in the genus *Uca* are sexually dimorphic, with males displaying extreme claw asymmetry in all species. It is thought that this extreme claw asymmetry is due both to inter-sexual selection and intra-sexual combat. This study examines 21 species within the genus *Uca*, measuring claw force production and resistance to cuticle puncture. During intra-sexual combat fiddler crab claws can occlude at the claw tips or at tubercles along the claw gape. We used morphology and measurements of muscle forces to estimate the force production at the tips and at tubercles. We also measured the resistance to puncture of the claw manus, which is gripped during combat, and the carapace. We recorded both the force required to initially puncture the cuticle (initial break force, IBF), and the force required to cause a major structural failure of the cuticle (structure failure force, SFF). It was found that any part of the claw produces sufficient force to damage the carapace. The force produced by each species at the claw tip was significantly lower than both the IBF and SFF for the manus, indicating that for an individual matched against another of equal size no damage can be inflicted. Forces produced at the tubercles are very similar to the IBF, but much lower than the SFF. This suggests that crabs should be able to cause some surface damage to competitors using these tubercles, but cannot produce sufficient forces to cause structural failure.

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

***Whole animal performances vary with body temperature and ecological function in a lizard***

Whole animal performance is expected to vary with body temperature in ectotherms, but patterns of performance of a task with body temperature may depend on the body temperatures at which the task is ecologically relevant. The northern alligator lizard, *Elgaria coerulea*, was used to test the relationship between body temperature and performance in three performance measures that were expected to vary differently with body temperature: sprint speed, bite speed, and bite force. Mean field active body temperatures and body temperatures chosen by lizards in a thermal gradient were approximately 28ºC. Lizards were found at a very broad range of body temperatures and were willing to eat over a range of body temperatures, hence the lizards were considered to be relatively eurythermic. All performance measures were strongly correlated to body temperature, but the patterns and peaks of performance temperatures differed among the three performance measures, in accordance to specific predictions of performance associated with antipredation and food acquisition.

***3.5*** ARCH, V.S.*; GRAFE, T.U.; SIMMONS, D.D.; NARINS, P.M.; University of California, Los Angeles, University of Brunei Darussalam; *varch@ucla.edu*

***A Neuroethological Analysis of Ultrasonic Communication in an Endemic Bornean Frog***

*Huia cavitympanum*, an endemic Bornean frog, is the first amphibian known to emit exclusively ultrasonic (*i.e.*, > 20 kHz) vocal signals. To test the hypothesis that these frogs use purely ultrasonic vocalizations for intraspecific communication, we performed playback experiments with male frogs in their natural calling sites. We found that the frogs respond with increased calling to broadcasts of conspecific calls containing only ultrasound. The field study was complemented by electrophysiological recordings from the auditory midbrain. These measurements revealed that the frog's auditory system is broadly tuned over a wide frequency range, with peak sensitivity occurring above 20 kHz. Our results demonstrate that *H. cavitympanum* is the first non-mammalian vertebrate described to communicate with purely ultrasonic acoustic signals. To explore the morphological underpinnings of the species' extraordinary high-frequency sensitivity, we are using immunohistochemistry to fluorescently label hair cell components of the frogs' inner-ear auditory organs. With confocal microscopy, we are able to visualize the labeled organs in 3-dimensions. Comparisons between the auditory epithelia of *H. cavitympanum* and *Rana pipiens*, a frog with a more typical anuran hearing range, reveal differences in a number of inner-ear morphometrics including hair cell number and length. These differences may permit insights into the mechanistic foundations of amphibian high-frequency detection.

***37.9*** ARCHIE, James W*; QUIJANO, Marc Oliver; California State Univ., Long Beach; *jarchie@csulb.edu*

***Fine Scale Phylogeography of Sceloporus occidentalis) in the Transverse Ranges of California Reveals Coincidence with Geological Complexity***

The Transverse and South Coastal Ranges of California have undergone complex geological changes affecting resident taxa. The Transverse Santa Inez Range originated from a 90° crustal rotation of a crustal block that resulted in uplift. Crust folding and uplift along strike-slip faults occurred further inland forming South Coast Ranges. The eastern extension of the transverse ranges are part of a continental margin region that experienced drift associated with two different fault systems. This resulted in at least four distinct geological regions associated with distinct phylogeographic breaks in different taxonomic groups although samples were inadequate to associate phylogeographic complexity with the full complexity of the geologic history. We sampled western fence lizards (*Sceloporus occidentalis*) from 150 populations along the Transverse and Coastal Ranges and adjacent Los Angeles Basin. Individuals were sequenced for 1550bp of mtDNA. Phylogenetic and nested clade analyses were carried out. Nearly all sequences were distinct (<1% identical); maximum differences were >7%. Five major clades were identified: 1) LA Basin + San Diego, 2) Ridge Basin + Sierra Pelona, 3) South Coast Ranges north of Cuyama River drainage, 4) Western Transverse Ranges south of Cuyama River drainage, and 5) Pine + Topatopa Mountains. A Great Basin clade was most closely related to the northeastern South Coast Range. Additional geographic structure is present at a finer scale within nested clades. The distribution of clades coincides with major fault blocks and geological regions resulting from geological processes that began during the Miocene era and completed in the Holocene. Only some of these have been identified in previous studies.

***71.3*** ARMOUR, Maria T.*; SIMMONS, Nancy B.; SCHUTT, WIlliam A. Jr.; Emerson College, Boston, MA, American Museum of Natural History, New York, NY, C.W. Post College of Long Island University, Brookville, NY; *m.t.armour@gmail.com*

***Wing folding in bats: Aspects of morphology and phylogenetic interpretation***

The bat forelimb is functionally unique among mammals because it enables powered flight in all currently recognized taxa (approximately 1,100 species and 18 families). There is considerable morphological variation in chiropteran wing structure, including the manner in which the wings can be folded. Previous research identified three distinct wing folding patterns among bats, and in this study we investigated this variation from ecomorphological and phylogenetic perspectives. Questions that were addressed included: 1) Does morphological variation at articulation points along the digits determine the folding pattern of the wing? 2) Are there correlations between wing shape and wing folding pattern? 3) How do these patterns map out on recent bat phylogenies? We examined wing folding patterns and morphological characters of the wing digits in 292 species representing 18 bat families. In a subset of twelve species, we studied digital osteology with the goal of identifying aspects of joint morphology involved in different wing folding patterns. Mapping the resulting data onto phylogenetic trees based on both morphology and DNA sequences showed that phylogeny has a significant influence on wing folding pattern, although some patterns have apparently evolved more than once. The relationship between wing shape indices (which have been used as ecomorphological indicators) and folding patterns was statistically significant, suggesting that certain wing shapes fold a specific way – possibly because of how the bats make their living. We also found that variation exists at the articulating surfaces of digits and that some features are related to specific wing folding patterns.

***S7.2*** ARRIGO, K.R.; Stanford University; *arrigo@stanford.edu*

***Marine Microalgae in Antarctic Sea Ice***

Antarctic sea ice is often home to a rich microbial community, generally dominated by microalgae such as diatoms. These organisms have unique adaptations that allow them to grow at the low light, reduced temperatures, and high salinities that characterize the sea ice interior. Nevertheless, these microbial communities develop to their full potential in sea ice that has little snow cover and is relatively warm. Under these conditions, the sea ice environment receives considerable light and has a brine salinity that is sufficiently low to facilitate rapid algal growth. Consequently, the highest algal biomass is often attained in the austral spring just before the ice has begun to melt. Because these communities are often so concentrated, they represent a valuable food source for larger organisms that both live within the ice and enter the ice from the water column through the myriad cracks and brine tubes that characterize the ice pack. They also become a rich source of food when they are released from the ice matrix as the ice begins to melt. As this material sinks through the water column, some is consumed by pelagic zooplankton and the rest sinks to the bottom where it nourishes a diverse benthic community. In areas with annual ice cover, the productivity within the ice can represent a large fraction of total production, the rest being contributed by pelagic phytoplankton. Unfortunately, to date, there are few comprehensive estimates of total sea ice algal production within the Antarctic ice pack, due to the fact that direct measurements are so sparse. Those estimates that do exist are based on a limited number of modeling studies and suggest that total productivity within Antarctic sea ice is probably less than 100 Tg C/yr. Although this is a small fraction of total production in the Southern Ocean, it can represent a locally important carbon source.

***43.2*** ASTLEY, H. C.*; ROBERTS, T. J.; Brown University; *henry_astley@brown.edu*

***Decoupling of muscle shortening and joint kinematics during frog jumping***

Elastic tendons can decouple changes in muscle length from changes in joint angle, allowing the muscle to function at closer to optimal conditions for force production and allowing elastic energy storage in the tendon. While elastic tendons have been well-studied in steady-speed locomotion, their role in acceleration is not well understood. The remarkable jumping ability of anurans is an excellent system for addressing this issue due to well-characterized muscle physiology, extensive prior work, static pre-jump posture, and recent data suggesting that elastic energy storage in tendons may occur. In order to test the hypothesis that elastic tendons decouple muscle contraction from joint movement during accelerations, we quantified simultaneous joint movement and muscle contraction in the ankle of *Rana pipiens*. The ankle is extended almost exclusively by the plantaris, a large pennate muscle with a long, prominent tendon sufficient to generate noticeable decoupling. Jumps were studied using X-ray Reconstruction Of Moving Morphology (XROMM), a high-speed biplanar X-ray cinefluoroscopy system, with radiopaque markers implanted into the muscle and bones to simultaneously track muscle strain and joint movement. Preliminary data from 7 jumps shows 7.7% (±0.8%) shortening strain of the muscle fascicle preceding any substantial joint movement, followed by a 38.7° (±3.4°) joint extension with minimal muscle fascicle length change, after which both joint and muscle display rapid change. Fascicle strain rate showed peaks prior to the initiation of joint movement and shortly after maximal joint angular velocity, separated by a period in which the strait rate was close to zero with high angular acceleration of the joint. These data indicate a decoupling of muscle strain from joint angle as well as the storage of strain energy in the tendon. Funded by NSF Grant 064242.

***S2.1*** AUSTAD, Steven N; Univ, of Texas Health Science Center, San Antonio; *austad@uthscsa.edu*

***Comparative Biology of Aging in the 21st Century***

Laboratory models have suggested a link between metabolism and life span in vertebrates, and it is well known that the evolution of specific life histories can be driven by metabolic factors. However, there is little known regarding how the adoption of specific life history strategies can shape aging and life span in populations facing different energetic demands from either a theoretical or a mechanistic viewpoint but significant insight can be gained by using a comparative approach. Comparative biology plays several roles in our understanding of the virtually ubiquitous phenomenon of aging in animals. First, it provides a critical evaluation of broad hypotheses concerning the evolutionary forces underlying the modulation of aging rate. Second, it suggests mechanistic hypotheses about processes of aging. Third, it illuminates particularly informative species to be interrogated about potentially novel aging mechanisms. Although comparative biology has played a significant role in aging research for more than a century, the new comparative biology of aging is poised to dwarf those earlier contributions, because: (1) we have much better information on the comparative longevity of a growing array of species, (2) new cellular and molecular techniques for investigating novel species are in place and more are being continual generated, (3) molecular systematics and new statistical techniques have provided helpful analytical tools for comparative biology, and (4) the dramatic acceleration in DNA sequencing technology is providing us with new tools for a comparative genomic approach to understanding aging.

***34.2*** AZIZI, E*; ROBERTS, TJ; Brown University;
*manny_azizi@brown.edu*
***Geared up to stretch: pinnate muscle behavior during active lengthening***
Many locomotor activities require muscles to actively lengthen and absorb energy in order to decelerate the body. These eccentric contractions can disrupt cytoskeletal structures within myofibrils and reduce force output. Here we examine how architectural features of pinnate muscles can provide a protective mechanism against eccentric muscle damage by limiting fiber lengthening. It has been previously shown that the angled fibers of pinnate muscles change orientation when shortening. This change in fiber orientation can amplify fiber velocity, resulting in a velocity advantage at the level of the muscle-tendon unit (MTU) that is characterized by a gear ratio (MTU velocity/fiber velocity). Muscle gearing has been shown to be variable during shortening, while gearing during lengthening remains unknown. We used sonomicrometry to measure fiber length and a servomotor to measure the MTU length and force *in vitro* in the bullfrog plantaris. We characterized the muscle's force-velocity curve and gear ratio during both shortening and lengthening across a broad range of forces (10%-190% peak isometric force). Gearing was measured during the isotonic portion of each contraction, to eliminate possible contributions of series elasticity to MTU length changes. During shortening the muscle operated with a variable gear ratio that decreased with increasing force. A similar pattern was observed during lengthening, however, the gear ratio was significantly higher than during shortening, indicating that lengthening of the MTU results in a relatively small and slow stretch at the level of the fiber. Since the magnitude of fiber strain is considered an important determinant of muscle damage, a high gear ratio likely affords pinnate muscles significant protection against the damaging effects of active lengthening. Supported by NIH AR054246 to EA AR055295 to TJR.

***S6.5*** ÅKESSON, S; University of Lund, Lund;
*susanne.akesson@zooekol.lu.se*
***Endogenous migration programs and orientation in passerine birds***
The solo-migrations by young songbirds are known to be controlled by an endogenous program inherited from their parents. In this program the migratory direction, distance and physiological changes to meet the migration flights are encoded, as well as decisions when to depart for migration flights and when to end the migration. I will talk about interactions between the endogenous migration programs and external information, for instance the geomagnetic field, during migration in passerine birds. How does the inherited migration program interact with external information both during natural long-distance displacements as well as in simulated laboratory situations? What can we learn from such experiments? The functional characteristics of the migration program and how it interacts with external information will have a resulting effect on the output, the physiology and compass orientation of the bird in a given situation. We might expect differences between age groups, which will be discussed.

***10.1*** BABONIS, L.S.*; EVANS, D.H.; Univ. of Florida;
*babonis@ufl.edu*
***Salinity acclimation in sea snakes: A comparison of specialized and unspecialized cephalic glands***
Laticaudine sea snakes experience frequent fluctuations in environmental salinity, making them valuable models for studies of salt gland (SG) function. Though the SG is known to function primarily in osmoregulation, little is known about the osmoregulatory capacity of other cephalic secretory glands. The functional difference between SGs and other cephalic secretory glands may derive from the abundance/distribution of ion transporters like $Na^+/K^+$-ATPase (NKA), $Na^+/K^+/2Cl^-$ cotransporter (NKCC), and cystic fibrosis transmembrane conductance regulator (CFTR). After 7 days in 100% seawater (SW; time 0) we acclimated sea snakes (*Laticauda semifasciata*) to 0, 50 or 100% SW (n = 6 per treatment) for 14 days. We then compared the abundance/distribution of NKA, NKCC, and CFTR in the SG and the (unspecialized) Harderian gland (HG) across treatments. As HGs are not known to be involved in osmoregulation, we expected expression of NKA, NKCC, and CFTR to be low in all treatments. In contrast, NKA, NKCC, and CFTR were expected to show greater expression in the SG from 100% SW animals than either 50% or 0% SW animals. Using quantitative real-time PCR, we found expression of NKA to be higher in the SG in all treatments than it was in the HG. Additionally, in the SG, expression of all genes was highest in the control group (100% SW, time 0) and decreased in all remaining groups. Expression of NKCC and CFTR did not vary with salinity in the HG but decreased with increasing salinity in the SG. These results suggest that the osmoregulatory capacity of the SG may lie in the overall abundance/response of NKA to variations in salinity. This research was funded by the National Science Foundation (IOB-0519579 to DHE and EAPSI to LSB).

***71.6*** BAHLMAN, Joseph Wm*; SCHUNK, Cosima; SWARTZ, Sharon M.; BREUER, Kenneth S.; Brown University, Hochschule Bremen, University of Applied Sciences;
*joseph_bahlman@brown.edu*
***The effect of wingbeat frequency on aerodynamic force and wake structure using a bat-like mechanical flapper***
The aerodynamic forces produced by a bat's wings depends on its flapping kinematics. However, the relationship between flapping kinematics and aerodynamic force can be difficult to study in live animals because live animals typically change multiple kinematic parameters simultaneously, and because detailed force measurements cannot be made on a live flying animal. To help isolate the aerodynamic effects of wingbeat frequency, we built a mechanical flapper with bat-like wings. For this experiment, the flapper moved with a single degree of freedom at the shoulder, resulting in a vertical stroke plane with an amplitude of 42 degrees. The planform was modeled after the lesser dog-faced fruit bat, *Cynopterus brachyotis* . The wing skeleton was constructed from rigid plastic, and the wing membranes made from a deformable latex sheet (500 microns thick). The model was mounted in a wind tunnel on a six-axis load cell, and actuated with wingbeat frequencies ranging from 1 to 8 Hz at wind speeds ranging from 2.5 to 5.0 m/s (reduced frequencies, k, ranging from 0.1 to 0.5). Force measurements were taken simultaneously with particle image velocimetry (PIV). Force, measured with the load cell, increased to a maximum at mid-downstroke and decreased to a minimum at mid-upstroke. The magnitude of maximum and minimum forces increased with flapping frequency so that at 8 Hz, during the downstroke, the maximum lift reached nearly 4 times the amount of lift generated by non-flapping wings, and during the upstroke, the minimum lift was -3 times the non-flapping value. Comparison with the PIV data shows the wake transitioning from a nearly continuous tip vortex structure at 1 Hz to discreet structures alternating with counter-rotating vortices at 8 Hz.

***14.1*** BAKER, T.V.*; ANDERSON, E.J.; LIM, J.L.; LAUDER, G.V.; Grove City College, Harvard University, Harvard University; *bakertv1@gcc.edu*

***Locomotion by flexible foils: effect of length and stiffness on performance***

The propulsive and control surfaces of swimming and flying organisms are flexible and variously shaped. These physical characteristics affect how such structures interact with the surrounding fluid, and therefore have an impact on swimming performance. Plastic strips (height = 6.9 cm) of various stiffness and length (l = 0.5 – 30 cm) were flapped in a flume by a robot mounted on air-bearings. This made it possible to measure the self-propelled speed of each strip, which was used as a metric of swimming performance. The strips were mounted in the streamwise direction and actuated at the leading edge in heave only (i.e. the transverse direction). Swimming speeds ranged from 15 to 50 cm $s^{-1}$ representing Reynolds numbers between 2.6 x $10^4$ and 8.7 x $10^5$. The motion of the flapping strips was captured by high-speed video and digitized. Stiffness and strip length had significant effects on swimming performance. Most interestingly, strips of particular stiffnesses exhibited multiple maxima and minima in self-propelled speed at different lengths, suggesting a mechanism with resonant harmonics. However, the wave forms observed in the strips did not match standing-wave patterns calculated from the strip wave speeds and lengths, assuming even partial reflection of the strip wave. Nevertheless, for a given strip stiffness the average wave amplitude over the entire strip and self-propelled speed rose and fell together as strip length was increased. These findings are evidence of a fluid-structure interaction that is strongly affected by the length and stiffness of the strip. This phenomenon may be an important factor in understanding the functional morphology of flexible propulsors.

***61.4*** BALBAG, B.S.; WEISS, S.L.*; Univ. of Puget Sound; *sweiss@pugetsound.edu*

***Bigger is better: The effect of female ornamentation on male mate choice in the striped plateau lizard, Sceloporus virgatus***

When females vary in reproductive quality, they may be selected to honestly signal that quality and males may be selected to express mate choice based on this variation. In the striped plateau lizard, females with larger and more saturated orange throat patches are of higher phenotypic quality, and males more closely associate with females painted to express deeper orange ornaments. More recently, it has been found that only ornament size, and not ornament color, can predict female allocation of antioxidants to egg yolk and offspring quality. Thus, we hypothesized that males should be more responsive to variation in ornament size than to variation in ornament color. We examined male response to natural variation in female ornamentation by housing males in large outdoor tents with two females and measuring their spatial relationships as well as male courtship intensity toward each of the two females. Female ornamentation was quantified in terms of size, brightness, chroma and hue. As predicted, we found that males prefer to associate with females with larger ornaments and that aspects of ornament color (i.e., brightness, chroma and hue) had no effect on male association patterns. Courtship behavior was low during our trials and was unrelated to any aspect of female color. These data suggest that males are attending to the aspect of female ornamentation that best predicts a female's reproductive value and support the hypothesis that this ornament is sexually selected.

***82.2*** BALDWIN, J.L. *; JOHNSEN, S. ; Duke University; *jlb54@duke.edu*

***Does this color make my claws look phat? Evaluating claw color preferences in male blue crabs, Callinectes sapidus***

The blue crab, *Callinectes sapidus*, relies partially on color cues to determine an appropriate mate. In our previous work, we found that male blue crabs prefer females with red claws to those with claws modified to be white or black. Additionally, our results demonstrating the blue crab's ability to discriminate red from an isoluminant black suggest that blue crabs are capable of color vision. Here, we have extended the study of blue crab color vision in relation to female claw color variations. Female blue crab claws vary in color from pale orange to deep red; and while no correlations between claw color and quality exist, it is possible that claw coloration serves as a sexual cue. In this study we presented male blue crabs with a choice between a photograph of a female with red claws and a photograph of a female with orange claws. The brightness of one orange hue was adjusted to create several variations of light to dark orange. Each orange variation was presented along with the red clawed photograph in binary choice tests. Male preferences were scored according the number of sexual displays made towards each picture. The results will be discussed in relation to blue crab color vision and the likelihood of female quality evaluation based on claw color.

***45.6*** BALTZLEY, MJ; St. Mary's College of Maryland; *mjbaltzley@smcm.edu*

***Comparative physiology of mechanosensory neurons in three species of leeches.***

In the leech *Hirudo verbana*, each midbody ganglion has four pressure (P) mechanosensory neurons, six touch (T) mechanosensory neurons, and four nociceptive (N) neurons. Putative P cell homologues in the leech *Erpobdella obscura* were previously identified based on cell location, morphology, and physiology. To determine whether the putative P cell homologues were responding to mechanical stimulation, we recorded from the putative P cells in *E. obscura* while stimulating the body wall in a semi-intact preparation. Additionally, we used a similar preparation to record from putative T and N cells in *E. obscura* as well as P, T and N cells in a third leech species, *Macrobdella decora*. Phylogenetically, *M. decora* and *H. verbana* are more closely related to each other than they are to *E. obscura*. We found that the P cells in *M. decora* and *E. obscura* generate more action potentials in response to a given mechanical force applied to the body wall than do the P cells in *H. verbana*. Similarly, compared to T cells in *H. verbana*, the T cells in *M. decora* generate more action potentials in response to a given mechanical force applied to the body wall. However, when standardized to the maximum response, the intensity tuning curves for P and T cells are similar across species. We also examined the action potentials of P, T, and N cells of all three species to identify which characteristics are variable across species.

***S8.5*** BARBEITOS, MS*; ROMANO, SL; LASKER, HR; University of Kansas, University of the Virgin Islands, University at Buffalo; *msbb@ku.edu*

***Phylogenetics and morphological evolution in Scleractinian corals***

Over recent years, molecular phylogenetic analyses have repeatedly made it clear that Scleractinian taxonomy does not reflect phylogenetic relationships within the order. Pervasive plasticity of skeletal characters and evolutionary convergence make it very difficult to assess homology in traditional diagnostic characters. Here, we review the current understanding of relationships within Scleractinia and expand on previous results by sampling extensively among azooxanthellate lineages, which account for more than half of extant coral richness. We used partial sequences of two rRNA genes (mitochondrial 12S and nuclear 28S) for phylogenetic reconstructions. Phylogenetic accuracy was enhanced by incorporating a Cnidaria-wide putative secondary structure model in our alignment, thus improving assessment of positional homology, and also by using evolutionary models that account for lack of independence among nucleotides due to compensatory mutations in stem regions. We uncovered well supported sister relationships among several reef and deep-water corals and also a previously ignored link between reef corals of the Western Atlantic and azooxanthellate lineages of the Eastern Atlantic/Mediterranean. Ancestral character state reconstruction revealed that at least three solitary, azooxanthellate lineages descend from colonial ancestors. In the light of paleontological evidence that reefs have waxed and waned continuously during the Phanerozoic, we hypothesize that loss of coloniality via heterochrony may have allowed some lineages to overcome periods of widespread extinction due to reef recession.

***67.1*** BARBER, A.M.*; DRAKE, K.K.; NUSSEAR, K.E.; ESQUE, T.C.; TRACY, C.R.; MEDICA, P.A.; University of Nevada, Reno, U.S. Geological Survey, Western Ecological Research Center, USGS, USGS, UNR; *barberam@unr.edu*

***Structural equation modeling as a tool to evaluate translocation stress in the desert tortoise.***

Translocation has been proposed as a conservation strategy for the threatened desert tortoise. Translocation of individuals from one area to another results in a cascade of stressors that can impact not only translocated individuals, but also resident animals present in the translocation area. Ecological factors and physiological and behavioral responses can interact complexly to influence the success of translocation. We used structural equation modeling (SEM), a powerful inference tool to understand complex, multivariate hypotheses in natural systems, to explore how the ecological and physiological factors contributing to stress interact as the result of translocation. Several candidate SEM models (hypotheses) were compared using data prior to translocation, and the model most consistent with the data was identified. Multigroup analysis showed that the structure of this model changed after translocation for resident and introduced animals.

***77.5*** BARTH, BJ*; FITZGIBBON, S; CARTER, AJ; WILSON, RS; Univ. of Queensland; *b.barth@uq.edu.au*

***Effects of resource availability on dung beetle abundance and male horn size in Australian urban forest fragments***

The rate of urbanisation is increasing rapidly, with more than 50% of the world's population now living in cities. Urbanisation drastically alters ecological communities via processes such as habitat loss, fragmentation, and degradation. Resource availability is important in explaining changes in ecological communities, with the availability of food resources dictating the abundance of a species and the development of condition-dependent traits. However the effects of altered resource availability in urban areas on such traits, especially those that are subject to sexual selection, are unclear. We examined how urbanisation affects the availability of the food resources and the resulting changes in abundance and condition of sexually selected traits of male dung beetles. Horn and body size of male dung beetles are important in male-male interactions and sexual selection, and are a function of food resource availability during larval development. In suburban Brisbane, the amount of macropod dung decreases in small urban forest fragments, while the amount of domestic dog dung greatly increases. This region is dominated by two species of dung beetle, Onthophagus tweedensis and O. dandalu, whose relative proportions in community assemblage vary in response to the urban gradient. O. dandalu is able to utilise dog dung and greatly increases in abundance in urban areas, while O. tweedensis is reliant on macropod dung and so decreases in abundance. The effects of resource availability on the abundance and condition of competing males have large implications for intra-specific interactions such as male-male competition and sexual selection. We are examining effect of resource availability on horn size, sex ratios and the presence of alternative male strategies for both species of dung species along the urban gradient.

***12.2*** BATAVIA, M.P.; University of California, Berkeley; *mbatavia@berkeley.edu*

***The evolution of "endothermy": terminological constraints and a phylogenetic analysis of metabolic rate evolution in non-mammalian therapsids***

Numerous studies and reviews over the last several decades have addressed the evolution of endothermy in mammals (synapsids) and birds (diapsids). However, inconsistent usage of the term *endothermy* has hindered progress toward understanding the evolution of the complex suite of thermoregulatory and metabolic traits that characterizes these two clades of vertebrates. Furthermore, the term is often used to mean not only metabolically controlled thermoregulation, but also stable body temperature (homeothermy) and high metabolism (tachymetabolism). I propose that the evolution of metabolic rate (tachymetabolism versus bradymetabolism), stability of body temperature (homeothermy versus poikilothermy) and thermoregulatory mode (endothermy versus ectothermy) should be treated as potentially independent events. When broken down in this way, most work that has been done on the evolution of "endothermy" actually pertains to tachymetabolism only. A phylogenetic analysis of morphological traits associated with tachymetabolism indicates the possible acquisition of high metabolic rate early in therapsid evolution.

***45.2*** BATTELLE, B-A.*; KATTI, C; LEGG, A; GONZALES, R; RIVERA, E; KEMPLER, K; Whitney Laboratory, Univ. of Florida; *battelle@whitney.ufl.edu*

***Diurnal and circadian regulation of opsins co-expressed in Limulus photoreceptors***

Three opsins co-express in *Limulus* lateral eye (LE) photoreceptors: opsins1 and 2, which are 99% identical to one another and called here ops1-2, and ops5, which is only 45% identical to ops1-2. Ops5, like ops1-2, is probably sensitive to visible light, but its spectral properties may be different from ops1-2. In phylogenetic analyses, ops5 does not cluster with ops1-2 and other chelicerate long wavelength sensitive opsins, but with crustacean opsins with largely unknown spectral properties. To test whether ops5 could contribute significantly to *Limulus* vision, we quantified ops5 levels relative to ops1-2 in LE membranes. Antibodies specific for ops5 and ops1-2 were used to immunostain Western blots of LE membranes and known amounts of the antigens against which the antibodies were raised. Immunoreactivity (ir) in the membranes was then compared to that of the antigen standards. We also quantified immunocytochemically changes in relative levels of these opsins at the rhabdom. In nighttime dark-adapted LEs, when most opsin-ir is in the rhabdom, ops5 in LE membranes is about 35% of ops1-2. Immunocytochemistry showed that rhabdomeral ops1-2-ir falls during the day to about 50% of its nighttime level due to rhabdom shedding while rhabdomeral levels of ops5 do not change. Thus, during the day, rhabdomeral ops5 is about 70% of ops1-2. Also, rhabdomeral ops1-2-ir is about 40% lower in nighttime LEs deprived of circadian clock input compared to control eyes with clock input, while ops5 levels are not significantly reduced. We conclude that ops5 can contribute significantly to *Limulus* vision especially during the day, and that the levels of ops5 and ops1-2 in the rhabdom are regulated differently by diurnal light and the circadian clock.

***41.2*** BEAUPRE, Steven J.; University of Arkansas, Fayetteville; *sbeaupre@uark.edu*

***Long-Term Studies of Field Metabolic Rate in Timber Rattlesnakes (Crotalus horridus): Annual Variation, Critical Factors, and Implications for Bioenergetic Studies.***

Mechanistic studies of bioenergetics are critical to developing a predictive understanding of organismal responses to environmental change. Field metabolic rate (FMR) integrates energetic expenditures due to maintenance, biochemical activity, and physical activity. As such, field metabolic rates constitute an important response that provides insight regarding ecological factors that influence the mass-energy flux of individuals. I used the doubly-labeled water method to measure FMR in a large sample of radio-tagged Timber Rattlesnakes (*Crotalus horridus*) at a long-term study site in Northwest Arkansas. One hundred and ninety-five measurements of FMR were made among 59 individuals during the active season (May-September) over nine years (1996 to 2004 inclusive). FMR scaled allometrically with body mass following $0.477W^{1.13}$. Water efflux and influx were nearly isometrically related to body mass. Significant variation in the magnitude of FMR was apparent among years and among seasons (spring-summer transition, summer, and summer-fall transition). Supplemental feeding of experimental snakes increased FMR by a factor of two over naturally foraging (control) snakes. No effects of sex or ecdysis were apparent. High variability in observed FMR of Timber Rattlesnakes, especially with respect to annual variation, elicits caution when interpreting scaling relationships based on small samples from geographically focused and temporally limited studies. Mass scaling exponents that exceed 1.0 have been previously reported among snakes and have potentially important implications for estimation of field energy budgets and interpretation of factors that influence FMR.

***87.4*** BECKMAN, Brian R*; LUCKENBACH, J Adam; METZGER, David C; SHIMIZU, Munetaka; DICKEY, Jon T; NWFSC, NOAA Fisheries, School of Fisheries, University of Hokkaido, SAFS, University of Washington; *brian.beckman@noaa.gov*

***Endocrine control of growth in coho salmon: validation of a multiplex gene expression assay and quantification of relations between messenger RNA levels and proteins during feeding and fasting***

We have explored the efficacy of the recently-released Quantigene Plex (QGP) technology for measuring a panel of endocrine growth-related transcripts in the liver of coho salmon, *Oncorhynchus kisutch*. The QGP technology uses sequence specific probes and requires no reverse transcription or amplification as does real-time, quantitative RT-PCR (qRT-PCR). Using liver homogenates from fed, fasted and re-fed coho salmon, we compared the detectable fold changes of steady-state mRNA levels between the QGP and probe based qRT-PCR assays for insulin-like growth factors (*igf1* and *igf2*), insulin-like growth factor binding proteins (*igfbp1*, *igfbp2a*, and *igfbp2b*), somatolactin receptor (*slr*), and growth hormone receptors (*ghr1* and *ghr2*). A positive and significant relation between QGP and qRT-PCR results was found for each gene target, demonstrating that the QGP assay is a valid approach for assessing gene expression of each of these genes. Messenger RNA levels of *igf1*, *igf2*, *igfbp2a*, and *slr* decreased with fasting, levels of *igfbp1*, *ghr1* and *ghr2* increased with fasting, and there was little change in levels of *igfbp2b*. Positive and significant correlations were found between *igf1* and *igf2* mRNA levels, *igfbp2a* and *igfbp2b*; *igf2* and *igfbp2a*; *igfbp2a* and *igfbp2b*; and *ghr1* and *ghr2*. Finally, positive and significant relations were found between liver *igf*1 mRNA and plasma IGF1 and liver *igfbp1* mRNA and plasma IGFBP1.

***72.9*** BEECHLER, BB*; BELL, A; EZENWA, VO; JOLLES, AE; Oregon State University, University of Montana; *breebeechler@gmail.com*

***Innate immunity in free-ranging African buffalo (Syncerus caffer): Variability with reproductive status and parasite infestation, and a context-dependent trade-off with adaptive immunity***

Mammalian immunology has been studied in great detail in laboratory animals, but few of the tools, and less of the insights derived from these studies have been placed in the context of natural, outbred populations subject to variable environments. We investigated patterns of innate immunity in free-ranging African buffalo in relation to host traits (age, reproductive status, body condition, white blood cell counts and differentials) and infection profiles (bovine tuberculosis (BTB), gastrointestinal helminths, coccidia, ticks). We used an in-vitro assay measuring bactericidal competence of blood to assess innate immunity in 200 female buffalo captured at Kruger National Park, South Africa, in June/July and October 2008. Bactericidal competence of blood is mediated by cell and protein components of the innate immune system, which provide an immediate, constitutive defense against invading microorganisms. Pregnant animals, and individuals with high tick burdens had lower bactericidal competence of blood. Animals captured in October, but not those captured in June / July revealed a negative association between innate and adaptive immunity as measured by lymphocyte counts. Bactericidal competence of blood did not vary with host body condition, age, lactation, TB infection, helminths or coccidia. Our results suggest a role for innate immunity in mediating ectoparasite burdens, and trade-offs between innate immunity and other costly activities such as reproduction and adaptive immunity in free-ranging buffalo.

***S10.11*** BELL, Susan*; MEYERS, Allison; THOMAS, Florence; Univ. of South Florida, Univ. of Hawaii; *sbell@cas.usf.edu*
***Lessons learned about ecosystem function and biogenic structure from experimental work on seagrasses and macroalgae***
Seagrasses and rhizophytic macroalgae provide multiple ecosystem functions including provision of structure for fauna and epiphytes. However modification of the abiotic environment is also notable. Sediment trapping by canopies is well known. The modification of the abiotic environment by these marine plants may have positive or negative effects on other organisms and thus plants may act as ecological engineers. However it is important to establish whether such actions are consistent over larger temporal and spatial scales. We combined studies of underwater landscape change with field experiments to assess the impact of each of these plants on different measures of ecosystem function. Experiments showed that flow regimes within the canopy of these plants differed. Additionally, in field studies conducted using in situ flumes, nutrient uptake was distributed differently among the organisms in the two types of vegetation. Specifically in seagrass beds, epiphytes played a predominant role in removing nutrients from the water column; however, in areas dominated by algal beds, the macroalga was responsible for a large percentage of the whole community uptake. Additional studies revealed that even when seagrass density was held constant, sediment retention varied with hydrodynamic setting. Thus changing landscape composition of these plants within the same locale or the same plants operating within different hydrodynamic conditions can lead to modification of a variety of ecosystem processes. Such variation in time and space presents challenges to assessing the impacts of these potential ecological engineers.

***S5.6*** BELY, A.E.; Univ. of Maryland, College Park; *abely@umd.edu*
***Evolutionary loss of animal regeneration: pattern and process***
Regeneration ability has been greatly restricted or altogether lost numerous times among animals. Yet despite its prevalence, regeneration loss and the mechanisms by which it occurs remain poorly studied. I will provide a phylogenetic overview of regeneration ability across animals, highlighting both old and recent regeneration losses, and will discuss diverse hypotheses that have been proposed to explain why and how regeneration loss occurs. I will also describe our findings from studies on a group of small asexual annelids, the naidines, in which the ability to regenerate a head has been lost multiple times. In one species that has recently lost head regeneration abilities, amputation within the fission zone, a narrow proliferative region that forms during asexual reproduction, can still elicit regeneration of an essentially normal head. This finding demonstrates that regeneration abilities can remain latent and still be elicited following a recent evolutionary loss of regeneration.

***66.1*** BEN-DAVID, J; CHIPMAN, A.D.*; The Hebrew University of Jerusalem; *ariel.chipman@huji.ac.il*
***Blastoderm patterning and gap gene interaction in the milkweed bug Oncopeltus fasciatus***
The early embryo of the milkweed bug, *Oncopeltus fasciatus*, appears as a single cell layer – the embryonic blastoderm – covering the entire egg. It is at this blastoderm stage that morphological domains are first determined, long before the appearance of overt segmentation. Central to the process of patterning the blastoderm into distinct domains are a group of transcription factors known as gap genes. In *Drosophila melanogaster* these genes form a network of interactions, and maintain sharp expression boundaries through strong mutual repression. Their restricted expression domains define specific areas along the entire body. We have studied the expression domains of the four trunk gap genes in *O. fasciatus* and have determined their interaction through dsRNA gene knockdown experiments, followed by expression analyses. While the blastoderm in *O. fasciatus* includes only the first six segments of the embryo, the expression domain of the gap genes within these segments are broadly similar to those in *Drosophila* where the blastoderm includes all 15 segments. Surprisingly, mutual repression between the genes seems to play a much less significant role than it does in *Drosophila*.

***10.5*** BEN-HAMO, Miriam*; PINSHOW, Berry; MCWILLIAMS, Scott R.; BAUCHINGER, Ulf; Ben-Gurion University of the Negev, Israel, University of Rhode Island, Kingston., University of Rhode Island, Kingston.; *miriammi@bgu.ac.il*
***A reassessment of the proximate factors that trigger hypothermia in Japanese quail Coturnix japonica***
We tested three hypotheses about the environmental cues that elicit facultative hypothermia in birds and the energy savings associated with reduced body temperature ($T_b$) using Japanese quail (*Coturnix japonica*) as a model: 1) Ambient temperature ($T_a$) influences the onset and depth of hypothermia (sleep $T_b$ < euthermic sleep $T_b$) in Japanese quail; 2) $T_a$ does not affect their use of hypothermia; 3) $T_a$ acts along with body energy reserves in shaping the birds' use of hypothermia. Eight quail were maintained within their thermoneutral zone (TNZ) at 32.6 ± 0.2 °C, and eight below their lower critical temperature ($T_{lc}$) at 12.7 ± 3.0 °C for 10 days. All the quail entered hypothermia upon 4 days of food deprivation, even quail kept within their TNZ, wherein thermoregulatory costs are ostensibly minimal in active animals. $T_b$ decreased more (38.36 ± 0.53 °C vs. 39.57 ± 0.57 °C) and body mass ($m_b$) loss was greater (21.0 ± 7.20 g vs.12.8 ± 2.62 g) in those quail kept at the lower $T_a$, and the energy saved by using hypothermia was greater (45.01 ± 4.54 % vs. 28.06 ± 3.33 %) for quail kept at low $T_a$ than those kept within their TNZ. Interestingly, depth of hypothermia was positively correlated with $m_b$ loss in low $T_a$ quail, but not in TNZ birds. We conclude that the data supports hypothesis (3) that both thermoregulatory costs and body energy reserves are proximate cues for entry into hypothermia in quail. This is not surprising below the $T_{lc}$, however, the quail responded to food deprivation by entering hypothermia within their TNZ with no apparent dependence on $m_b$ loss. Apparently, cues other than thermoregulatory costs and body condition are involved with the use of hypothermia within the TNZ.

***53.1*** BENNETT, K.C.*; EMLET, R.E.; YOUNG, C.M.; Oregon Institute of Marine Biology; *kbennet4@uoregon.edu*
***Larval Development and Metamorphosis of the Deep-Sea Cidaroid Urchin Cidaris blakei***
Extant urchins are divided into two lineages, the Cidaroida and the Euechinoidea. Cidaroida, the order of "pencil urchins," is an ancient lineage and is thought to represent the primitive form of euechinoids. This study describes the embryonic and larval development through metamorphosis and into the juvenile stage of the bathyal cidaroid *Cidaris blakei*. Morphological features of *C. blakei* such as egg size, presence of an apical tuft, ectodermal invaginations at gastrula stage, an extended lecithotrophic stage prior to completion of the gut, and juvenile spine shape distinguish this species from other planktotrophic cidaroids. We compare the development of *C. blakei* to that of other cidaroids and also other deep-sea echinoids. We discuss which characteristics are common to cidaroids, and potentially attributable to phylogenetic constraints, and which adaptations may be specific to the deep-sea environment.

***97.3*** BENTLAGE, B*; CARTWRIGHT, P; COLLINS, A G; University of Kansas; *bentlage@ku.edu*
***Evolution of box jellyfishes (Cnidaria: Cubozoa)***
Cubozoa (Cnidaria: Medusozoa) represents a small clade of approximately fifty described species, some of which are highly toxic, causing serious human envenomations. Our understanding of the evolutionary history of Cubozoa has been limited by the lack of a sound phylogenetic hypothesis for the group. As part of the Cnidarian Tree of Life project we assembled a comprehensive cubozoan phylogeny. This phylogeny has the potential to further our understanding of cubozoan venom evolution, biogeography and life history evolution. In particular, the phylogenetic hypothesis we present suggests that: 1) the poorly understood mechanisms that can cause a severe medical condition (Irukandji syndrome) caused by several box jellyfish species arose early in cubozoan evolution, 2) deep divergences between Atlantic and Indo-Pacific clades may be explained by ancient vicariant events and 3) sexual dimorphism evolved a single time in concert with complex sexual behaviour. In addition, cubozoan species identities have long been misunderstood and our data support many of the recent scientific descriptions of cubozoan species. However, a phylogeographic analysis of Alatina spp. from the Pacific reveals that at least two species in this genus represent artificial taxonomic units, highlighting the need for integrating molecular techniques with more traditional taxonomic methods in order to understand species' identities.

***70.1*** BERG, Angela M*; BIEWENER, Andrew A; Harvard Univ; *aberg@oeb.harvard.edu*
***Mechanisms of takeoff and landing flight***
Takeoff and landing are essential elements of flight for birds. During takeoff, birds accelerate forward to attain cruising speed; during landing, birds decelerate to zero velocity. These accelerations are the result of the interaction of moving wings and surrounding air. To understand how birds use their wings to accelerate and decelerate, we investigated short flights of pigeons from multiple perspectives. Birds were filmed with high-speed video to collect kinematic data. We used sonomicrometry to record muscle strain and EMG to record muscle activation. Using DPIV, we measured airflow around the birds and estimated aerodynamic parameters. Implementing these methods allowed us to link kinematics, muscle function, and aerodynamics to create an integrated understanding of takeoff and landing flight. We found that most of the acceleration during takeoff and landing occurred when the bird was not in contact with the perch, demonstrating that the wings, rather than the legs, provided most of the acceleration. Body, tail, and wing angles increased dramatically from takeoff to landing. During takeoff and midflight, the stroke plane angle tilted downward, but during landing, the stroke plane angle tilted upward. We therefore hypothesized that the wingstroke pushes air rearward during takeoff, but forward during landing. Our aerodynamic results support these hypotheses and suggest that the direction of the net airflow due to a wingstroke is roughly normal to the stroke plane. Wingbeat amplitude was greater during takeoff and landing than during midflight. Pectoralis strain changes reflect this pattern. Differences in muscle function among flight modes in the biceps, scapulotriceps, and humerotriceps were more subtle and variable. The biceps and humerotriceps appear to contribute to wing stability during the downstroke.

***18.3*** BERGEON BURNS, C.M.*; WINGFIELD, J.C.; KETTERSON, E.D.; Center for the Integrative Study of Animal Behavior, Indiana University, Bloomington; *cbergeon@indiana.edu*
***Seasonal and individual differences in elevation of LH and T in response to GnRH in female Dark-eyed Juncos***
Evolutionary endocrinology seeks to understand how hormone-mediated traits evolve. An essential first step is to understand the basis for individual variation in circulating hormones. Our focus is the steroid hormone testosterone (T) in birds. A standardized injection of gonadotropin releasing hormone (GnRH) triggers secretion of luteinizing hormone (LH) from the pituitary, which in turn triggers a transient increase in T from the gonads. Previous study has shown that male dark-eyed juncos (*Junco hyemalis*) vary widely in the degree to which they elevate T after a GnRH challenge and in related behavior. While T is typically considered a ‘male hormone,’ gravid female juncos also elevate T in response to GnRH, presumably via an increase in LH. Whether T co-varies with other aspects of female phenotype remains to be seen. Also unknown are the causes of among-female variability in elevation of T in response to GnRH, i.e., how much of the variability can be attributed to variation in pituitary sensitivity to GnRH (as measured by production of LH) vs. variation in gonadal sensitivity to LH (as measured by T)? Is a strong responder to GnRH more sensitive to both GnRH and LH, or do these sensitivities vary independently? Interestingly, although females elevate T in response to GnRH only when gravid, they elevate LH in response to GnRH at other stages of reproduction. From April-July 2009, we challenged 72 free-living female juncos in the Black Hills of South Dakota with GnRH and examined patterns of LH and T across the season and stages of breeding. We will report determinants of strong and weak response to GnRH and whether strong and weak responders differ in phenotype.

***8.5*** BERGMANN, P.J.*; IRSCHICK, D.J.; University of Arizona, University of Massachusetts Amherst; *pjbergma@email.arizona.edu*

***Tempo and mode of lizard axial evolution. Is body elongation a key innovation?***

Recent approaches for studying the mode and tempo of trait evolution and diversification allow us to test hypotheses of key innovation with unprecedented rigor. Among vertebrate clades, there is considerable variation in both vertebral number and the degree of constraint on vertebral number. This variation is hypothesized to influence body shape diversity, and ultimately species diversification. We tested the hypothesis that the evolution of a snake-like body represents a key innovation, using a supertree of lizards, a vertebral count dataset including ~1400 species, and a body shape dataset including ~650 species. These data allowed us to calculate rates of morphological evolution, the density of lineages in morphospace, and a new metric that measures the level of dispersion of a clade in morphospace. We found that an elongate body shape does not represent a key innovation, leading to clade diversification. Instead, rapid vertebral number evolution acts to diminish constraints on body shape evolution, and this tends to occur in relatively elongate clades with more trunk vertebrae. However, this phenomenon does not translate into increased rates of species diversification. Our results illustrate how a key innovation can hold sway on some aspects of diversity and not others, suggesting that the role of key innovations may be more complex than previously envisioned.

***42.1*** BERGOU, Attila J*; RISTROPH, Leif; GUCKENHEIMER, John; COHEN, Itai; WANG, Z. Jane; Cornell University; *ajb78@cornell.edu*

***Fruit flies modulate passive wing pitching to generate in-flight turns***

To control their flight, insects must have mechanisms to modulate their wing kinematics. Exactly how insects control their wing motions to execute observed flight maneuvers is poorly understood. Here, we measure the wing and body kinematics of freely flying fruit flies performing turns and, in conjunction with numerical simulations and mathematical models, probe how they control their wing motion to ultimately alter their flight path. We find that these flies induce sharp turns by applying an overall bias to the passive pitching motion of their wings. We present a simple mechanical model for the wing actuation that quantitatively predicts the turning dynamics of the insect.

***S10.1*** BERKE, Sarah K; Smithsonian Environmental Research Center, Edgewater, MD; *skberke@gmail.com*

***Ecosystem Engineering in the Marine Realm***

Ecologists have long known that certain organisms fundamentally modify, create, or define habitats by altering the habitat's physical properties. In the past decade, these processes have been formally defined as 'ecosystem engineering'. This definition has alternately been lauded as a fundamental advance in ecological theory and derided as the unwarranted introduction of an overly general buzzword. Despite this vigorous initial controversy, the emerging consensus is that ecosystem engineering is indeed a fundamental class of ecological interactions occurring in most, if not all, ecosystems. In the marine realm, ecosystem engineers such as seagrasses, seaweeds, oysters, and tube-building or burrowing infauna occur across an enormous range of habitats, from the tropics to the sub-arctic, from sheltered muds to wave-exposed rocks, from the high intertidal to deep-sea vents. What, if any, commonalities unify these diverse systems? What aspects of morphology, physiology, life-history, and ecology are most critical in making an ecosystem engineer? After reviewing the origins and development of the ecosystem engineering concept, I will survey the major groups of marine ecosystem engineers with an eye towards establishing commonalities among them as well as drawing broad comparisons between marine and terrestrial ecosystem engineering processes.

***31.8*** BIERMANN, C.H.*; WHITE, T.A.; PALUMBI, S.R.; Friday Harbor Labs and Portland State Univ., Univ. of Washington, Seattle, Hopkins Marine Lab, Stanford; *biermann@pdx.edu*

***Strongylocentrotus sea urchin eggs choose conspecific over heterospecific fertilization***

When given no choice, eggs of the green sea urchin *Strongylocentrotus droebachiensis* can be fertilized with sperm from the related, sympatric species *S. pallidus* and *S. purpuratus*. When green urchin sperm are added along with heterospecific sperm, conspecific sperm father over 90% of eggs – as assessed by genotyping three-day old embryos. The conspecific sperm precedence remains strong even if there is an excess of heterospecific sperm. However, if heterospecific sperm are given a head start, hybrid fertilizations increase. This increase is linear with delay time; conspecific fertilization reaches zero when heterospecific sperms had a one minute head start. In the reciprocal cross with eggs from *S. pallidus*, no-choice hybridization with *S. droebachiensis* sperm is lower with a mean of 40%, and conspecific sperm precedence is 100%. *Strongylocentrotus purpuratus* eggs block hybrid fertilization efficiently, even if given no choice. *Strongylocentotus purpuratus* sperm are very successful at fertilizing heterospecific eggs, and bypass the other species' conspecific precedence to a small degree. These results suggest that hybrid fertilization studies should include sperm competition experiments since no-choice crosses are not representative even in simple broadcast-spawning systems.

***79.5*** BLANK, L.M.*; VALEN, A.; University of Montana, Missoula; *lisa.blank@mso.umt.edu*
***Advancing Interest in Graduate Research through Undergraduate/Scientist Partnerships: The Tioga Learning Community***
Creating dynamic learning communities for undergraduate science students that motivate and support their interest in pursuing graduate research opportunities and develop their ability and commitment to successfully communicate complex scientific information to the general public is a perennial challenge. The Tioga Learning Community Internship project partnered undergraduate science majors and science education majors with research scientists and education faculty. Students and faculty met as a learning community for a one-semester seminar where students developed a deeper understanding of stress ecology, proficiency in field research techniques, and the ability to use educational research to develop a teaching module on the behavior, telemetry study, and general biology of white-crowned sparrow (Zonotrichia leucophrys) populations established in the high Sierra Mountains. Students then spent four weeks in the field with research faculty examining the adrenocortical response to stress and the behavioral and cellular actions of glucocorticoids in the white-crowned sparrow; and, visited three local schools where they taught the stress ecology modules they had co-developed with education faculty. At the completion of the project, undergraduate students demonstrated deeper knowledge of the scientific principles underlying stress ecology, proficiency in a variety of teaching pedagogy, increased self-efficacy in designing and pursuing research questions in the field, and an enhanced interest in pursuing graduate research opportunities in ecology and/or science education.

***S11.11*** BLOB, R.W.*; KAWANO, S.M.; BRIDGES, W.C.; MAIE, T.; PTACEK, M.B.; JULIUS, M.L.; SCHOENFUSS, H.L.; Clemson Univ., St. Cloud State Univ.; *rblob@clemson.edu*
***Morphological selection and tradeoffs between predator escape and climbing in Hawaiian gobies***
Environmental pressures may vary over a species range, exposing different subpopulations to opposing functional demands. How does exposure to competing demands shape fish morphology and influence population divergence? We performed selection experiments on the Hawaiian goby *Sicyopterus stimpsoni*, an amphidromous fish facing potentially opposing selection on juvenile body shape as a result of (1) avoiding predators in lower stream reaches, and (2) climbing waterfalls to reach adult habitats. Adult fish differ in shape between islands where different pressures predominate: *S. stimpsoni* from Kaua'i have deep bodies, improving thrust for predator escape in long estuaries on the way to adult habitats, whereas *S. stimpsoni* from the Big Island have low body heights, reducing drag in waterfalls that juveniles climb shortly after entering streams. To evaluate how competing selection pressures contribute to this divergence, we compared selection imposed on juvenile body shape by (1) predation by the native fish *Eleotris sandwicensis*, vs (2) climbing an artificial waterfall (~100 body lengths). Fineness ratio (length/height) showed opposing selection patterns that matched predictions: predation survivors had lower ratios than control fish (i.e., greater body depth for a given length), whereas successful climbers had higher fineness ratios (reducing drag) than fish that failed. However, most variables showed significant selection in only one treatment, rather than opposing selection across both. Thus, both predators and flow conditions might influence body shape differences acoss goby subpopulations, but divergence might result from differing, rather than opposing, selection patterns. NSF IOS-0817794, 0817911.

***74.6*** BOETTGER, S.A.*; TARASKA, N.G; LOCK, N.C.; WALKER, C.W.; West Chester University, The University of New Hampshire; *aboettger@wcupa.edu*
***Development of hemic neoplasia and surveys in different populations of Mya arenaria.***
Disseminated neoplasia in bivalve mollusks is characterized by mitotic hemocytes with a nuclear to cytoplasmic ratio of 1:1. Efforts to link environmental contaminants to the initiation of this fatal disease have depended on data collected followed episodic contamination events. No studies have characterized the prevalence of this leukemia-like disease in sites with different pollution levels/concentrations over an extended period of time. Here we examine the development of disseminated neoplasia in the soft shell clam, *Mya arenaria*, at six sites in New England where clam fisheries have been negatively impacted and we also provide the first evaluation of development of clam neoplasia at different sites. Surveys of populations of *Mya arenaria* between New Brunswick and Maryland indicated a higher frequency of neoplasia in animals from Rhode Island and New York (>20%) compared to all other populations, while animals from Maryland <1%) had the lowest frequency of neoplastic individuals. Our transplants of healthy, hatchery raised *Mya arenaria* document the highest frequency of neoplasia development and link neoplasia occurrence to sediment charcteristics and environmental contaminants. These results may indicate vulnerability of neoplastic clams to environmental stress. (CASSDA through WCU to SAB and Saltonstall/Kennedy NA08NMF4270416 to CWW)

***74.1*** BOLDEN, A.M.*; VAJDA, A.M.; BARBER, L.B.; SCHOENFUSS, H; NORRIS, D.O.; University of Colorado, Boulder, University of Colorado, Denver, U.S. Geological Survey, St. Cloud St. University; *alan.vajda@ucdenver.edu*
***Reproductive disruption of fishes by endocrine-active wastewater effluent***
We investigated the impact of a wastewater treatment plant (WWTP) effluent on fish reproduction. This effluent is known to contain endocrine-active compounds including alkylphenols, reproductive steroids, and pharmaceutical contraceptives. Previously, we identified female biased sex ratios, gonadal intersex, asynchronous ovarian development, and other forms of reproductive disruption in feral white suckers (Catostomus commersoni) collected downstream of WWTP effluent but not at reference sites. To investigate the putative link between reproductive disruption observed in feral fish and wastewater effluent, we conducted on-site exposure experiments in 2005 and 2006 using a mobile flow-through laboratory. In these experiments, adult male fathead minnows (Pimephales promelas) were exposed to either WWTP effluent, reference water from Boulder Creek upstream of the wastewater plant, or mixtures of reference water and WWTP effluent. Exposure to diluted wastewater treatment plant effluent significantly elevated vitellogenin and suppressed primary and secondary sex characters. In 2008, we conducted similar on-site experiments to determine effects of an engineering upgrade (change from trickling filter to activated sludge) on the estrogenicity of the effluent. We report a physiological assessment of changes that have occurred in the endocrine activity (estrogenicity) of the WWTP effluent.

***98.5*** BOLINGER, M.T.*; RODNICK, K.J.; Idaho State University; *bolimark@gmail.com*
***Glucose Inhibition and Temperature Sensitivity of Glycogen Phosphorylase in Rainbow Trout***
Glycogen is an important endogenous fuel that is mobilized primarily by glycogen phosphorylase (GP). GP is highly regulated and can exist in activated (a) and inactivated (b) forms based on the presence or absence of adenosine monophosphate (AMP). Storage of glycogen and GP activity varies between tissues, and the latter may be influenced by carbohydrate inhibition and temperature. Trout are carnivorous ectotherms that are relatively intolerant of carbohydrate. Our objective was to determine the extent of GP inhibition by glucose and temperature sensitivity in ventricle, liver and white muscle tissue of sexually-immature male and female fish. GP activity was measured spectrophotometrically using glycogen as substrate at 14°C in the presence of glucose (1.25 to 50 mM). To assess thermal sensitivity (Q10), measurements were also carried out at 24°C. At 14°C, GP activity (-AMP) was 50-60% higher in ventricle and white muscle than liver while with AMP it was twice as high in striated muscle than liver. A physiological concentration of intracellular glucose (5 mM) inhibited GP activity (-AMP) by 39, 14, and 3% in white muscle, ventricle, and liver respectively. In contrast, GP activity (+AMP) was inhibited less and uniformly (8-11%) in all three tissues. Based on a Q10 of ~3, GP was quite sensitive to temperature and might limit glycogen use at cold temperatures. In summary, glucose can serve as a potent inhibitor of GP activity in multiple tissues of the rainbow trout and help define glycogen utilization rates. Higher levels of intracellular glucose in trout muscle compared with mammals may increase the importance of other glycogenolytic enzymes. A high temperature sensitivity of GP may also promote glycogen mobilization at higher body temperatures, and the potential loss of glycogen.

***S4.5*** BOLLER, M.L.; St. John Fisher College; *mboller@sjfc.edu*
***Reconfiguration and the biomechanics of flexible wave-swept macroalgae***
The hydrodynamic forces experienced by wave-swept intertidal macroalgae are influenced by reconfiguration, i.e. the change in size and shape of the organism projected into the flow. These changes result from the forces generated by that flow and modify the change in force associated with a change in flow velocity. Reconfiguration mollifies the effect of increased flow velocity, allowing organisms to be larger at low, benign flows and smaller with lower potential for dislodgement at high and potentially damaging drags. Reconfiguration influences the hydrodynamic performance (measured as the ability to resist damage with increased flow velocity) and has been said to be a prerequisite for macroalgal survival in the wave-swept intertidal zone. Here I will present my and my collaborators' work exploring the mechanisms of reconfiguration, our ability to predict drag and reconfiguration in macroalgae, and some of the theoretical implications of reconfiguration on the evolution of macroalgae. A model that isolates the separate mechanisms of change in size (area projected into the flow) and shape (drag coefficient) in reconfiguration was developed and refined. With this model, mechanistic predictions of drag at high field velocities are possible and have been tested under controlled conditions. Further, the isolation of size and shape effects has revealed different potential mechanical strategies among algae. Some species may be more effective at reducing size, while others shape, with both strategies achieving similar hydrodynamic performance. These emergent properties of flexibility may have influenced the evolution of intertidal macroalgae, contributing to the wide range of morphologies that are successful in the intertidal zone.

***55.1*** BOMPHREY, R.J.*; TAYLOR, G.K.; University of Oxford; *richard.bomphrey@zoo.ox.ac.uk*
***Optomotor frequency response in hawkmoths.***
We investigated the optomotor responses of several species of hawkmoth in a virtual reality flight simulator. Subjects were rigidly tethered to a 6-component force-moment balance inside a 1m diameter sphere which served as a back-projection surface for providing wide field optic flow stimuli. The insects were presented with harmonic roll, pitch and yaw stimuli at discrete frequencies, and were also presented with frequency sweeps. The simulator allows us to present arbitrary moving greyscale patterns at temporal and spatial resolutions well in excess of those of the insects' visual systems, so patterns were selected that would stimulate the optomotor response strongly, based on knowledge from previous studies of Lepidoptera. The dynamics of the insects' responses to optomotor stimuli were analysed for all six measured components of force and torque, and were also analysed in respect of wing and head motions measured using a high-speed digital video camera and automated video tracking.

***63.3*** BOURDEAU, PE; Michigan State University; *bourdea7@msu.edu*
***Mechanism of an inducible morphological defense: active physiological response or behavioral by-product?***
Many organisms have evolved inducible defenses in response to spatial and temporal variability in the risk of predation. These defenses are assumed to be costly, but few studies have investigated the mechanisms and of these adaptive responses, which can often elucidate associated costs. I examined the proximate cause of a known inducible defense; crab-induced shell thickening in the marine snail *Nucella lamellosa*. Results indicate that although crabs (*Cancer productus*) induce thicker shells, the response is a passive consequence of reduced feeding and somatic growth rather than an active physiological response to predation risk. Physical tests indicate that the shells of crab-induced snails are stronger, but the increase in strength is no different than that of snails with limited access to food. Increased shell strength is also attributable to an increase in the energetically inexpensive microstructural layer rather than to material property changes in the shell. This mechanism suggests that crab-induced shell defenses may be neither energetically nor developmentally costly. Positive correlations between behavioral responses and morphological defenses may explain the commonly observed associations between growth reduction and defense production in other systems and could have important implications for the evolutionary potential of these plastic traits.

***S6.1*** BOWLIN, MS*; BISSON, I-A; WIKELSKI, M; Lund University, Princeton University, Max Planck Institute for Ornithology; *melissabowlin@gmail.com*

***Integrative migration biology: Past, present and an exciting future***

Billions of animals migrate each year and can have enormous effects on the communities and ecosystems they inhabit. To migrate successfully, organisms must integrate many different aspects of genetics, physiology, biomechanics, behavior, and the environment. The phenomenon of migration therefore represents an excellent system in which to study the interplay between these different levels of analysis. However, research on migration has often tended to focus on one narrow aspect of migratory behavior or physiology, largely due to methodological constraints. Integrative migration biology, an emerging discipline, takes aim at the 'big questions' in the field such as how and why migration evolves, how migratory populations are regulated, and how environmental change will affect migrants by attempting (1) to examine migration from several different ecological and evolutionary perspectives, (2) to use new technology to measure physiology and behavior in the field, and/or (3) to understand migration within the context of the annual cycle. Ultimately, practicing integrative migration biology will result in a better understanding of costly life history strategies such as migration as well as an increased ability to conserve migrants and the various habitats they depend on.

***34.3*** BRAINERD, E.L.*; RITTER, D.A.; DAWSON, M.M.; SULLIVAN, A.; Brown University; *brainerd@brown.edu*

***XROMM analysis of rib kinematics and intercostal muscle strain during breathing in Iguana iguana***

The functions of external intercostal (EI) and internal intercostal (II) muscles have been debated for centuries. In this study we used X-ray Reconstruction of Moving Morphology (XROMM) to create accurate animations of 3D rib and sternal movements during breathing in green iguanas. We measured intercostal muscle strain by mapping the attachment points of EI and II muscle fascicles onto the 3D rib models for each individual iguana, and running the XROMM animations to measure the change in distance between the fascicle attachment points during exhalation and inhalation. Green iguanas have four cervical (Cv) ribs, four sternal (St) ribs that articulate with the sternum via costal cartilages, and three ziphisternal ribs. Our x-ray videos and XROMM analysis of deep breathing movements show little movement of Cv1 and Cv2, increasing amounts of rotation in Cv3-4 and St1, the greatest rotation in St2, and gradually decreasing rotation in St3-4 and more caudal ribs. In the intercostal space between the osseous portions of St1 and St2, the EI fascicles lengthened during exhalation and shortened during inhalation, whereas between St3 and St4, the EI shortened during exhalation and lengthened during inhalation. The costal cartilages rotate posteromedially during exhalation such that the interchondral spaces all decrease in width, and subsequently increase in width during inhalation. However, the parasternal II muscle fascicles lie at steep angles (>55 degrees) to the costal cartilages, so the II fascicles lengthen during exhalation and shorten during inhalation. These results are consistent with the previously described activation patterns of the EI and II in iguanas (Carrier, 1989), and are strikingly similar to recent consensus developing on the functions of EI and parasternal II in dogs.

***52.1*** BOYER, S.L.*; HOWE, A.A.; HOVE, M.C.; Macalester College, Macalester College; University of Minnesota; *boyer@macalester.edu*

***A DNA barcoding approach to identifying newly transformed juvenile freshwater mussels (Bivalvia: Unionidae) recovered from naturally infested fishes***

We have developed a multilocus DNA barcoding approach to identification of newly transformed juvenile unionid mussels collected from naturally infested fishes from a federally protected waterway that is home to a highly diverse mussel community. We built reference databases from identified adult mussels using both new data from freshly collected specimens and publicly available data downloaded from GenBank. We assessed the efficacy of the mitochondrial loci COI and ND1 for DNA barcoding and concluded that both loci perform well for species identification in phylogenetic analyses, with the majority of species forming monospecific clades with high bootstrap and posterior probability support. Exceptions to this rule involve previously published sequences and likely represent errors in labeling of samples, demonstrating the value of voucher specimens and highlighting the importance of caution when working with publicly available data. To obtain newly-transformed juvenile mussels, we collected three fish species that were naturally infested with unionid glochidia and held them in aquaria until the mussels emerged. When sequences from these juveniles were included in phylogenetic analyses, they grouped with single species (or in one case a pair of closely related species) with high support. In many cases, it is impossible to identify juveniles using morphology alone, so this approach will be of great utility to researchers and interested in the relationship between unionid mussels and their fish hosts.

***52.2*** BRANNOCK, Pamela M*; HILBISH, Thomas J; University of South Carolina; *pamela.m.brannock@gmail.com*

***Hybrid sterility limits introgression between invasive and endemic blue mussels***

The mechanisms of speciation in marine ecosystems have interested scientists for decades. Since many marine species spawn gametes into the water column and fertilization occurs externally, there is relatively little opportunity to develop pre-mating reproductive barriers based upon mate recognition. A majority of the research on speciation in marine systems has focused on pre-mating reproductive isolation mechanisms and very seldom have post-mating reproductive isolating mechanisms been examined. Marine mussels in the *Mytilus edulis* complex (*M. edulis*, *M. trossulus*, and *M. galloprovincialis*) are emerging as a model system for examining the role of post-mating reproductive isolation in limiting hybridization and introgression. *Mytilus gallorprovincialis* and *M. trossulus* are sympatric and hybridize on both coasts of the North Pacific. Hybridization levels differ among geographic locations, but in all regions introgression beyond the $F_1$ generation is either rare or absent. While assessing gender of mussels in the summer of 2008 for another study, we documented a noticeably low ability to determine gender of individuals in both hybrid zones in Hokkaido, Japan. Eighty percent of individuals where gender could not be determined utilizing traditional field methods had a hybrid multi-locus genotype. Histological examination of the gonad tissue revealed unusual cell types present in hybrid individuals that appeared to be arrested in a meiotic phase. The arrest of gametogenesis in both male and female individuals results in very low fertility and thus represents a formidable level of post-zygotic reproductive isolation between these species. This is the first report of reduced fertility as a result of hybridization among any of the species in the blue mussel species complex.

***87.2*** BRAR, N.K.*; WAGGONER, C.; REYES, J.A.; FAIREY, R.; KELLEY, K.M.; California State University, Long Beach, Pacific Coast Environmental Conservancy [pceconservancy.org], Moss Landing Marine Laboratories; *kmkelley@csulb.edu*

***Evidence for Thyroid Endocrine Disruption in Wild Fish in San Francisco Bay. Relationships to Contaminant Exposures.***

It is well documented that many coastal and estuarine environments adjacent to developed, industrialized urban centers, such as the San Francisco Bay Area, are significantly contaminated by human-derived chemicals. However, it is not well understood to what extent existing contaminants, many with continuing inflows into the environment, may impact exposed wildlife. This study characterized thyroid endocrine-related effects and their relationship to accumulated contaminants in two indigenous fish species sampled from different SF Bay study sites. Plasma concentrations of thyroxine (T4) were significantly reduced in fish sampled from highly impacted locations such as Oakland Inner Harbor and San Leandro Bay as compared with fish from other locations representing relatively lower human impact, including Bodega Bay, Redwood City and Catalina Island. Triiodothyronine (T3) also exhibited significant location-associated changes, with increased T3/T4 ratios in fish from some locations suggestive of enhanced peripheral 5'-deiodinase activity. The alterations in thyroid endocrine parameters were significantly correlated with hepatic concentrations of environmental contaminants, particularly PCBs, which were inversely correlated with T4 but positively correlated with T3 and T3/T4 ratio. Some relationships between chlorinated pesticides, but fewer relationships with PAHs, were also observed. These findings suggest that the fish thyroid endocrine system may be disrupted in SF Bay, which is significantly related to exposures of the fish to contaminant chemicals such as PCBs.

***59.5*** BRASHEARS, J.A.*; DENARDO, D.F.; Arizona State University; *jake.brashears@asu.edu*

***Hormonal correlates accompanying reproductive behavior in three species of python***

Parental care, while ubiquitous among mammals and birds, is also common in ectothermic vertebrates. The examination of parental care across major taxa sheds light on the physiological context within which it evolves. Pythonidae offers a unique opportunity to study parental care due to the interspecific variation in the complexity of parental behavior found within the family. To date, little is know about the hormonal mechanisms that are involved in the expression of parental care of ectotherms. We determined hormonal levels of 4 sex steroids – estradiol, progesterone, testosterone, and corticosterone - as well as free thyroxine during three reproductive stages: non-reproductive, gravid, and brooding.

***6.5*** BRAYER, KJ*; LYNCH, VJ; WAGNER, GP; Yale University; *kathryn.brayer@yale.edu*

***Evolution of physical interactions between transcription factors HoxA-11 and FOXO1A: thinking beyond cis-regulation.***

The cis-regulatory paradigm attributes evolutionary novelty to changes in non-coding DNA sequences. According to the theory, changes in DNA sequence affect the ability of transcription factors to bind regulatory regions leading to changes in gene regulation and novelty. While not incorrect, this theory is limited as it ignores evolutionary change in the transcription factors themselves, thereby ignoring changes that affect DNA binding and interactions with other transcription factors, co-factors, and signaling molecules. Here, we examine the functional evolution of transcription factors involved in the decidualization of endometrial stromal cells, a critical step in the successful establishment of pregnancy. Although the molecular mechanisms that regulate decidualization are poorly understood, the importance of decidual prolactin expression, a derived characteristic of Eutherian mammals, has long been recognized. In humans and many other primates decidual prolactin expression is regulated by a tissue specific promoter comprised of two transposable elements, MER20 and MER39, located upstream of the transcription start site. MER20 contains binding sites for numerous transcription factors, including HoxA-11 and FOXO1A. Recently, we observed phylogenetically derived protein-protein interactions between these two transcription factors in mammals; however, the derived functional interaction, resulting in upregulation of expression from the MER20 promoter, is restricted to Eutherian mammals. Here we examine the evolution of physical interactions between ancestral and derived HoxA-11, FOXO1A and MER20 by testing whether the derived functional interaction involves novel or stronger binding affinity among the molecules or whether it also includes a derived transcriptional activity by the transcription factor proteins. Implications for the evolution of prolactin regulation will be discussed.

***S10.10*** BREITBURG, DL; Smithsonian Environmental Research Center; *breitburgd@si.edu*

***Ecosystem engineers in the plankton - habitat alteration by species from microbes to jellyfish***

Ecosystem engineers are species that alter the physical environment in ways that create new habitat or change the suitability of existing habitats for themselves or other organisms. In marine systems, much of the focus has been on species such as corals, oysters and macrophytes that add physical structure to the environment. But planktonic organisms ranging from microbes to jellyfish and finfish alter the chemical and physical environment both within the water column and on the benthos. By causing hypoxia, changing light regimes, and influencing physical mixing, these organisms may have as strong an effect as species that fall more clearly within the classical category of ecosystem engineer. In addition, planktonic species such as jellyfish may indirectly alter the physical environment through predator-mediated landscape structure. By creating spatial patterns of habitats that vary in their rates of predation mortality, planktonic predators may control spatial patterns and abundances of species that are the direct creators or modifiers of physical habitat.

***87.8*** BREVES, J.P.*; WATANABE, S.; HELMS, R.; KANEKO, T.; HIRANO, T.; GRAU, E.G.; Univ of Hawaii, Univ of Tokyo; *breves@hawaii.edu*

***Chloride cell differentiation in Mozambique tilapia: roles of prolactin, growth hormone and cortisol***

A series of hypophysectomy (Hx) and hormonal replacement therapy experiments were conducted to characterize the regulation of branchial chloride cell (CC) differentiation in Mozambique tilapia (*Oreochromis mossambicus*). In tilapia, a recently identified $Na^+/Cl^-$ cotransporter (NCC) is specific to freshwater (FW)-type CCs, while seawater (SW)-type CCs specifically express a $Na^+/K^+/2Cl^-$ cotransporter (NKCC). NCC and NKCC therefore provide markers for the presence of CCs tied to ion absorptive and secretive processes, respectively. First, we assessed the effect of Hx on mRNA levels of these ion transporters in the gill during acclimation to both FW and SW. In both salinities, Hx markedly reduced NCC gene expression when compared with sham-operated controls; no effect of Hx on NKCC was evident. In FW, NCC expression was restored in Hx fish by treatment with ovine prolactin (oPRL) alone or in combination with cortisol; there was no effect of cortisol alone. In contrast, expression of NKCC was stimulated by cortisol, an effect that was attenuated by co-treatment with oPRL. In SW, cortisol and ovine growth hormone showed no clear actions on NKCC expression. Taken together, our findings suggest that the hyperosmoregulatory actions of PRL derive from its ability to simultaneously stimulate NCC expression (ion absorption) and inhibit NKCC (ion extrusion) and that the recruitment of SW-type CCs does not necessarily require pituitary control in this euryhaline tilapia. Supported by NSF (IOB05-17769), USDA (2008-35206-18785) and the Pauley Foundation.

***64.3*** BRIDGE, E. S.*; KELLY, J. F.; BJORNEN, P. E; CURRY, C. M.; CRAWFORD, P. H. C.; PARITTE, J. M.; University of Oklahoma Center for Spatial Analysis, Oklahoma Biological Survey, University of Oklahoma Department of Zoology; *brid0030@tc.umn.edu*

***Effects of Nutritional Condition on Migration: Do Dark-Eyed Juncos Use Resource Availability to Keep Pace with a Changing World?***

Because of their reliance on temporally predictable resources across large spatial scales, migratory birds may be especially vulnerable to anthropogenic climate and land-use changes. Although some long-distance migrants appear unable to adjust to phenological shifts on their wintering grounds, several short- and medium-distance migrants appear to have altered the timing and/or distance of their yearly movements to compensate for the environmental effects of global warming. Which environmental cues are responsible for stimulating these adjustments is an open question, although most studies have focused on weather conditions. In this study, we present a novel field experiment that demonstrates an alternative cue, food availability, may be a critical link between local conditions on the wintering grounds and the timing of spring departure. We captured free-living Dark-eyed Juncos (*Junco hyemalis*) and held some individuals captive for 5 to 7 days during which they were fed either an *ad libitum* diet consisting of a variety of foods or a restricted diet limited to 3g of millet per day. We then released these birds and initiated daily resighting surveys to determine when individuals left the study area (i.e., began migration). Juncos given an abundant food supply demonstrated advanced spring migration, and this was especially apparent among individuals with the most pronounced increases in mass and fat stores. This finding indicates a simple mechanism by which short-distance migrants may calibrate their migration behavior such that arrival on the breeding grounds and initiation of reproduction are in sync with resource availability.

***87.7*** BRIDGHAM, J.T.*; ORTLUND, E.A.; THORNTON, J.W.; Univ. of Oregon, Eugene, Emory University School of Medicine, Atlanta, GA, Howard Hughes Medical Institute, Univ. of Oregon, Eugene; *jamieb@uoregon.edu*

***Molecular Evolution of Mineralocorticoid Receptor - Hormone Interactions***

Mineralocorticoid receptors (MRs) in mammals are activated by the hormone aldosterone whereas MRs of teleosts are activated by deoxycorticosterone. In order to examine the evolution of these specific interactions between MRs and their hormones, we use a combination of techniques of molecular endocrinology, phylogenetics, and crystallography. We first characterize receptors isolated from extant species, and use molecular phylogenetic techniques to infer the sequences of ancestral receptors of the MRs, then resurrect and functionally characterize these ancestral receptors. Our results reveal a promiscuous ancient receptor that was activated by the mineralocorticoids aldosterone and deoxycorticosterone as well as cortisol. The MR-aldosterone partnership therefore evolved through a process of molecular exploitation, where the structure of the receptor was already capable of being activated by aldosterone before the enzymes to produce this hormone evolved. By characterizing MRs from multiple vertebrate species including agnathans, elasmobranchs, teleosts and tetrapods, we show that MRs lost activation by deoxycorticosterone and cortisol and became more specific for aldosterone once the enzymes to synthesize the hormone evolved.

***67.10*** BRIGHAM, Christy; BOWMAN-PRIDEAUX, Chris*; SCHIFFMAN, Paula; National Park Service, SAMO, CSU, Northridge; *cmb24722@csun.edu*

***Intersite Variation in the Endangered Plant, Astragalus brauntonii (Fabaceae)***

Local adaptations occur as a result of selection pressures on isolated populations where gene flow is restricted or non-existent. When this happens, adaptations beneficial in one location may be detrimental to other populations. *Astragalus brauntonii* is an endangered species threatened by land use change. It is currently found in isolated patches through out the foothills surrounding the Los Angeles Basin. Understanding whether populations have developed local adaptations is essential for determining future management of the species. Using demography studies and common gardens, 6 populations of *A. brauntonii* were compared. Demographic studies indicate significant differences in a number of physical and reproductive characters despite little difference in stand age. Fecundity differed significantly as did germination rates. These findings suggest that the populations are distinct and care should be taken in management of the species to take into consideration these differences with more emphasis on certain populations.

***S5.7*** BROCKES, Jeremy P; UCL; *j.brockes@ucl.ac.uk*
***Evolution of mechanisms underlying limb regeneration in salamanders***
The most extensive regenerative ability among adult vertebrates is found in various species of salamander. In our work on the mechanism of limb regeneration we have identified a protein called Prod 1 which seems to be central to certain aspects of pattern formation, in particular proximodistal identity. We identified a secreted protein ligand for Prod 1 called nAG which seems to be central to the nerve dependence of regeneration. Prod 1 is a GPI anchored protein which signals to cells in part by interacting with the EGF receptor. The EGFR and nAG are familiar examples of well conserved 'old' proteins found in all vertebrates. By contrast, Prod 1 is a salamander specific protein which does not have a mammalian or zebra fish orthologue. It belongs to the 3 finger protein superfamily which takes up a versatile structure, a superfold, that can be accessed by many different postions in amino acid sequence space. 3FPs can be identified by the stereotyped spacing of 8 or 10 cys residues forming disulfide bonds. There are some striking examples of local evolutionary change which depend on the expansion and diversification of members of this family, for example the evolution of the venom apparatus in elapid snakes. I will review our data on Prod 1 which suggests a new view of salamander regeneration that emphasises such local evolutionary change. The salamander has 'slotted in' a new protein to interact with several old proteins and orchestrate their activities. It seemed unlikely to be the only such case, and this led us to identify another locally expanded group of 3FPs which also includes members that are involved in limb regeneration.

***S2.10*** BRONIKOWSKI, Anne; Iowa State University; *abroniko@iastate.edu*
***Physiological Evolution in Natural Populations of Snakes with Divergent Lifespans, but Negligible Senescence***
Reptiles are an underutilized model for studying the biology of senescence; the existence of negligible senescence in many reptile species suggests that their study could provide intriguing insights into the biology of "not aging." Long-term studies of natural populations of garter snakes combined with laboratory manipulative experiments will be discussed. Specifically, populations of garter snakes (Thamnophis elegans) in the Sierran Nevada range are differentiated along a slow/fast pace-of-life continuum. Individuals either: grow slow, reproduce late, and live many years; or they grow fast, reproduce early, and have short lifespan. I will present results on the sources of mortality in the wild that have likely moulded their respective life-histories. And I will provide detailed results of physiological experiments in the laboratory that reveal that the long-lived phenotype has evolved better resilience to oxidative and other stresses

***29.1*** BROWN, FD*; KEELING, EL; LE, AD; SWALLA, BJ; University of Washington, Seattle; Universidad de los Andes, BogotÃ¡, University of Washington; California Polytechnic State University, San Luis Obispo, University of Washington, Seattle; *federico.brown@tuebingen.mpg.de*
***Bloody Whole Body Regeneration!***
Colonial ascidians exhibit one of the most extreme cases of regeneration. Upon removal of all individuals in a colony of *Botrylloides violaceus*, the vascular network and blood left within the tunic of the colony reorganizes, and aggregates of blood differentiate into buds. One of these buds continues to complete regeneration of a whole individual. Using phase contrast microscopy, time-lapse video recording and detailed histological studies of regenerating colonies, we describe the earliest events of regeneration. We examine the pattern of cell proliferation by immunohistology using proliferating cell nuclear antigen (PCNA) antibodies. Next, we report the expression of *piwi*, a stem cell maintenance marker involved in microRNA processing and stem cell maintenance, in hemocytes surrounding the early regenerates. We rarely found Piwi or PCNA in differentiating tissues during vascular budding, suggesting that cells that form the epithelial tissues during budding and regeneration originate mostly from circulatory hemocyte precursors, and likely include stem cell progenitors. First attempts to establish lineage tracing are now in progress. Preliminary results using the nuclear stain DAPI (<360 nm excitation range to avoid endogenous autofluorescence) show that it can be reliably followed in the colony up to a month after labeled hemocyte injection. We find DAPI labeled cells integrate into tissue epithelia of different germ layers. Taken together, we propose that multiple stem cell types occur within the hemocytes, and that they undergo proliferation in the vasculature before differentiating into epithelial tissues.

***38.11*** BRYER, PJ*; DAVIS, BL; SUTHERLAND, MA; Lamar University, Beaumont TX, Texas Tech University, Lubbock TX, AgResearch, Hamilton NZ; *pamela.bryer@lamar.edu*
***Science based criteria for assessing humane euthanasia***
Humane methods of on-farm euthanasia are currently a topic of interest both for producers and the public. There are many different views on what is considered humane euthanasia. Clear, objective, and measurable assessment endpoints that indicate distress and pain are needed to compare and contrast existing and developing euthanasia methods. The AVMA says inhalation of gases is one of the most humane euthanasia methods and is used extensively in laboratory animals. We euthanized piglets ranging from 1 to 6 weeks old using a 100% $CO_2$ gradual-fill protocol (n=5/ wk). An additional group of 3 week old pigs (n=5) were euthanized via a 100% $CO_2$ pre-fill protocol. Behaviors associated with asphyxiation, escape, and consciousness were recorded. Blood was collected before and after death for plasma cortisol. Older pigs took longer to sense the $CO_2$ gas due to their taller height. After the initial gas sensing however, age did not influence the onset of any behaviors or timing of death. Pre-fill pigs showed consistently shorter intervals to unconsciousness and death. Cortisol concentrations rose dramatically in all pigs following euthanasia ($t=1.69$, $df=34$, $p<0.0001$). Age did not effect the cortisol response to euthanasia ($p= 0.08$, $r^2= 0.10$). Pre-fill pigs had a lower cortisol increase than similarly aged gradual-fill pigs ($t=2.78$, $df=4$, $p=0.049$). Age did not appear to affect pigs' responses to 100% $CO_2$ gas. Pre-filling the chamber decreased the amount of time to unconsciousness and to death; this in turn may have contributed to lower cortisol levels. These results indicate that the more intense pre-fill chamber experience may ultimately be more humane because of the shorter period of suffering.

***81.4*** BRZĘK, P; CAVIEDES-VIDAL, E; KARASOV, W.H.*; Univ. of Bialystok, Poland, Univ. of San Luis, Argentina, Univ. of Wisconsin, Madison; *wkarasov@wisc.edu*

***House sparrow fledglings leave the nest digestively immature but more flexible than adults***

Young altricial birds may leave the nest before completion of their development. However, the relative level of their physiological maturity, including digestive function, is almost unknown. In some species, development is also concurrent with gradual change in diet type, e.g. from insect- to seed-dominated diet in House sparrow (*Passer domesticus*). We compared digestive function and its plasticity in adult House sparrows with those of nestlings about fledging age (12 days). Fledglings had lower intestinal disaccharidase activity and lower glucose absorption rate than adults, which correlates with fledglings' lower maximal rate of energy assimilation. However, in contrast to adults, nestlings and fledglings were able to modulate tissue-specific activity of intestinal disaccharidases in response to varying diet starch content. We conclude that House sparrow fledglings are still not fully digestively mature, which could limit their ecological performance. On the other hand, nestlings have a capacity for diet-induced modulation of mass-specific activity of intestinal enzymes that is lost sometime between fledging and adulthood. We hypothesize that this ontogenetic decrease in the level of plasticity results from both the lack of necessity (completed diet switch) and presumably from costs involved in maintaining the capacity for such plasticity. Supported by NSF IOS 0615678 to WHK.

***53.4*** BUCKLEY, David; WAKE, Marvalee H.; WAKE, David B.*; Univ. of California, Berkeley; *wakelab@berkeley.edu*

***Comparative Skull Morphology of Karsenia koreana (Amphibia, Caudata, Plethodontidae)***

*Karsenia koreana* is the only Asiatic representative of the salamander family Plethodontidae. Its recent discovery challenged our understanding of the biogeographic history of the family, which otherwise is distributed in the New World with a few European species. Molecular studies suggest that *Karsenia* forms a clade with *Hydromantes (sensu lato)* , which includes among its species the only other Old World plethodontids. Morphologically, *Karsenia* closely resembles *Plethodon*. We studied the skull of *K. koreana* and compared it to that of other plethodontines. No clearly autapomorphic states were detected, and no synapomorphies can be found that would link it to other genera. The *Karsenia* skull is cylindrical and well ossified, giving an impression of strength. In contrast, the skull of *Hydromantes* is highly derived; the skull is flattened and the bones are weakly ossified and articulated. *Hydromantes* and *Karsenia* share no unique anatomical features; differences between them are especially evident in the hyobranchial skeleton, which is generalized in *Karsenia* but highly modified in *Hydromantes*, a clade well-known for its highly projectile tongue. *Plethodon* and *Plethodon*-like species, including *Karsenia* and to a lesser degree *Ensatina*, represent the more generalized and apparently ancestral plethodontid morphology. Specialized morphologies in plethodontids have evolved along only a few morphological axes, resulting in a pattern of rampant homoplasy. Our analysis of the anatomy of the new Asiatic lineage illuminates some potential mechanisms underlying adaptive morphological evolution within the Plethodontidae. Research supported by NSF AmphibiaTree program (EF-0334939).

***S8.6*** BUDD, A.F.; University of Iowa; *ann-budd@uiowa.edu*

***Rethinking the phylogeny of scleractinian reef corals: reconciling morphologic and molecular data in the families Faviidae and Mussidae***

Recent molecular phylogenies conflict with traditional scleractinian classification at ranks from suborder to genus, challenging morphologists to discover new characters that better agree with molecular data. Such characters are essential for including fossils in analyses and tracing evolutionary patterns through deep time. The present study evaluates traditional macromorphological characters and newer micromorphological and microstructural characters in 5 related families including Faviidae and Mussidae (more than1/3 of reef-building genera). Previous molecular analyses show that the 5 families are not monophyletic, but consist of 7 family-level clades, with one clade composed only of Atlantic faviids and mussids. Comparisons of Atlantic mussids and faviids with their Pacific counterparts show that: (a) the septal teeth of Atlantic mussids are formed by well-developed secondary calcification axes with limited thickening deposits, whereas the teeth of Pacific mussids are formed by weak secondary axes with extensive thickening; (b) the septal teeth of Atlantic faviids have transverse axes that cross the main septum axis, whereas the teeth of Pacific faviids are often multi-directional; (c) corallite walls in Atlantic faviids are mostly septothecal, whereas walls in Pacific faviids are trabeculo- or parathecal. Development of secondary axes are similar in Atlantic faviids and mussids. Phylogenetic mapping of morphologic characters on molecular trees indicate that micromorphological and microstructural characters are diagnostic of clades and subclades, but macromorphologic characters are not. Phylogenetic trees constructed using new micromorphologic and microstructural characters have relatively high bootstrap support, and are congruent with molecular trees.

***5.5*** BUDKE, J.M.; University of Connecticut; *jessica.budke@uconn.edu*

***Examining the gametophytic calyptra and its role in moss sporophyte development using the cord moss (Funaria hygrometrica).***

In bryophytes (mosses, liverworts and hornworts) the diploid sporophyte is small, unbranched, and physically attached to the maternal haploid gametophyte. One of the major maternal influences in moss plants is a cap of gametophyte tissue (the calyptra) that covers the sporophyte's apex during early developmental stages. Previous studies indicate that the calyptra functions mechanically to influence sporophyte development and is necessary for spore formation. Sporophytes without their calyptra wilt at the apex; they survive only when placed in a high humidity chamber. These observations stimulated the hypothesis that the maternally derived calyptra functions as a waterproof cap, preventing desiccation of the developing sporophyte's apex. In plants the cuticle, an external layer of lipids and waxes, maintains internal hydration. To explore this hypothesis, I am using scanning and transmission electron microscopy to examine cuticle morphology and development of both the calyptra and sporophyte in the moss *Funaria hygrometrica*. Results for this species indicate that the calyptra's cuticle is thicker and more complex than other gametophyte tissues; the cuticle is also present on the calyptra throughout sporophyte development. These observations support the calyptra as a specialized maternal gametophyte structure and provide a mechanism by which the calyptra prevents harmful water loss during critical sporophyte developmental stages. Sporophyte development is directly related to reproductive output and thus evolutionary fitness in mosses. The material care provided by the calyptra and its cuticle may have been a critical innovation for the evolutionary success of the ~12,500 moss species worldwide. This research is supported by a 2009 AMS Student Research Fellowship.

***76.4*** BUEHLER, Deborah M*; TIELEMAN, B. Irene; PIERSMA, Theunis; Royal Ontario Museum, University of Groningen; *d.buehler@utoronto.ca*

***Variation in constitutive immune function in a long distance migrant shorebird during migratory stopover in Delaware Bay***

Delaware Bay, USA, is used by thousands of shorebirds as a final stopover site before migration to breeding areas in spring. The bay provides them with abundant food, horseshoe crab (*Limulus polyphemus*) eggs, which they use to lay down fat stores necessary for continued migration and subsequent survival on the breeding grounds. However, abundant food attracts dense mixed-species flocks, which may facilitate pathogen transmission, while migration itself may suppress immune defense. Despite the potential importance of disease risk and immune function during migration, little is known about how immune function changes during stopover in migratory shorebirds. To examine this, we measured constitutive immune function in Red Knots (*Calidris canutus rufa*) during stopover in Delaware Bay. We found lower total leukocyte, lymphocyte and monocyte concentrations, complement-mediated lysis, and haptoglobin activity in birds recovering protein after migration than in birds laying down fat as fuel for subsequent flight. We discuss two possible reasons for this result. First, fueling birds may have an increased rate of infection or be bolstering immune defense in response to high antigen exposure. Second, recovering birds may be immunocompromised due to the physical strain of migratory flight or due to adaptive trade-offs between immune function and migration.

***58.1*** BULLOCK, J. M. R.*; CLEMENTE, C. J.; FEDERLE, W.; University of Cambridge ; *jmrb3@cam.ac.uk*

***Pushing and pulling: beetles use different tarsal pads to walk and climb***

Many species of leaf beetle have evolved the ability to run and climb on smooth surfaces and do so using sets of highly specialised adhesive pads. Each leg supports three such pads, which consist of arrays of adhesive hairs (setae) and differ in morphology, both between the sexes and between pads on the same leg. Here we investigate in dock beetles (*Gastrophysa viridula*) the effect of this variation in seta structure on the mechanical and adhesive properties of the pads. To determine the effective elastic modulus of the arrays, we vertically compressed individual adhesive pads. Distal adhesive pads were significantly softer than middle and proximal ones. Attachment performance was then measured during shear movements and pull-offs from various substrates. Consistent with their greater compliance, distal pads generated higher adhesion and friction on rough substrates. However, the greater stiffness of proximal pads conveyed a superior ability to push. Proximal pads were less direction-dependent than distal pads and generated larger pushing forces in the distal and lateral directions. Locomotion recordings of vertically climbing beetles confirmed that each pad was used differently. When legs above the body centre of gravity were pulling, beetles mainly engaged the distal pads, whereas legs below the body mainly pushed with the proximal pads. We confirmed our findings in flea beetles that have to generate large pushing forces for jumping. While distal pads are used to adhere to smooth substrates, only the proximal pads push when the beetles accelerate for a jump. Our findings demonstrate that there is a division of labour between different adhesive pads on the same tarsus.

***S4.2*** BURGERT, I*; FRATZL, P; Max Planck Institute of Colloids and Interfaces, Potsdam, Germany; *ingo.burgert@mpikg.mpg.de*

***Plant Movement Mechanisms - Cell Wall Architectures Enable Actuation without Muscles***

Plants are able to adjust the mechanical properties of their tissues to cope with external stresses, and they even generate internal stresses and actuate organ movements. Due to their hierarchical organization, it is mainly the specific cell wall assembly which affects the mechanical performance of the material. By arranging and adapting the orientation of cellulose microfibrils in the cell walls, plants are able to control and to adjust the mechanical properties of their tissues. Moreover the direction of cellulosic fibrils plays a crucial role for internal stress generation and organ movement. The movements of seed dispersal units upon humidity changes are controlled by the architecture of the stiff cellulose fibrils embedded in a swellable matrix. Some impressive examples are pine cones and wheat awns. The fibril design is also explaining the origin of growth stresses in reaction wood of softwoods. Indeed, the microfibril angle by which the cellulose fibrils spiral around the cell lumen controls the anisotropic swelling of the cell wall and, thus, the generation of directed strains and stresses leading to complex bending or torsional movements. Finally, we report on the crucial role of an additional cell wall layer, the so called G-layer, which can be found in leaning stems and branches, in tendrils and contractile roots of a large variety of species. This G-layer consists of almost pure axially oriented and swellable cellulose which enables the plant to generate much higher longitudinal tensile stresses in the G-fibers than in regular fibers. All these examples show the incredible versatility of a system, based on oriented cellulose fibrils in a matrix swelling or shrinking with (ambient) humidity, in constructing actuators providing motility or compensating for external loads.

***9.3*** BURNAFORD, J.L.; California State University Fullerton; *jburnaford@fullerton.edu*

***Slow recovery or community shift? Assessing the long-term effects of kelp canopy removal in the rocky intertidal zone.***

*Saccharina sessile* is a stipeless canopy-forming kelp that forms extensive beds in the low rocky intertidal zone of the Pacific Northwest. In 1998, to evaluate the effects of the *S. sessile* canopy on community structure, I removed all individuals from twenty $1m^2$ plots at Pile Point, San Juan Island, WA. For the duration of this 2-year study, I continually removed *S. sessile* recruits in the plots. Community structure in treatment plots was compared with five $1m^2$ control plots in which the *S. sessile* canopy was not manipulated. In 1998 before the start of the study, all plots had at least 70% canopy cover of *S. sessile*, with an average cover of 73%. Following termination of the experiment in 2000, no further manipulations were conducted in any of the 25 study plots. In 2008 and 2009, I re-surveyed plots to assess their recovery from this long-term canopy removal. In 2008, only one of twenty treatment plots had reached pre-removal *S. sessile* cover levels, and average cover in the treatment plots was 31%. Comparisons of community structure in treatment plots in 2008 and 1998 show substantial differences, including an increase in the abundance of the canopy-forming mid-intertidal alga *Fucus distichus* from an average of 0.1% cover in 1998 to an average of 12.1% cover in 2008. Across the treatment plots in 2008 and 2009, *F. distichus* cover was negatively correlated with *S. sessile* cover. Canopy dynamics also shifted in un-manipulated areas, with an average drop in canopy cover in control plots of more than 23% since 1998. Determining whether these changes represent natural fluctuations and slow recovery in the *S. sessile* population or a larger shift in community structure will be the topic of ongoing study.

***32.5*** BURNETTE, M.F.*; GIBB, A.C.; Northern Arizona University; *morgan.burnette@nau.edu*

***Feeding behavior and jaw kinematics in Ptychocheilus lucius, an endangered, cyprinid piscivore.***

Prey capture in piscivorous fishes is thought to be restricted by two factors: the body depth of the prey and the size of the predators mouth gape; previous studies have established the optimal prey depth to predator gape ratio as 0.4-0.7. In this study we investigate feeding behavior of the endangered Colorado pikeminnow, *Ptychocheilus lucius*, historically the top predator in the Colorado river and its tributaries. Our overarching goal is to track changes in gape and prey capture behavior across development to determine at what age and size juvenile pikeminnow are capable of capturing native and/or introduced fish species. Study animals were obtained from Bubbling Ponds Native Fish Hatchery in Cornville, Arizona as very young juveniles and reared in captivity at Northern Arizona University. High-speed digital-imaging was used to record feeding trials: foods offered to animals during these trials included frozen red mosquito larva, frozen *Artemia*, and live juvenile poecilids. Preliminary results suggest that the upper limit for the prey depth: gape ratio is approximately 0.7 (that is, live prey that exceeded 0.7 of the predators gape were not consumed). Consequently, fish smaller than 38 millimeters are incapable of taking juvenile poecilids, which are among the smallest juvenile fish present in the Colorado. By tracking behavioral changes in *P. lucius* as it transitions from a non-piscivorous to a piscivorous life history stage, we hope to provide information that may aid in the management and recovery of this imperiled species.

***36.3*** BUSCH, D. S.*; ROBINSON, T. R.; ROBINSON, W. D.; WINGFIELD, J. C.; NOAA - Northwest Fisheries Science Center, Oregon State Univ., Univ. of California, Davis; *shallinbusch@gmail.com*

***Living on the edge: does proximity to a geographical range boundary influence physiology in tropical song wrens (Cyphorhinus phaeocephalus)?***

A species' geographic range can be limited by a variety of biotic and abiotic factors. We studied the physiology of the song wren (*Cyphorhinus phaeocephalus*) along a rainfall-induced habitat gradient across the Isthmus of Panama, searching for a physiological signature of the species' range edge. We measured body condition, hematocrit (% packed red blood cells in a given blood sample), and corticosterone levels (CORT, a steroid hormone that regulates the availability of energy and the stress response) in males and females. To lure our study subjects into mistnets for capture, we used recorded conspecific song (playbacks). We found that birds living in drier habitat near the range edge were significantly more likely to have abnormally low hematocrit scores. In one of our four PATH models, baseline CORT levels were negatively associated with rainfall, indicating potential energetic challenge or possibly chronic stress in some individuals. Body condition was positively correlated with rainfall; birds with the poorest body condition lived at the dry end of the gradient. Birds with better body condition and low baseline CORT levels were captured more quickly and, thus, exposed to conspecific playback for a shorter duration. Stress-induced CORT levels correlated significantly with sex only, being higher in females. Our results indicate a link among an environmental gradient and baseline CORT levels, body condition, response to playback, and hematocrit. Given the nature of the direct and indirect relationships in our data, we advocate the need for integrative studies that consider abiotic, behavioral, and physiological variables to better understand factors influencing the distribution of birds.

***72.3*** BUTLER, MW*; MCGRAW, KJ; Arizona State University; *Mike.Butler@asu.edu*

***Immunological perturbations during neonatal development reduce immunocompetence and body mass in adult mallards***

Perturbations during the neonatal stage of development can shape adult phenotype and fitness. In particular, immune challenges during ontogeny can affect adult body size, immunocompetence, and expression of sexually selected traits. We tested how immune challenges at different stages of development affected adult characteristics in mallard ducks (*Anas platyrhynchos*). Mallards are ideal for this line of work because (1) they are easy to rear in the lab independent from post-hatch parental input, (2) there are commercial antibodies available for quantifying immune responses, and (3) males have carotenoid-pigmented bills that reflect immunocompetence are used in mate choice. Besides acting as pigments, carotenoids also enhance immunoresponsiveness and may act as antioxidants, thus forming a potential mechanistic link between early-life immune response and adult sexually selected traits. In a lab experiment, we found that immune challenges (three weekly injections of sheep red blood cells) issued when male ducklings had finished the linear phase of growth resulted in a decreased cutaneous immune function (as assessed by a phytohemagglutinin challenge) when those individuals were sexually mature adults (18 weeks of age). These birds also exhibited lower body mass at adulthood. Individuals who had received immune challenges during the period of linear growth or while molting into adult plumage did not differ from controls in any of the above metrics. Also, beak coloration was not affected by any developmental immune challenges. Therefore, we found evidence that immune challenges during one stage of neonatal development affected survival (e.g., immunocompetence, size), but not reproductive (e.g., sexual coloration), traits in mallards.

***38.7*** BUTLER, L.K.*; HAYDEN, T.J; ROMERO, L.M.; The College of New Jersey, Engineering Research and Development Center, Tufts University; *lbutler@tcnj.edu*

***Environmental and life-history correlates of glucocorticoid physiology in an arid-country bird***

We investigated hypothalamic-pituitary-adrenal axis activity in a free-living migratory songbird that exhibits an uncommon suite of environmental and life-history traits. Painted Buntings at our study site in Texas breed in areas altered heavily by human activity, and in areas relatively undisturbed by people. Male Painted Buntings show striking delayed plumage maturation, with males in their first breeding season appearing drab green and nearly identical to females, and older males exhibiting an unmistakable bright red and blue plumage. Accordingly, males usually do not breed in their first season on the breeding grounds. Finally, unlike most temperate migratory songbirds, Painted Buntings at our study site in Texas do not molt on the breeding grounds after breeding, but molt only after migrating to special molting grounds in the Mexican monsoon region. We compared baseline and stress-induced corticosterone concentrations between disturbed and relatively undisturbed habitats; between first year and older males; and between the start and end of the breeding season in Texas. We used these intra- and interspecific contrasts to address how glucocorticoids help animals cope with predictable and unpredictable challenges from the environment.

***25.5*** BUTLER, MA*; SCALES, JA; University of Hawaii; *mbutler@hawaii.edu*

***Effects of load and reproduction on locomotor performance in the lizard Iguana iguana***

One demand placed exclusively on females is maintaining locomotor performance during the large increase in mass as females produce offspring or eggs (gravidity). Since the females of many taxa carry large reproductive loads, often repeatedly throughout life, this is a widespread and potentially important selective pressure that has received comparatively little study. Are females designed for the gravid state, implying that their musculoskeletal systems are overengineered for the majority of the year? Or alternatively, do they suffer a great performance decline when they are gravid? In addition, what happens when they are immediately post-gravid if their body wall is greatly stretched during reproduction? Reproduction sometimes results in reduced locomotor performance, but it is unclear whether performance is affected by load (mass) or the physiological changes associated with carrying an internal load. Green iguanas (*Iguana iguana*) are excellent runners and carry very large clutches ranging from 31% to 63% of their nongravid mass. We compared performance in gravid and post-gravid iguanas experiencing natural reproductive cycles with iguanas implanted with artificial loads. The implants were filled with saline, mimicing pregnancy (volume + mass), with air (volume) or empty (no mass, reduced volume). We report the changes in performance in velocity, acceleration, and force production.

***61.1*** BYWATER, C.L.*; WILSON, R.S.; The University of Queensland; *c.bywater@uq.edu.au*

***Costs and benefits of unreliable signalling in males of the two-toned fiddler crab (Uca vomeris).***

Many species possess exaggerated secondary sexual structures which are used for signalling during mate attraction and pre-fight assessment. Signals are either reliable, where information about underlying quality is accurately conveyed to the receiver or unreliable, where signallers send inaccurate information. Theoretical models predict that reliable signals should be more prevalent in nature, as a purely unreliable system would collapse due to the redundancy of the signal. However, documented cases of naturally occurring unreliable signals are becoming more frequent with unreliable signallers present in much greater numbers than predicted. Understanding the costs and benefits of unreliable signals of strength are critical to theoretical models, but these have not been fully established, nor has it been ascertained whether unreliability is a condition-dependant strategy. The fiddler crab is an ideal system for studying unreliability as males possess a greatly enlarged claw used for displaying during mate attraction and male-male combat. We first determined the relationship between claw size and strength for 120 individual male two-toned fiddler crabs (*Uca vomeris*) to identify reliable and unreliable signallers. We then assessed the competitive ability of each individual male and their attractiveness to females in the field to determine the social benefits and costs of unreliable signals. Finally, we tested each individual's sprint speed and endurance before and after major-claw removal to determine the relationship between an individual's condition and their signal reliability. We will discuss the costs and benefits of unreliable signals for male *U. vomeris* and their implications for signalling theory.

***62.3*** CAHILL, A.E.*; CRICKENBERGER, S.; CRIM, R.N.; SELDEN, R.L.; Stony Brook University, Clemson University, University of British Columbia, University of California, Santa Barbara; *acahill@life.bio.sunysb.edu*

***Dispersal limitation and post-settlement survival of an introduced ascidian (Botrylloides violaceus) in San Juan Islands, WA***

Distributions of introduced species are often patchy; however, the mechanisms regulating these patchy distributions are poorly understood. Sessile organisms with short-lived larvae provide an opportunity to test whether these distributions are dispersal-limited or determined through post-metamorphic survival and growth. Here we used the non-native colonial tunicate *Botrylloides violaceus* to examine the roles of dispersal and predation in determining its distribution by transplanting recently settled juveniles to locations with and without adult *B. violaceus* colonies. Survival and growth were not different between caged and uncaged treatments at any site, suggesting that predation is not controlling the distribution of this species. However, survival and growth were different among locations. One site without established colonies had significantly lower growth and survival than all others, suggesting the importance of abiotic factors at this site. The other site where adults were absent had similar growth and survival to sites with established colonies, indicating that dispersal limitation is more important at this site than abiotic factors. Our study suggests that the distribution of *B. violaceus* is limited by both dispersal and environmental conditions that affect juveniles after settlement.

***46.2*** CAIN, KRISTAL E*; RICH, MIRIAM S; DAPPER, AMY L; KETTERSON, ELLEN D; Indiana University, Swarthmore College; *caink@indiana.edu*

***Trade-offs between aggression and parenting in female birds: what's testosterone got to do with it?***

Males exhibiting parental care generally express an inverse relationship between effort (amount of time, energy, and/or resources) devoted to mate acquisition, and effort devoted to rearing offspring. Testosterone (T) is thought to mediate this trade-off because males with experimentally elevated testosterone (T) often invest more in mate acquisition and less in parenting. A recent study confirmed this relationship in unmanipulated males of a songbird, the dark-eyed juncos (*Junco hyemalis*). Individual ability to produce T in response to a challenge with gonadotropin releasing hormone (GnRH challenge) was positively related to aggression towards a conspecific intruder, but negatively related to offspring provisioning rates. Less is known regarding the extent to which females face a similar trade-off, and the degree to which T plays a role in mediating aggressive and parental behavior in females. We predicted that if T has similar effects in both sexes, then female behavior should exhibit similar relationships to T, i.e., greater aggression to a conspecific, and reduced parental effort. To test this we measured individual female dark-eyed juncos' (*Junco hyemalis*) ability to produce T in response to a GnRH challenges early in the breeding season. Aggression was measured by presenting females with a caged conspecific in the immediate vicinity of the nest early in the incubation period. Parental behavior was measured by quantifying provisioning behavior for four hours early in the nestling period. Results will be discussed in the context of T as a mediator of female behavior and the resolution of the mating/parenting trade-off in females.

***40.1*** CALEDE, Jonathan JM*; HOPKINS, Samantha SB; University of Oregon; *jcalede@uoregon.edu*

***Does the Red Queen control the evolution of fossorial rodents in the Miocene of the southern Columbia Plateau?***

Several authors have proposed that the richness and species composition of the burrowing rodent guild was shaped by a series of competitive replacements. A test of this idea in the Miocene of the southern Columbia Plateau (encompassing parts of Oregon, Nevada and Idaho) includes fossorial rodents present there between the Barstovian and the Hemphillian (17 to 4.8 Ma) , members of the Aplodontidae, Geomyidae, Mylagaulidae, Palaeocastorinae, and Marmotini. Competitive replacement has been suggested to be a difficult process to demonstrate in the fossil record but some patterns and ecological parameters can be investigated to corroborate such biological interaction. Examination of relative diversity, body size, habitat use, and diet makes it possible to recognize patterns consistent with competitive replacement in these groups of rodents. Preliminary data suggest the possibility of competition between Barstovian mylagaulids and fossorial castorids. Moreover, a significant Hemphillian increase in diversity of geomyids corresponds with a significant decrease in that of the Mylagaulidae and might explain their extinction; this may also reflect changes in the environment favoring a change in the dominant group of burrowers. The diversity of Marmotini does not significantly vary through time suggesting that ground squirrels do not interact competitively with these other burrowing rodents. Finally, the lack of significant change in the diversity of aplodontids throughout most of the Miocene, remaining low compared to contemporaneous burrowers, is yet to be understood.

***18.2*** CALISI, R.M.*; PERFITO, M.N.; BENTLEY, G.E.; Univ. of California, Berkeley, Max Planck Institute for Ornithology, Univ. of California, Berkeley, Univ. of California, Berkeley,; *calisi@berkeley.edu*

***How can stress affect the neural control of reproduction? An examination of gonadotropin inhibitory hormone (GnIH) and glucocorticoid receptors (GR) in songbirds***

Stress can have an inhibitory effect on reproduction in many organisms. However, the direct links between stress physiology, sexual behavior and reproduction are not very well understood. Generally in vertebrates, the adrenal glands produce the glucocorticoids cortisol and corticosterone in response to stressors. The neuropeptide gonadotropin inhibitory hormone (GnIH) inhibits reproduction via its action on gonadotropin-releasing hormone (GnRH) in the hypothalamus, on luteinizing hormone in the pituitary, and on testosterone and estradiol in the gonad. We recently reported that the hypothalamic content of GnIH peptide increases in house sparrows during times of stress at the beginning of the breeding season, demonstrating a mechanism by which reproduction could be delayed or disrupted in response to environmental stimuli. Using an avian model, we examined how different types of stress could affect the hypothalamic control of reproduction and sexual behavior. Specifically, we investigated the expression of hypothalamic glucocorticoid receptors (GR) and hypothalamic GnIH. We are the first to report the co-localization of GR mRNA within GnIH-producing cells in birds. This co-localization provides the neuroanatomical infrastructure for glucocorticoids to influence GnIH synthesis and release directly. In addition, we compared GnIH content and GR expression in European starlings experiencing intense nest site competition. These data represent the first indicating effects of social environment on GnIH.

***S10.2*** CALLAWAY, R.; Swansea University, UK; *r.m.callaway@swansea.ac.uk*

***Tube building polychaetes: from ephemeral bio-engineer to reef builder***

Tube-building polychaetes are widely recognized as bio-engineers. It has been suggested that under certain conditions the structures created could qualify as reefs. Being designated a reef builder would have profound implications for their protection under European nature conservation law. In this presentation it is discussed what it takes for a polychaete to be classified as a reef builder. The focus will be on the sand mason *Lanice conchilega* (Pallas, 1766), a ubiquitous tube worm found around the European coast. As a reef, tube aggregations need to fulfill physical, biological and temporal characteristics. They have to be spatially discrete, support a diverse benthic community and possess stability properties such as resistance to disturbance or high resilience. These characteristics were assessed. The distribution patterns of *L. conchilega* and the spatial and temporal stability of aggregations were analyzed. The effect of tube aggregations on biodiversity and community structure was investigated in sheltered and exposed environments. Diversity and community structure turned out to be affected in all *L. conchilega* habitats, whether tubes were sparse or dense. It appears that just a fraction of the *L. conchilega* community is strongly associated with this tube dweller while most species benefit from subtly ameliorated environmental conditions in the tube lawns. The results suggest that calm hydrodynamic conditions combined with the absence of extreme weather events and regular, successful recruitment are pre-conditions for less rigid bio-engineers to develop extensive, persistent features hosting unique benthic communities.

***63.8*** CAMERON, S. F.*; WILSON, R. S.; The University of Queensland, Australia; *s.cameron3@uq.edu.au*

***Can temperature drive the intensity of male-male competition across a latitudinal cline?***

Theory predicts that increased competition for resources should lead to a higher level of intensity of male-male combat in highly territorial species. Environmental temperature has the potential to indirectly drive such increases in competition via changes in population density, activity and aggressive behaviour. However, the role temperature plays in mediating the intensity of competition and sexual selection among populations is relatively unknown. In this study, we investigated the intensity of male-male combat and sexual dimorphism among populations of the Asian house gecko (*Hemidactylus frenatus*) along a latitudinal cline. Asian house geckos are a highly invasive species that have recently dispersed across Australia, from the tropics to temperate regions. Males of *H. frenatus* are also highly territorial and frequently engage in intense disputes and physical fights. We quantified the influence of temperature on the level of activity, aggression, sprint performance and maximum bite performance in males of *H. frenatus*. In addition, we quantified the level of male-male aggression, activity and competitive signalling along their latitudinal distribution. Finally, we assessed the extent of sexual dimorphism in body and head size among populations and determined their functional consequences for sprint and bite performance. We predicted there would be higher levels of male-male aggression in warmer environments and this would be associated with increased sexual dimorphism. As expected, acute increases in temperatures resulted in higher levels of activity and aggression and better whole-animal performance. We also found marked differences in the level of male-male aggression among the populations and their relationship to sexual dimorphism will be discussed.

***13.2*** CAMPOS, E. O.; University of Washington, Seattle; *eocampos@u.washington.edu*

***Rowing with Multiple Appendages in Stomatopod Crustaceans: Beyond Single Paired Appendages***

Unsteady fluid dynamic forces are crucial components of the mechanisms underlying propulsion at high Reynolds numbers, including motion with undulating surfaces or rowing appendages. An understanding of the emergent wake structures should provide validation of theoretical estimates of these mechanisms. Time-dependent hydrodynamic forces derive from momentum imparted to the fluid medium, manifested as vortex structures which can be visualized and quantified. Flapping and rowing have received considerable attention in a comparative context since they are viewed as two extremes along a continuum of appendage reciprocation. These analyses have focused almost exclusively on rowing and flapping of a single pair of appendages for locomotion. However, many animals row by reciprocating multiple appendages arranged serially along the anteroposterior axis, as in many crustaceans and polychaetes. Stomatopod crustaceans take this type of rowing to the extreme, employing it to achieve escape swimming speeds of over 30 body lengths per second (BL/s). Individual *Odontodactylus havanensis* (35-64 mm total length) were filmed at 60 and 500 frames per second (fps) and tracked with position-tracking software. Visual examination of individual frames confirms that stomatopods can reach and exceed 30 BL/s, with a peak velocity of 35.8 BL/s. Stroke frequencies exceeded 16 Hz. Such rapid appendage accelerations point to significant added mass effects or other unsteady phenomena. Studying the fluid wake patterns generated by different coordination schemes may yield interesting results that could enhance our understanding of animal locomotion. Stomatopod swimming provides a model system for studying the rowing mechanics of multiple paired appendages.

***12.10*** CAREAU, V.*; REALE, D.; HUMPHRIES, M.M.; THOMAS, D.W.; DÃ©partement de Biologie, UniversitÃ© de Sherbrooke, Sherbrooke, QC, Canada, Canada Research Chair in behavioural ecology, DÃ©partement des Sciences Biologiques, UniversitÃ© du QuÃ©bec Ã  MontrÃ©al, MontrÃ©al, QC, Canada, Natural Resource Sciences, Macdonald Campus, McGill University, Ste-Anne-de-Bellevue, Qc, Canada; *vincent.careau@usherbrooke.ca*

***Of Voles, Mice, Chipmunks and Dogs: The Energetics of Animal Personality***

Individuals consistently differ in their levels of activity, exploration, boldness, and aggressiveness. These differences – referred to as personality – are highly relevant to the evolutionary causes and consequences of variability in energy metabolism. However, few studies have considered whether variation in personality influences (or is influenced by) metabolic rates. In this presentation, we will test for the presence/absence of links between various metabolic and personality traits, working our way from inter-specific (comparative approach) to inter-individual level, using multiple study models (muroid rodent species, dog breeds, inbred mice strains individual lab mice, and free-ranging chipmunks). When appropriate, links with life-history traits are also shown. Ultimately, this research helps to better understand how suites of integrated traits evolve along a slow-fast life-history continuum to form a more general “pace-of-life” syndrome.

***46.3*** CARLETON, J*; RENN, Suzy C. P.; Reed College, Portland OR; *renns@reed.edu*

***Molecular modules of maternal aggression in the African cichlid Astatotilapia burtoni***

Thirty years of research have contributed to our understanding of the physiological mechanisms of the socially regulated switch between dominant and subordinate phenotypes among males of the African cichlid species *Astatotilapia burtoni*. Meanwhile, the female phenotypes have been largely ignored by all but a few studies regarding the reproductive cycle and affiliative behavior. Maternal mouthbrooding females of a recently collected *A. burtoni* wild stock from Zambia display a "good mother" phenotype that includes defensive aggression to protect free-swimming fry for up to 15 days post-release, whereas labstock females show similar aggression but tend to eat their fry within 2-3 days post-release. Our current research employs a systems biology approach to investigate the neuroendocrine and genomic contribution to the novel phenotype of maternal aggression, helping us understand the physiological basis of the behavioral differences observed in lab stock and wild stock fish. Here we describe the behavior of each stock in detail through repeated, ten-minute focal observations. We find no significant differences in plasma testosterone levels between stocks either before or after release of fry, although we do find an increase in plasma testosterone levels in wild stock in response to territory challenge during maternal care. We use a cDNA microarray to identify incredible differences in gene expression between stocks. A module of gene expression, upregulated specifically in maternal wild stock post fry release, contains some genes previously identified as important in male territorial behavior and also a novel set of genes related to maternal aggression, which is absent in the lab stock. This work establishes a female model for aggression, which will be explored at the hormonal, molecular and genetic level.

***63.1*** CARMODY, R.N.*; WEINTRAUB, G.S.; SECOR, S.M.; WRANGHAM, R.W.; Harvard University, University of Alabama; *carmody@fas.harvard.edu*

***Energetic significance of food processing: a test of the cooking hypothesis***

Cooking has been hypothesized to support increased energy demands in human evolution, including growth in body size and relative brain size that occurred ~1.9 mya. Alternatively, non-thermal forms of food processing, such as pounding, could have supported the dramatic rise in energy requirements at this transition, with the effects of cooking limited to subsequent, more modest signals of dietary improvement. However the relative effects of cooking and non-thermal processing on the energy gained from key hominin foods like tubers are not known. In this study, we compared the relative effects of cooking and pounding on energy gain among mice fed jewel yams, a starch-rich tuber, using a balanced within-subjects study design. Adult male CD-1 mice (n = 17) were fed yams in four treatments: raw/whole, raw/pounded, cooked/whole, cooked/pounded. Each treatment was administered ad libitum for four days, followed by a washout period of six days during which time the mice received ad libitum chow. Repeated-measures ANOVA revealed that cooking, but not non-thermal processing, improved energy gain as indexed by change in body mass. Whereas mice lost weight on raw treatments (whole: -4.3 ± 0.4 g; pounded: -3.8 ± 0.6 g), they gained weight on cooked treatments (whole: 0.1 ± 0.4 g; pounded: 0.2 ± 0.3 g). Post-study preference tests further support the superior effects of cooking. Fasted mice presented with equal rations of all treatments concurrently and in random configuration preferred cooked treatments in 17 out of 17 cases as measured by first bite, and in 16 out of 17 cases as measured by total intake over a 3 h trial. Our results indicate that, in contrast to cooking, non-thermal processing would likely have provided little energetic benefit for ancestral hominins reliant on starch-rich plant foods.

***45.10*** CARO, S.P.*; SEWALL, K.B.; SALVANTE, K.G.; ALDREDGE, R.A.; SOCKMAN, K.W.; Univ. of North Carolina, Chapel Hill, Simon Fraser University, Burnaby, Canada; *scaro@email.unc.edu*

***Behavioral and brain responses of female Lincoln's sparrows to variation in male song quality***

In many songbird species, females assess the quality of males and choose mates based, in part, on the quality of their song. In Lincoln's sparrows (*Melospiza lincolnii*), annual changes in the ecological environment are associated with variations in several components of the population's mean song quality, including song length, song complexity, and trill performance. This suggests that the average attractiveness of males and therefore choosiness of females can vary. Using female Lincoln's sparrows, we are currently examining how variation in male song quality and females' recent song experience, simultaneously affect their behavior, auditory forebrain sensitivity to variation in song quality (measured as expression of immediate early genes), and forebrain secretion of monoamines, which in some species modulate behavior based on experience. We found a higher level of behavioral activity in females exposed to high quality songs than in those exposed to low quality songs. This was especially true for females that had first been exposed to low quality songs, suggesting a role for recent song experience in the modulation of behavioral responses to song. We also found that females moved more toward songs with experimentally elevated trill performance than toward songs with experimentally reduced trill performance, suggesting that trill performance *per se* is a major component of male song quality. We propose that complex behaviors such as mate-choice are plastic and can be influenced by recent experience with ecologically dependent social cues. Understanding how the brain integrates such cues and then guides adaptive behavior is an important challenge for understanding the evolution of mate choice.

***101.5*** CARR, J.A.*; BIEWENER, A.A.; Harvard University; *carr@fas.harvard.edu*

***Self-ReInnervation of the Lateral Gastrocnemius in Guineafowl***

Running and walking requires that animals be able to negotiate variable terrain and recover from unexpected perturbations. Reflex responses that monitor and respond to changes in muscle force and length play an important role in controlling how an animal stabilizes its center of mass and produces ground reaction forces during locomotion.

One method of studying the role of muscle reflexes during locomotion is to eliminate reflex responses by performing surgical self-reinnervation. Self-reinnervation experiments have demonstrated that motor innervation can be restored, but not sensory afferents. The goal of this study was to determine whether self-reinnervation in the Lateral Gastrocnemius (LG) in guineafowl caused the loss and subsequent reestablishment of motor innervation and the permanent loss of sensory afferents. Muscle function was monitored during locomotion by measuring joint kinematics, muscle electrical activity, and the presence or absence of a calcaneal reflex. Measurements were performed at three times: prior to denervation surgery, then at three and six weeks post surgery. By demonstrating a loss of function followed by the recovery of motor function we will validate a bipedal model that allows us to study the role of reflexes during legged locomotion.

At three weeks post surgery we demonstrated a loss of function in the LG. The denervation of this muscle affected joint kinematics at both the ankle and TMP joints. There was a significant increase in the amount of ankle flexion that occurred during running. There was also a significant increase in both flexion and extension at the TMP joint. At six weeks post surgery we demonstrated successful reinnervation of the LG by measuring muscle activity during locomotion. Also at six weeks post surgery we demonstrated the lack of a sensory reflex in the LG by the inability to elicit calcaneal tendon reflex.

***100.1*** CARTER, M.C.; LIDGARD, S.*; GORDON, D.P.; GARDNER, J.P.A.; Victoria University of Wellington, New Zealand, Field Museum, Chicago , National Institute of Water and Atmospheric Research, Wellington, New Zealand ; *slidgard@fieldmuseum.org*

***Darwin's Avicularia: How an Early Sense of Modularity Links Vestigiality, Functional Innovation and the Evolution of Polymorphism***

Few studies indicate morphological vestigialization, co-option, and functional innovation of polymorphs in the same genetic individual, combined with other evidence of transitional stages of polymorph evolution among closely related living and fossil species. Here we provide that rare example, based on discoveries of vestigial and augmented homologous structures coincident with discrete functional innovations in a zooid polymorph, the bryozoan bird's-head avicularium originally described by Darwin. Darwin's studies on colonial animals shaped a remarkable but under-appreciated theoretical synthesis that anticipates modern concepts of biological modularity. This early sense of modularity is that these morphological entities develop and evolve as units that interact with other units and are integrated in an inclusive whole. Darwin later hypothesized that feeding zooids and nonfeeding polymorphic zooids (avicularia) were derived from an ancestral form most similar to the feeding zooid. Our research disclosed an array of muscular and exoskeletal homologies of feeding zooids and avicularia, more numerous and detailed than in any previous studies. Unlike the feeding zooid, the avicularium frequently captures small invertebrates, including predatory epibionts, which we recorded for the first time. Species in a living bryozoan genus and a Cretaceous one also show a skeletal transformation series between feeding zooid and avicularium. Our research thus connects disparate ideas about structural modularity, vestigialization and polymorphism, and confirms Darwin's hypothesis.

***S8.11*** CARTWRIGHT, Paulyn*; BARBEITOS, Marcos S.; COLLINS, Allen G.; DALY, Marymegan; FRANCE, Scott C.; MCFADDEN, Catherine S.; University of Kansas, National Systematics Lab of NOAA's Fisheries Service, Ohio State University, University of Louisiana at Lafayette, Harvey Mudd College; *pcart@ku.edu*

***Investigating cnidarian phylogeny using rDNA secondary structure models***

Elucidating higher-level cnidarian relationships presents challenges due to the ancient and rapid divergences between many of the major cnidarian lineages. Cnidaria contains a deep divergence separating two major clades, Anthozoa and Medusozoa. The monophyly of these two clades is well supported by compelling morphological and molecular evidence. However, there is uncertainty about many of the major relationships within each of these clades. As part of the Cnidarian Tree of Life effort, we sequenced nearly complete large and small subunit nuclear ribosomal (18S and 28S) and partial large subunit mitochondrial (16S) genes in a comprehensive sampling of cnidarian taxa. Ribosomal genes have traditionally been useful in elucidating higher-level relationships, but alignment is problematic due to length variable regions within these molecules. These length variable regions are often removed from phylogenetic analyses, which can reduce the number of potentially informative characters. In an effort to improve the alignment and maximize the number of unambiguously aligned characters, we incorporated models of secondary structure into our alignment. These models were developed specifically for cnidarians and enable us to confidently increase the number of hypothesized homologous regions in the rDNA molecules and thus retain more potentially informative sites. Here we present the results of our analyses and evaluate the utility of secondary structure models for investigating cnidarian phylogeny. In addition, we present the most up to date phylogenetic framework for Cnidaria and discuss these patterns and their implications for early cnidarian evolution.

***87.5*** CARUSO, M.A.*; SHERIDAN, M.A.; North Dakota State University; *Michael.Caruso@ndsu.edu*

***Expression of Insulin and Insulin Receptor mRNAs is Regulated by Growth Hormone and Somatostatin in Rainbow Trout***

Insulin (INS) coordinates various aspects of growth, development, and metabolism. In teleost fish, the INS signaling system consists of multiple INSs as well as multiple insulin receptor (IR) subtypes. In this study, we used rainbow trout (*Oncorhynchus mykiss*) as a model to examine the regulation of the INS signaling system by growth hormone (GH) and somatostatin-14 (SS-14). Juvenile fish were implanted with mini-osmotic pumps containing saline, GH, or SS for 21 days, and the expression of INS- (INS1, INS2) and IR- (IR1, IR2, IR3, and IR4) encoding mRNAs was measured by quantitative real-time PCR. GH regulated the expression of INS and IR in a subtype- and tissue-specific manner. GH- implanted animals displayed reduced INS1 in adipose, increased INS2 in the brain, reduced IR1, IR2, IR3, and IR4 expression in cardiac muscle, reduced IR1 in the gill, increased IR3 in the liver, and increased INS1, INS2, IR2, IR3, and IR4 in the pancreas. SS-14 also regulated INS and IR expression in a subtype- and tissue-specific manner. SS-14-implanted animals displayed increased INS1 and INS2 in adipose, increased INS1 in the brain, reduced expression of IR1, IR2, and IR4 in cardiac muscle, reduced IR2 and IR3 in gill, reduced IR2 and IR4 in the liver, increased INS1 and reduced INS2, IR1, and IR2 in the pancreas. These results demonstrate that GH and SS-14 modulate the expression of INS1, INS2, IR1, IR2, IR3, and IR4, and imply that independent mechanisms may serve to regulate the various hormone isoforms and receptor subtypes in a tissue-specific manner. (Supported by NSF IOS 0920116)

***19.2*** CASEY, J.P.*; GARNER, S.A.; SOUTHWOOD, A.L.; Uni. of North Carolina,Wilmington, West Indies Marine Animal Research and Conservation Service, Inc., Frederiksted, St. Croix, USVI, Uni. of North Carolina, Wilmington; *jpc3073@uncw.edu*

***Stomach Temperature Recordings Provide Evidence of Feeding During the Internesting Interval for Leatherback Turtles, Dermochelys coriacea***

Leatherback turtles (*Dermochelys coriacea*) are long-distance ocean migrants that travel from foraging habitats in temperate latitudes, to tropical nesting beaches to lay eggs every 2-5 years. It is generally assumed that leatherback turtles, like other species of sea turtle, do not feed while offshore from nesting beaches, and rely instead on fat reserves to fuel reproductive activities. We used a combination of physiological sensors, data loggers and telemetry to investigate the foraging behavior and habitat of adult female leatherback turtles from the St. Croix, USVI nesting population. Leatherback gastrointestinal temperatures ($T_{GT}$) were analyzed for rapid fluctuations that were indicative of ingestion events and laboratory ingestion simulations were used to characterize temperature fluctuations associated with ingestion of prey vs. seawater. Seven leatherbacks were documented to have made a combined total of over one-hundred ingestion events of gelatinous prey items (>300 g) during the turtle's internesting periods. The number of prey ingestions ranged from 6 to 62 for individual turtles, and the majority (85%) of these events occurred during the daytime (05:00-19:00). The mean (±1S.D.) depth of prey ingestions ranged from 111 ± 70 to 170 ± 90 m for individual turtles, and mean ambient temperature was 23.0 ± 0.9ºC. Mean depth of daytime and nighttime prey ingestions was not significantly different ($t = 3.11$, $df = 3$, $P = 0.052$). Our results indicate the leatherbacks from the St. Croix, USVI nesting population opportunistically feed during the internesting interval to top-off energy stores for reproductive activities.

***65.1*** CASS, AN*; SERVETNICK, MD; MCCUNE, AR; Cornell University, University of Washington, Bothell; *anc24@cornell.edu*

***Of mice and fish: expression of lung morphogenesis genes in the actinopterygian swimbladder***

A defining but often ignored synapomorphy of osteichthyes is the presence of an air-filled organ, either lungs as in tetrapods and several fishes or swimbladders of certain rayfin and lobefin fishes. Lungs and swimbladders have long been hypothesized to be homologous because of their similar function, development, anatomy and phylogenetic distribution. Though the molecular development of lungs is well studied, swimbladder development remains largely ignored. Here we ask to what extent is the gene regulatory network deployed during early lung development also involved in early swimbladder development? We have investigated the expression of the zebrafish homologs to mouse TTF-1 (*Danio Nkx2.1a* and *Nkx2.1b*), HNF3β (*Danio FoxA2*) and *Wnt7b*, three integral factors which synergistically modulate early lung development. Using reverse-transcriptase PCR and whole-mount *in situ* hybridization, we show that these factors have the same expression pattern in developing and adult zebrafish swimbladder as in tetrapod lungs. Preliminary results show the same basic, but somewhat modified, pattern of gene expression in other phylogenetically relevant fishes. Similar patterns of expression in mouse lung and zebrafish swimbladder suggest that at least the same genetic "cassette" is involved in the early budding of these two kinds of air-filled organ. The phylogenetic distribution of the same basic expression pattern in both swimbladders and lungs across both the Sarcopterygii and Actinopterygii, is consistent with the previously postulated phylogenetic hypothesis that lungs and swimbladders are homologous at the level of Osteichthyes.

***44.3*** CHAMPAGNE, CD*; FOWLER, MA; COSTA, DP; HOUSER, DS; CROCKER, DE; UC Santa Cruz, Sonoma State University; *champagn@biology.ucsc.edu*

***A complete profile of carbohydrate metabolism during prolonged fasting in the northern elephant seal***

During prolonged fasting, glucose derives from gluconeogenesis and is required as an energy source by some tissues (e.g. CNS, erythrocytes). Glucose production is typically suppressed while fasting to reduce strains on protein reserves resulting from the commitment of amino acids to gluconeogenesis. Previous work in fasting northern elephant seals, however, has found elevated rates of glucose production. To further investigate carbohydrate metabolism during prolonged fasting in elephant seals, this study used a recently developed tracer technique utilizing $D_2O$, [U-$^{13}$C]propionate, and a continuous infusion of [1,6-$^{13}$C]glucose. We used nuclear magnetic resonance (NMR) to measure the abundance of each resulting positional isotopomer of glucose. Relative peak heights from the resulting NMR spectra were used to quantify the rate of glucose production, the contribution of major gluconeogenic precursors (glycerol, glycogen, and phosphoenolpyruvate (PEP)) to glucose production, the flux through the tricarboxylic-acid cycle, and the activity of the PEP cycle. The contribution of glycerol to gluconeogenesis was low, only 5% of glucose production, confirming recent measurements of glycerol gluconeogenesis. Less than one-fifth of glucose flux was derived from glycogen with the balance derived from PEP. The significant contribution of PEP to glucose production is consistent with our previous suggestion that the elevated rates of glucose production observed in elephant seals are due to recycling through three-carbon intermediates such as lactate. This is the first use of this positional isotopomer technique in a free-ranging animal and provides the first comprehensive carbohydrate metabolism profile of an animal undertaking a prolonged fast.

***62.7*** CHAN, K.Y.K.*; GRÜNBAUM, D. ; Univ. of Washington, Seattle; *kychan@u.washington.edu*
***Larvae of sand dollar behaviorally compensate for temperature constraints on swimming***
Many marine invertebrate larvae actively swim to regulate water column position. Because environmental characteristics such as food availability and temperature often vary strongly with depth, vertical position has important consequences for larval growth, survival and dispersal. Little is known about effects of these environmental characteristics on larval swimming, but previous work suggests that larvae displaced downwards into colder water swim more slowly and consequently may have difficulty returning to warmer surface layers. We used non-invasive video tracking techniques to quantify swimming in larvae of the sand dollar, *Dendraster excentricus*, raised on four algal diets differing in fatty acid profile and exposed to an ecologically relevant temperature reduction from 20°C to 12°C. While larval swimming speeds decreased across all diet treatments, larvae's net vertical velocities did not decrease. Changes in swimming trajectories suggest larvae behaviorally compensated for reduced swimming speeds by reducing horizontal movement. Differences in diet quality led to significant morphological differences by the 8-arm larval stage, accompanied by significant diet/temperature interaction effects on swimming patterns. The observed behavioral compensation effectively circumvents swimming constraints due to lowered temperatures. More generally, video tracking of free-swimming larvae can yield quantitative data to inform coupled biophysical models to better predict consequences of larval dispersal for adult population dynamics under current and future environmental conditions.

***1.7*** CHARMANTIER, G.*; CHARMANTIER-DAURES, M.; ANGER, K.; Univ. Montpellier 2, France, AWI, Helgoland, Germany; *guy.charmantier@univ-montp2.fr*
***Loss of hypo-osmoregulation in a land-locked population of the shrimp Macrobrachium amazonicum***
Two separate populations of this shrimp, from the Amazon delta (A), and from the Pantanal (P), were compared as to their ontogeny of osmoregulation and ecology. Adult A shrimps live in brackish and fresh water (FW) habitats. Their ovigerous females presumably migrate down river, so that hatching occurs close to estuarine waters, where early larval development occurs. Early juveniles later migrate back to FW. The P shrimps, by contrast, spend their entire life cycle in FW. **In the A population**, tolerance of FW occurred temporarily in the zoea I stage and, again, after metamorphosis. All stages tolerated sea water (SW), being hyper-osmoregulators at salinities <17 ppt, and **hypo-regulators** at higher salinities including SW. The ability to hyper-regulate was temporarily high in the zoea I, lower in the subsequent larval stages, and increasing again after metamorphosis. Hypo-regulation was efficient throughout their ontogeny, particularly in the late larval and early juveniles stages. **In the P population**, all stages tolerated FW. Saline waters up to 25 ppt were tolerated by all stages, but mortality was high in SW, reaching 100 % in adults. All stages were hyper-osmoregulators at salinities <17 ppt, with a high osmoregulatory capacity in FW. In contrast to the A population, all stages were **osmoconformers** at salinities >17 ppt. In conclusion, these results show a close relationship between ontogenetic changes in osmoregulation and migratory patterns of the A population. Among the differences in salinity tolerance and osmoregulation observed between the two populations, the loss of the ability to hypo-osmoregulate in all post-embryonic stages of land-locked, FW-inhabiting shrimps from the Pantanal is most striking.

***15.9*** CHEN , Quinn; BRANN, Kalvin; PHANPAKTRA, Atchara; DORES, Robert M.*; University of Denver; *rdores@du.edu*
***Novel Posttranslational Processing of POMC in the Anterior Pituitary of the Adult Frog Silurana tropicalis***
In most adult vertebrates the posttranslational processing of the prohormone precursor, POMC, yields ACTH(1-39) as a major end product. This outcome is due to the action of the prohormone convertase, PC1. However, steady state analyses of acid extracts of the anterior pituitary of the anuran amphibian Silurana tropicalis yield different results. Sephadex G-50 fractionation of an acid extract of 10 pooled anterior pituitaries yielded a column profile in which ACTH-sized immunoactivity was a minor end product, and the major end-product was an MSH-sized immunoactive form. Subsequent reversed-phase HPLC analysis of the MSH-sized material indicated that this immunoreactive form had the same retention time as S. tropicalis ACTH(1-13)amide. This posttranslational processing pattern has been observed in the anterior pituitaries of larval and neotenic urodele amphibians (Ambystoma tirgrinum and Ambystoma mexicanum), but is novel for the anterior pituitary of a sexually mature adult. An analysis of the posttranslational processing of POMC in the anterior pituitary of the frog Xenopus laevis revealed the typical adult processing pattern – ACTH as the major end-product. These observations would suggest that while the reproductive system of S. tropicalis reaches maturity in the adult stage, the corticotropic cells of the anterior pituitary appear to retain larval features. This conclusion may have implications in terms of the activation of the melanocortin receptor on the adrenalcortical cells of S. tropicalis that secrete corticosterone. This research was supported by NSF grant 0516958 (R.M.D.).

***42.2*** CHENG, Bo*; DENG, Xinyan; Purdue University; *xdeng@purdue.edu*
***Rotational flapping counter torque in insect flight***
We studied the aerodynamic torque generation of flapping wings during roll, pitch and yaw rotations of the stroke plane. The counter torques generated by the wing pair due to body rotations were previously termed as flapping counter-torques (FCTs). For all three types of rotation, stroke-averaged FCTs are collinear with the rotation axes but opposite to the directions of rotation. Experiment results using dynamically scaled robotic wings shown that FCTs are linearly dependent on the flapping frequency and rotational velocity. For each type of rotation, we compared the measured FCT with the prediction of a mathematical model based on a quasi-steady analysis, where we show that FCTs can be explained by considering the asymmetries of wing velocity and effective angle of attack caused by each type of rotation. For roll and yaw rotations, our model provided close estimations of the stroke-averaged values. However, for pitch rotation, our model tends to underestimate the FCT, which may be largely affected by the unsteady aerodynamic mechanisms such as wake capture.

***60.2*** CHRISTY, J.H.*; VARGAS, L.E.; Smithsonian Tropical Research Institute, Universidad de Costa Rica; *christyj@si.edu*
***Allometry of male fiddler crab genitalia varies with size relationships in mating pairs: a test of the one-size-fits-all hypothesis***
Sexual selection on male traits used as signals to court females or as weapons to fight other males typically results in their disproportionally rapid growth characterized by large (1.5 – 2) coefficients of allometry (hereafter "slopes"). Signal competition among males continues during copulatory courtship producing strong sexual selection on the morphology of male genitalia. However, unlike other sexually-selected traits, 196/207 (95%) of male genital structures of 117 arthropods have slopes less than 1 and less than those for non-sexually-selected body parts (Eberhard 2008). Eberhard has suggested that males are selected to fit and stimulate the average-size adult female; small males with relatively large, and large males with relatively small genitalia. We tested and found support for this "one-size-fits-all" hypothesis by examining the slopes of male fiddler crab genital traits in two species in which crabs do not pair by size and in one species in which they do because they mate only underground in males' burrows the diameters of which limit the sizes of females with which males can mate. Male gonopod tip and female gonopore diameters in the burrow-mating species exhibited strong positive allometry with slopes of 1.5, larger than for any other known arthropod genital traits used in copulatory courtship. By contrast, the two species that do not pair by size had gonopod tip diameter slopes of .81 and .83 significantly less than slopes of female gonopores at 1.2 and 1.1 respectively, and less than for non-sexually selected traits. Female genital size and factors that affect the sizes of mating pairs may affect how selection based on morphological and stimulatory "fit" affects the allometry of male genital traits.

***7.1*** CHURCHER, Allison M.*; TAYLOR, John S.; Univ. of Victoria; *amchurch@uvic.ca*
***Still smelling after 550 million years; the amphioxus (Branchiostoma floridae) genome encodes orthologs of vertebrate odorant receptors***
A common feature of chemosensory systems is the involvement of G protein-coupled receptors (GPCRs) in the detection of chemical stimuli. In vertebrates, the odorant receptor (OR) repertoires range from 44 genes in pufferfish to over 1000 in some mammals yet there is no evidence that these genes are related to the chemosensory genes found in invertebrates. Using vertebrate OR sequences as queries and a combination of bioinformatics tools, we identified 50 full-length odorant receptors in the cephalochordate (*Branchiostoma floridae*) all of which form a monophyletic clade with the vertebrate ORs. The majority of the *B. floridae* ORs are intronless genes and many are tandemly arrayed in the genome as is the case with vertebrate ORs. Comparative sequence analysis combined with searches of OR and non-OR databases revealed three OR-specific amino acid motifs common in cephalochordate, fish and mammalian ORs. The locations of these motifs within the intracellular loops of the protein suggest they are important for maintaining receptor conformation and regulating receptor activity. The identification of OR-specific motifs provides a new set of candidate sites for functional analysis. Moreover, the discovery that *B. floridae* has orthologs of vertebrate ORs demonstrates that the receptors, and perhaps other components of vertebrate olfaction, evolved at least 550 million years ago. We anticipate our results will lead to an improved understanding of OR gene family evolution, OR gene function, mechanisms that control cell-specific expression, axonal guidance, signal transduction and signal integration.

***64.10*** CLARK, A.D.*; WANG, G; ADDIS, E.A.; RAMENOFSKY, M; WINGFIELD, J.C.; University of Washington; *ascaphus@u.washington.edu*
***Wing Morphology in Relation to Migration in Zonotrichia Sparrows***
Within the Emberizine sparrow genus *Zonotrichia*, there exist migrant and non-migrant populations with varying degrees of reproductive isolation from the opposing migratory strategy. Taking advantage of both the reproductive isolation and migration behavior gradients in *Zonotrichia*, I compare wing shapes (specifically aspect ratio and wing pointedness, which are aerodynamically advantageous for long distance migration) within populations, subspecies, species, and the genus. The level of relatedness at which no wing morphology differences can be detected despite differing migratory strategy, appears to be within subspecies. In particular, the non-migratory morphological changes that are seen in resident *Z. l. nuttalli*, relative to migratory conspecifics, are not seen in non-migrant *Z. l. pugetensis* individuals from a partial-migrant population relative to migrant *Z. l. pugetensis*. However, differing wing morphologies were detected between the sister subspecies of non-migrant *Z. l. nuttalli*, and predominantly migrant *Z. l. pugetensis*. A steep and marked cline in wing aspect ratio was detected across a 200 mile-long "hybrid-zone" between the *Z. l. nuttalli* and *Z. l. pugetensis* breeding ranges, with lower aspect ratios in *Z. l. nuttalli* and higher aspect ratios in *Z. l. pugetensis*. Surprisingly, a sex-specific difference in wing shape appears to be conserved throughout all *Zonotrichia* groups studied, with females exhibiting lower aspect ratios than males, a trait that is independent of sex-specific allometry.

***30.1*** CLASS, A.M.*; MOORE, I.T.; Virginia Tech; *classam@vt.edu*
***Food supplementation promotes molt and not reproduction in a tropical bird***
Tropical vertebrates typically exhibit a 'slow pace of life' syndrome relative to their higher latitude counterparts. Characteristics of this syndrome include delayed maturation, slowed aging, low fecundity and high annual survival. Following from this, it is predicted that individuals exhibiting the slow pace of life should trade current reproductive effort for maintenance, supporting survival and future reproduction. Recently, a meta-analysis of supplemental feeding studies found that birds typically advance reproductive initiation with extra food, and that the degree of advancement is negatively associated with latitude. However, there was only one tropical study in the meta-analysis. We conducted two food supplementation studies on tropical rufous-collared sparrows *Zonotrichia capensis* in the eastern Andes of Ecuador. In the first experiment, we supplemented territorial pairs during the non-breeding life history stage and in the second experiment we supplemented pairs that were provisioning fledglings. In both experiments food supplemented birds molted (replaced feathers) rather than investing further into reproduction. To our knowledge, this is the first study to experimentally show that a food supplemented bird invests in maintenance over reproduction. This result is consistent with a slow pace of life in the tropics and demonstrates a fundamental difference between tropical and temperate species.

***84.2*** CLAVERIE, T.*; CHAN, E.K.; PATEK, S.N.; Univ. of Massachusetts, Amherst, Univ. of California, Berkeley; *tclaverie@gmail.com*

***Shape, size and performance of a crustacean predatory appendage***

While variation in size can be intuitively linked to performance, the role of shape in the development and evolutionary radiations of predatory structures is rarely studied. Here we examine correlates of shape, size and performance in the mantis shrimp, *Gonodactylaceus falcatus* (Crustacea: Stomatopoda). Mantis shrimp raptorial appendages are powered by springs, four bar linkages, and levers that work in concert to amplify rotation during predatory strikes. We applied geometric morphometric techniques and selected the appropriate recording methods and landmarks across a size range of individuals. We digitized 2D landmarks and semi-landmarks on the raptorial appendages of 56 individuals. Then, size was measured using traditional linear morphometrics. We used a published dataset of spring constants and spring forces from these individuals and also collected force data from these same specimens using piezoelectronic impact sensors. We found that females had relatively smaller appendages than males, appendages were left-right symmetric in both sexes, and subtle shape variations were correlated with size and sex. Spring force and strike force were positively correlated with body size, but not shape. The spring constant was correlated neither with shape nor size. Shape variation in the merus segment (housing the spring and linkage systems) was independent of the covariation observed between the propodus and dactylus segments (acting as levers and striking surfaces). While size provides the most explanatory power for performance differences, the independent variation of shape in the two functional regions of the raptorial appendages may indicate developmental modularity and could underlie the extraordinary diversity of these appendages across the 500+ mantis shrimp species.

***88.6*** CLEMENTE, C. J.*; BULLOCK, J. M. R.; BEALE, A.; FEDERLE, W.; University of Cambridge, University College London; *cc498@cam.ac.uk*

***Evidence for self-cleaning in fluid-based smooth and hairy adhesive systems of insects***

Insects possess adhesive organs that allow attachment to diverse surfaces. Efficient adhesion must be retained throughout their lifetime even when pads are exposed to contamination. Many insects groom their adhesive structures, but it is possible that self-cleaning properties also play an important role. To investigate a self-cleaning property of insect pads, we measured attachment forces of insect pads on glass after contamination with microspheres and found that both smooth pads of stick insects (*Carausius morosus*) and the hairy pads of dock beetles (*Gastrophysa viridula*) exhibit self-cleaning. Contaminated pads recovered high levels of adhesion after only eight simulated steps; this was accompanied by the deposition of spheres. Self-cleaning was strongly enhanced by shear movements, and only beetle pads showed the ability to self-clean during purely perpendicular pull-offs. Hairy pads also self-cleaned more efficiently than smooth pads for both large (45 µm diameter) and small (1 µm) particle sizes. However, the beetles' self-cleaning was not better than smooth pads when contaminated with 10 µm beads. This limitation of self-cleaning for hairy pads is explained by the coincidence of bead diameter and inter-seta distance, which caused beads to remain trapped in between setae. Though the mechanism of self-cleaning is currently under investigation, evidence suggests that both fluid and pad mechanics play a role.

***23.1*** CLEMMENSEN, S F*; HAHN, D A; University of Florida; *sclemmensen@ufl.edu*

***Size matters: seasonal plasticity of development in a diapause-destined moth, Helicoverpa zea.***

Seasonality presents a problem for organisms because inhospitable conditions like cold temperatures can adversely affect survival, development, and reproduction. Many species mitigate this environmental stress by undergoing a dormant phase, or an arrested period of development – insect diapause is one example of this type of dormancy. While diapause is advantageous it also has costs. For example, if diapause occurs in a stage where an insect can not feed, such as the pupal stage, the individual must contain all the resources needed to both maintain diapause and finish development. One potential strategy for reducing the costs of diapause is accumulating more resources (e.g., lipid stores) prior to entering the non-feeding diapause stage. We expect that there are several different ways that lipid stores may be increased: 1) becoming both larger and proportionally fatter, 2) becoming proportionally fatter without increasing size, and 3) becoming smaller and proportionally fatter. We examined lipid storage and lean mass accumulation in diapause-bound *Helicoverpa zea* (Lepidoptera: Noctuidae) moths compared to non-diapause individuals. Our results support our first possible scenario, wherein diapause-destined pupae were both larger and proportionally fatter. We also showed that the critical weight for pupation was increased in diapause-inducing conditions, and diapause incidence increased with peak larval weight. Our results indicate that *H. zea* adjust their developmental trajectory when entering the diapause preparatory program.

***75.1*** CLIFFORD, A B; Brown University, Providence RI; *andrew_clifford@brown.edu*

***Kinematics of the Forefoot in Minipigs (Artiodactyla: Suidae)***

Unguligrade foot posture is one where the bones of the foot are elevated from the locomotor substrate, except for the hoofed distal phalanx. Most unguligrade animals (horses and artiodactyls) posses foot joints that are very ginglymal (hinge-like) and are interpreted to restrict movement during locomotion to a parasagittal plane. This study tests whether the motion in minipigs' forefoot digits is restricted during locomotion and whether motion between foot bones changes in level walking versus downhill steps. XROMM (a novel bi-planar cinefluoroscopy data collection and analyzation procedure) was used to determine the 3-D positions of metacarpals, proximal phalanges, and ungual phalanges of a digit during stance. Level steps, 10cm downhill steps and 15cm downhill steps were compared using the same methods. Analysis of motion using bone models with anatomically-fixed x- (antero-posterior), y- (medio-lateral), and z- (long-axis) axes permitted description of bone rotations. In level steps, minipigs consistently used a small subset of poses at toe-on and toe-off conditions and underwent large antero-posterior rotation (APR), modest long-axis rotation (LAR), and small medio-lateral rotation (MLR). Rotation between consecutive bones yielded joint motion, and the bulk of this motion occurred at the combined interphalangeal joints rather than at the metacarpophalangeal joint. In downhill steps, poses at toe-off were identical to those in level steps while toe-on poses differed. APR and MLR decreased during stance as step height increased, while LAR maintained similar excursions. Most of the motion at joints of the digit is anatomically hinge-like, although there is a consistent MLR and LAR that makes motion of the foot non-parasagittal. Paradoxically, minipigs used straighter foot postures during downhill steps than in level walking.

***81.3*** CLISSOLD, Fiona J.*; TEDDER, Benjamin J.; CONIGRAVE, Arthur D.; SIMPSON, Stephen J.; The University of Sydney; *fiona.clissold@bio.usyd.edu.au*

***The gastrointestinal tract as a nutrient balancing organ***

Failure to provision tissues with an appropriate balance of nutrients engenders fitness costs. Maintaining nutrient balance can be achieved by adjusting the selection and consumption of foods, but this may not be possible when the nutritional environment is limiting. Under such circumstances, rebalancing of an imbalanced nutrient intake requires post-ingestive mechanisms. The first stage at which such post-ingestive rebalancing might occur is within the gastrointestinal tract (GIT) by differential release of digestive enzymes; releasing less of those enzymes for nutrients present in excess while maintaining or boosting levels of enzymes for nutrients in deficit. Here we use an insect herbivore, the locust, to show for the first time that such compensatory responses occur within the GIT. In response to precise manipulation of dietary composition that takes account of both the concentration and ratio of macronutrients, we show that proteases and carbohydrases were released differentially. Furthermore, this difference translated into differential extraction of macronutrients from host plants, with locusts sacrificing maximal nutrient assimilation rate for supplying a ratio of protein to carbohydrate that was closer to optimal than in the diet. In contrast to the current view that physiological and structural plasticity in the GIT serves to maximize absorption of all nutrients: our data show that GIT plasticity is integral to maintenance of nutrient homeostasis.

***30.2*** CLUCAS, B.*; MARZLUFF, J.M.; University of Washington, Seattle and Humboldt University, Berlin, University of Washington, Seattle; *baclucas@uw.edu*

***Human-avian interactions in urban areas***

Contact between humans and other animals can create positive or negative outcomes and these interactions can be quite numerous in urban areas. In particular, many avian species appear to have adapted to living in cities among high densities of humans. Here we explore the relationship between humans and birds (corvids and small songbirds) in Berlin, Germany by surveying residents' attitudes and actions concerning birds and then testing bird behavior towards humans (flight distances and foraging behavior). In addition, our study sites covered an urbanization gradient (city center to outlying villages) in order to compare responses across human densities and habitat types. We found that humans vary in their encouraging actions (e.g., feeding) depending on their age and if they own their home. Furthermore, due to demographic differences across sites, encouragement of birds was higher in suburban and outlying areas compared to the city center and in high-rise apartments. Discouraging actions were not prevalent. Bird behavior did not vary due to level of encouragement by humans; rather, behavioral responses differed due to human density and habitat type (e.g., degree of vegetation). These studies are now being replicated in Seattle, Washington, USA to determine if cultural differences exist and if they influence interactions between humans and avian species.

***2.1*** COATES, M. M.*; NARINS, P. M.; University of California, Los Angeles; *mcoates@ucla.edu*

***Manganese-enhanced magnetic resonance imaging in the frog brain***

Anuran amphibians (frogs and toads) have long been recognized as excellent organisms for studying auditory processing and physiology. Frogs rely strongly on auditory communication: they call to attract mates and establish territories. To date, however, most available methods for studying auditory processing in frogs are highly invasive and do not allow for longitudinal studies. To address this problem, we have modified a manganese-enhanced MRI (MEMRI) technique developed for rodents as a noninvasive method for mapping physiological parameters in the frog brain. With this technique, manganese chloride ($MnCl_2$) is administered systemically and manganese ions ($Mn^{2+}$) are taken up through voltage-gated $Ca^{2+}$ channels in synaptically activated neurons. $Mn^{2+}$ then accumulates in active neurons and because it is paramagnetic, leads to enhanced contrast in $T_1$-weighted MRI. This offers the ability to map accumulated stimulus-evoked activity. We use a Bruker 7 Tesla (7T) horizontal animal scanner to acquire high resolution (150 µm) brain maps. MEMRI has the potential for a range of functional neuroimaging studies where maps are produced in response to a variety of sensory stimuli (auditory, visual, motor, etc.) or to a combination of sensory stimuli to investigate multisensory processes. Preliminary results reveal that 24-hour noise stimulation produces a detectable signal in the torus semicircularis of the midbrain, and ongoing experiments will explore the locus of activity in response to auditory-plus-visual stimuli. [Supported by NIH grant no. DC00222 to PMN].

***55.5*** COHEN, I.*; RISTROPH, L.; BERGOU, A. J.; GUCKENHEIMER, J.; WANG, Z. J.; Cornell University; *ic64@cornell.edu*

***Rowing through air: A new mode of forward flight in insects***

We show that fruit flies employ rowing or paddling motions of their wings to generate drag-based thrust during forward flight. An aerodynamic model shows that this mode of locomotion has the advantage of recruiting drag to maneuver while maintaining lift that keeps the insect aloft. Further, despite the importance of fluid inertia over viscosity (Re = 100), the generated thrust primarily overcomes a viscous-like resistive force rather than body inertia. Thus, organisms as different in scale as swimming bacteria and flying animals can experience remarkably similar locomotion dynamics.

***S3.9*** COHEN, C.S.*; PADILLA, D.K.; San Francisco State University, Stony Brook University; *sarahcoh@sfsu.edu*
***Balancing local differentiation and adaptation with dispersal potential: limits and opportunities for range extensions, divergence, and invasion***
At an inaugural Larval Ecology summit in 1986, R. Strathmann summarized hypotheses about life history traits potentially associated with dispersal capability, leading to local adaptation and population structure, followed by inferences about species range distributions, and extinction probabilities. Since that time, advances in molecular methods have allowed the testing of hypotheses on the connection between life history variation, dispersal, population structure, and local and species level extinction. Further, advances in specific knowledge about candidate genes that may be related to particular selective forces allows testing of the relative roles of drift and selection on population differentiation. Species with limited natural dispersal potential across all life stages offer opportunities to test hypotheses about conditions appropriate for local adaptation. Highly variable genetic systems, such as immune system and biotransformation loci, may offer the most obvious cases where local adaptation may occur. In these cases, high genetic diversity and strong selection may together promote differentiation, depending on the relative temporal and spatial landscape of selection in comparison to the range of dispersal and species flexibility. Thus, predictions based on variation in life history traits may be coupled to population genetic parameters affecting the selective impact of different local environments. In addition to the geological scale comparisons suggested by Strathmann for testing hypotheses about local adaptation and extinction and life histories, the increasingly rich literature on marine invasions offers an additional opportunity to evaluate local adaptation, sometimes in replicated environments, to biotic factors like challenges from parasites, competitors and predators, as well as abiotic environmental features.

***23.2*** COLEMAN, Andrew T*; WIBBELS, Thane; HUANG, Yu-hui; MARION, Ken; DINDO, John; Univ. of Alabama at Birmingham, Dauphin Island Sea Lab; *colemana@uab.edu*
***Do larger females produce more fit hatchlings? Effect of female age and size on egg size and hatchling growth in the Mississippi diamondback terrapin, Malaclemys terrapin pileata***
Throughout their range, populations of diamondback terrapins, *Malaclemys terrapin* , are experiencing declines from historic levels due to a number of threats. Along the Gulf Coast of Alabama, only isolated remnant aggregations exist in areas where once a large terrapin farm existed. To address the high amount of nest predation by raccoons, which represents a major threat, a head starting program was initiated at U.A.B. The ultimate goal of the head starting program is to ensure the future survival of diamondback terrapins in Alabama. However, obtaining terrapin hatchlings have offered an opportunity to further study the species' biology, including relationships between female and hatchling physiology and fitness. In the summer of 2009, fourteen clutches for a total of 103 eggs (average of 7.4 eggs/clutch) were obtained from females that subsequently were measured, weighed, and tagged. The length, width, and mass of every egg were measured. After hatching, carapace length and width, plastron length, and mass of every hatchling were measured once a week. Each clutch was fed the same amount twice a week. The effect of female age and size on both egg size and hatchling growth was examined. Rate of hatchling growth was treated as an indicator of hatchling fitness, but other potential indicators were also evaluated. So do larger females produce more fit hatchlings? The answer to this evolutionary question has obvious conservation implications for populations facing extirpation.

***S10.8*** COLEMAN, Felicia C*; KOENIG, Christopher C; Florida State University; *coleman@bio.fsu.edu*
***The effects of fishing, climate change, and other anthropogenic disturbances on red grouper and other reef fishes in the Gulf of Mexico.***
In this paper, we evaluate the potential impact of anthropogenic disturbances like fishing, oil and gas exploration, and climate change on marine fish species known or suspected to be habitat engineers. The species of interest include those that inhabit remarkably different types of habitat at different life stages, and therefore can have significant influences across the sea floor at broad spatial scales. The emphasis is on a highly territorial reef fish, the red grouper *Epinephelus morio*, which excavates habitat throughout its life time in karst regions of the Gulf of Mexico and western Atlantic, in shallow (2-4 m) sites as juveniles and relatively deep (60-100 m) sites as adults. However, other species are evaluated as well, including the territorial but less agonistic goliath grouper *Epinephelus itajara*, which seeks shelter beneath mangrove root systems as juveniles and in caves, shipwrecks, and shallow water reefs as adults. We contend that disturbances that influence productivity in these species can and often do have cascading effects in marine communities that ultimately result in the loss of biodiversity and extreme community flux.

***8.3*** COLLAR, David; Harvard University; *dcollar@oeb.harvard.edu*
***Rates of morphological evolution vary with habitat use in dragon lizards***
Ecological factors are often implicated to explain differences in diversity between clades because the ecological conditions available to clade members contribute to the mode of natural selection they experience. In particular, habitat use is thought to be important for evolutionary diversification. Differences between habitats in structural complexity, the number of species interactions, and functional demands can result in differential opportunity for ecological and morphological differentiation. I tested the hypothesis that diversification of body and limb form varies as a function of habitat use in the Agamidae lizard radiation. I inferred a phylogenetic tree for 90 agamid species using mtDNA sequences, reconstructed ancestral habitat use for the four habitats used by species in this group (rocks, trees, ground, and both trees and the ground), and then fit multiple evolutionary models to species' values for morphological traits involved in locomotor performance. My results suggest that habitat use has had a strong effect on diversification. Models in which the rate of morphological evolution varied between lineages using different habitat types fit much better than models that constrained all lineages to the same rate. Moreover, in the best fitting models the evolutionary rate is much slower in rock-dwelling and arboreal lineages than in terrestrial or semi-arboreal lineages. This suggests that terrestrial habitats may facilitate ecomorphological differentiation, while the use of vertical habitats such as trees or rocky surfaces may impose constraints on morphological evolution and thus impede divergence.

***23.3*** COLLIN, R*; MéROT, C; Smithsonian Tropical Research Institute; *collinr@si.edu*
***Sex Change in Two Species of Calyptraeid Gastropods: Effects of Nutrition and Perceived Mortality Risk***
Although social control of sex-change has been well documented, little is known about other environmental influences that lead to differences in size at or timing of sex change. In protandrous calyptraeid gastropods, laboratory studies have shown that variation in associations with conspecifics do not explain the full range of variation in size at sex change. Therefore we examined how variation in food availability and perceived mortality risk affect size at sex change in two calyptraeids: *Crepidula* cf. *marginalis* and *Crepidula incurva*. High, medium and low food concentrations had significant impact on growth rates in both species, and *C.* cf. *marginalis* changed sex at a significantly larger size at high food concentrations than at medium concentrations. The duration of the transitional phase was significantly shorter in the high food than the medium food treatment. In the mortality risk experiment, *C.* cf. *marginalis* exposed to crab odor or daily drying did not differ in growth rate from the high food treatment, however animals exposed to the crab control grew faster than the other three treatments. These treatments generally did not affect the size at sex change and duration of sex change. Finally, we found that transitional animals had a higher growth rate than either males or females. Overall these experiments demonstrated that food availability has a significant effect on size at sex change, and that those experiencing harsh conditions show a different pattern, changing sex by losing male characteristics earlier and at smaller sizes, remaining longer in the transitional phase, and becoming female at smaller size. Interpretation of the perceived mortality risk treatment was complicated by the unexpected increased growth in one of the controls, but these treatments had a smaller effect on sex change than did food availability.

***79.6*** COLLINS, Allen G.*; BENTLAGE, Bastian; GILLAN, William; LYNN, Tara H.; MARQUES, Antonio C.; MORANDINI, Andre C.; National Systematics Lab of NOAA's Fisheries Service, University of Kansas, Boynton Beach Community High School, Systematics Lab of NOAA's Fisheries Service, Universidade de SÃ£o Paulo; *collinsa@si.edu*
***Naming the Bonaire banded box jelly, the dynamic science side of a public species-naming contest***
The public was enlisted in naming a new species to increase understanding of systematics, taxonomy, and the nature of science. A putative new species of Cubozoa, known as the banded box jelly (or BBJ) for its reddish and white banded tentacles, has been photographed or videotaped about 36 times, mostly in the shallow waters of Bonaire, Netherlands Antilles. Examination of the only available specimen indicated that in addition to the banded tentacles, this animal differed from all other known box jelly species in the form of its gastric phacellae. While the public was submitting potential names, a manuscript documenting the unique gastric phacellae and contrasting the cnidome and genetic data of the BBJ with that of *Tamoya haplonema* from the southeast USA was reviewed. Review revealed that occasional specimens of *T. haplonema* from Brazil, the species' type region, had banded tentacles. Nevertheless, the unusual gastric phacellae of the single specimen appeared to justify naming the BBJ in an imminent paper. At the time a candidate name was chosen by the public, a second BBJ specimen was located. This specimen does not have gastric phacellae differing from those of *T. haplonema* and the manuscript was pulled prior to publication. Genetic and cnidome data from *T. haplonema* from Brazil became critical for proceeding. Brazilian colleagues joining the scientific team find slight differences (~2% in mt16S, 5% in COI) between the BBJ and *T. haplonema* from Brazil. Naming the BBJ is not yet warranted. However, *Tamoya* from the southeast USA is distinct. This species is given a publicly chosen species name, and the public has been shown the dynamic nature of science.

***S8.9*** COLLINS, Allen G.; National Systematics Lab of NOAA's Fisheries Service; *collinsa@si.edu*
***Phylogeny, evolution, and systematics of the stalked jellyfishes (Cnidaria, Staurozoa)***
An early divergence within Medusozoa gave rise to the class Staurozoa. A relatively species poor group, there are approximately 50 species of benthic, stalked jellyfishes distributed in two orders. Many species are cryptic in their habitats -- most being found in near shore, temperate to polar waters on macroalgae -- and rarely encountered. As part of the Cnidarian Tree of Life project, a collaborative team has been working on conducting the most comprehensive phylogenetic analysis of the group possible. Our sampling includes 21 species representing four of the five families and 10 of the 13 genera. From these we have derived sequence data from five markers: nuclear 18S, 28S, and ITS1-2, and mitochondrial 16S and COI. Analyses of these data yield results with very little conflict resulting from marker or optimality-criterion choice. A claustrum vertically dividing the gastric cavities of some species appears to have evolved more than once, so the traditional orders defined by the presence/absence of this feature, Cleistocarpida and Eleutherocarpida, should be abandoned. Instead, it appears that an early divergence within Staurozoa separated those species with (the plesiomorphic condition) and without four septal muscles in the peduncle. Early diverging lineages within Staurozoa tend to have ephemeral primary tentacles that disappear during ontogeny. Those species with primary tentacles retained as adults appear to form a grade that has given rise to a clade characterized by the presence of rhopalioids or anchors. Some straightforward nomenclatural changes can bring the taxonomy of Staurozoa more closely in line with our phylogenetic results. We also calculate within and between species divergences with available data and conclude that mitochondrial 16S would make the most suitable “barcode” marker for the group.

***79.3*** COLLINS, Jennifer A; Consortium for Ocean Leadership; *jen@paleobio.org*
***Species Naming Contest: A Year of Science 2009 Effort That Engaged the Public in Science***
At last year’s SICB meeting in Boston, Ira Flatow kicked off the Coalition on the Public Understanding of Science (COPUS) 2009 Year of Science (YoS) celebration. Each month of the YoS has been themed, with June focusing on ocean and water science. During June, we launched a species-naming contest for the Bonaire banded box jelly (BBJ; Cubozoa, Tamoyidae). The contest was hosted on the YoS website and challenged visitors to learn about taxonomy, the science team, the process, the animal, and then submit a name to become the formal, published scientific name. Over four weeks, the contest attracted over 500 citizens of the world to submit potential names. The public learned how to engage in this piece of science through press releases, the YoS web page, list-serves, blogs, and public outreach events. The scientists then picked out seven of their favorite -- and appropriate -- potential names from those submitted. During the subsequent week, more than 800 votes were cast by individuals and a winning name was chosen. However, new information came to light and prompted the scientists to decide that naming the BBJ as a distinct species was premature and too tentative. The public witnessed the dynamic nature of science as the original team contacted foreign collaborators, made additional observations, and discovered that they had data on a closely related species needing a new name and description. The person who submitted the winning name for the BBJ has embraced the plan of having the winning name applied to this species, a close ally of the BBJ.

***22.2*** COLVARD, Nicholas B.*; EDMUNDS, Peter J.; California State University, Northridge; *ncolvard@gmail.com*
***The physiological response of tropical reef corals to light reflected from the benthos***
Here we test the effect on reef corals of heavily grazed (HG) and macroalgae-dominated (MD) substrata through alterations in reflected light. On shallow reefs in Moorea and Taiwan, the intensity of reflected light was reduced ~20% over MD compared to HG substrata, and its quality was modified through a depressed representation of red light. The effects of these contrasting regimes of reflected light were explored with two series of experiments. First, the photophysiology of *Porites lobata* and *Pocillopora verrucosa* on light and dark surfaces was measured at 3-m depth in the Moorea lagoon. Second, mesocosms were used to test for a growth response of *Montipora stellata* exposed to contrasting regimes of reflected light created under three categories of ambient irradiance mimicking shallow and deep water. For both experiments, the treatment surfaces were created with colored plates simulating HG and MD substrata. In the field, photosynthetic yield ($\Phi_{PSII}$) of *P. lobata* and *P. verrucosa* was affected by the substratum reflectance, but the effect differed 3-fold between species. In the mesocosm, growth of *M. stellata* was suppressed by the darkened surface under conditions simulating a deep-water environment, but the light surface mitigated this effect. We conclude that the reflectance characteristics of the substratum can affect coral physiology in shallow water, and suggest that this affect could represent a previously overlooked mechanism mediating the interactions between reef corals and macroalgae.

***80.2*** COMBES, S.A.*; CRALL, J.D.; MUKHERJEE, S.; Harvard University; *scombes@oeb.harvard.edu*
***Wing damage and flight performance in dragonflies: Effects of area loss on force production and aerial predation***
Age-related wing damage is common in flying insects, with accumulated tears and tattering often resulting in significant area loss. Aerodynamic theory predicts a resulting decline in flight performance, and previous studies have documented changes in biomechanical variables during simple flight assays. However, several studies have shown that these changes do not necessarily translate into increased energetic costs or decreased survival rates – thus, the impact of wing damage on wild insects remains unclear. We tested the effects of wing area loss on the ability of Libellulid dragonflies to produce flight forces and perform natural aerial behaviors. We first carried out a laboratory experiment designed to repeatedly elicit high force production. Dragonflies were dropped in mid-air and filmed with high-speed video as they attempted to arrest their fall and fly up towards a light. Drop tests were performed before and after symmetric wing area removal, with forewing and hindwing alterations performed on different groups. After wing area removal, dragonflies were less effective at producing vertical forces to arrest their fall, and their subsequent ascending flight was slower and less steep. To examine the relevance of these findings to more natural flight behaviors, we assessed aerial predation success of dragonflies in an outdoor artificial habitat, quantifying success rate before and after hindwing area removal. Our results suggest that wing damage does in fact compromise dragonfly flight performance, and highlights the importance of extending laboratory studies of locomotory performance to more complex, ecologically relevant behaviors.

***63.9*** CONDON, CH*; CHENOWETH, SF; WILSON, RS; The University of Queensland, Australia; *c.condon@uq.edu.au*
***Genetic variation in the plasticity of thermal performance in the zebrafish, Danio rerio.***
To adjust to seasonal variation in the environment many ectotherms are able to plastically alter the performance of a trait as a function of environmental temperature. Plastic changes in the shape, mean and height of thermal performance curves after acclimation are frequently found to enhance the performance of whole-animal traits (e.g. locomotion). While recent empirical work has focussed on whether acclimation provides an adaptive benefit to organisms, how short-term (i.e. seasonal) plasticity in thermal performance curves may evolve remains largely theoretical. Theory predicts that genetic variation is likely to exist in all traits including plastic acclimation responses. However, little is known of the genetic basis of the components of thermal performance curve shape (i.e. height, width and mean) upon which selection can act. Particularly, whether these components are constrained or can evolve independently. Here, we investigate the genetic variation in the thermal acclimation response of two whole-animal performance traits in the zebrafish, *Danio rerio*. We reared full-sib families in a common environment and exposed adults to either 16 or 32 °C to examine a GxE interaction on the plastic change in performance curve traits. After 6 weeks exposure, we tested the thermal performance of each animal for both burst swimming and routine activity between 12-36°C. Through the analysis of each individual's thermal performance within a quantitative genetic framework we are able to discuss the genetic basis of plasticity in thermal performance curve shape.

***69.5*** CONNER, S.L.*; BAUER, R.T.; Univ. of Louisiana at Lafayette; *sel6883@louisiana.edu*
***Reproductive biology of a bopyrid isopod, Probopyrus pandalicola, and its hyperparasite, Cabirops sp., parasitic on the river shrimp, Macrobrachium ohione***
*Macrobrachium ohione* is a freshwater caridean shrimp that migrates to brackish-water estuaries to release its larvae, which require development in salt water. Postlarvae then migrate upstream to the adult freshwater habitat. *Probopyrus pandalicola* is a bopyrid isopod parasite in the gill chamber of *M. ohione*. Although both species require saline water for larval development, the bopyrid releases larvae both upriver and in the estuary. The typical positive correlation between parasite and host body size was not found in this study. Shrimps can become infected either as juveniles or as reproductive adults when in the estuary. *Probopyrus pandalicola* was itself found to be parasitized by another isopod, the hyperparasite *Cabirops* sp. Collection data indicate that the hyperparasite distribution is more limited to saline waters, unlike its bopyrid host. Light and SEM microscopy, as well as observations of live specimens indicate that the seven thoracic segments of the female hyperparasite develop into bilobed pouches used for incubating embryos and brooding epicaridium larvae. However, the developmental origin of the pouches, e.g. from oostegites, is still uncertain. The female vigorously contracts, possibly to circulate water among the embryos/larvae. After larval release, the female dies and its body is removed by the host shrimp. The female is often accompanied by multiple cryptoniscus larvae (presumptive males) which may metamorphose into adult females when the resident female dies.

***26.1*** CONTRERAS, H.L.*; BRADLEY, T. J.; University of California, Irvine; *hcontrer@uci.edu*

***Respiratory gas exchange patterns of a semi-aquatic insect: effects of environmental humidity vs. oxygen demand***

The adaptive significance of insect gas exchange patterns, in particular the importance of the discontinuous gas exchange cycle (DGC), has been extensively debated by insect physiologist for decades. The debate continues to date and data supporting the importance of DGC for water conservation or to limit oxidative damage continues to flourish in the literature. In order to address the significance of the DGC as a response to environmental humidity or oxygen availability, we used a semi-aquatic insect (*Aquarius remigis*) to determine gas exchange patterns when these insects were found under humid conditions while their metabolic rates were altered using temperature (10, 20, 30°C). Insects were placed in a vial containing 1ml of degassed water while humid $CO_2$-free air entered the experimental chamber and then passed into a $CO_2$ analyzer. We found that at low temperatures, insects exhibited lengthy periods of spiracular closure reflecting a discontinuous pattern of respiration. In fact, on average *A. remigis* spent 80% of the total experimental time with the spiracles closed. As temperature and metabolic rate increased, the insects showed shortened closed periods, transitioning to the cyclical respiratory pattern (spiracles were closed only 35% of experimental time). Finally, at the highest temperatures, the insects exhibited a continuous respiratory pattern, were they spent only 9% of total experimental time with the spiracles closed. Our results suggest that environmental humidity does not play an important role in determining gas exchange patterns in these semi-aquatic insects as our data was collected while insects were found under very humid conditions. However, the insect's metabolic rate (oxygen demand) had a strong effect on the gas exchange pattern displayed and therefore our data continues to support the oxidative damage hypothesis.

***85.2*** COOPER, B.S.*; CZARNOłęSKI, M.; ANGILLETTA, M.J.; Indiana University, Jagiellonian University, Indiana State University; *brascoop@indiana.edu*

***Acclimation of thermal sensitivity in Drosophila melanogaster from high and low latitudes***

Organisms modify their physiological functions in response to changes in their environment, a process referred to as acclimation. Recent studies of acclimation have been influenced by verbal models, but these models cannot predict variation in acclimation capacity because they fail to consider the selective advantage of acclimation. We used a model of optimal developmental plasticity to generate predictions about the evolution of acclimation in *Drosophila melanogaster*. This model predicts that populations experiencing environmental variation among generations are more likely to evolve acclimating genotypes than are populations experiencing relatively constant environments. To evaluate this prediction, we compared the acclimation capacities of *Drosophila melanogaster* from two environments that differ markedly in thermal heterogeneity (Marlton, New Jersey and Miami, Florida); flies from New Jersey experience nearly twice as much among generation variation in body temperature and should developmentally acclimate to perform as adults. We raised flies from both populations in three thermal treatments and then measured their daily fecundity over a range of 14° to 36°C. Contrary to our prediction flies from both populations exhibited similar acclimation capacities. The fecundity of flies from both populations depended strongly on body temperature ($P = < 0.001$), but not in a way that can be predicted by theory. Flies produced the most eggs at 28° and 30°C regardless of their developmental environment. At all temperatures, flies that had developed in warm environments produced more eggs than flies that had developed in a cold environment. Our results suggest a need to refine current models of the evolution of developmental acclimation.

***86.5*** COOPER, W.J.*; PARSONS, K.; WESTNEAT, M.W.; ALBERTSON, R.C.; Syracuse University, The Field Museum; *wjcooper@syr.edu*

***Repeated patterns in the diversification of jaw and head length amongst perciform fishes***

The skulls of perciform fishes have an anatomical configuration that permits their oral jaws to perform complex and dynamic movements, and this condition has frequently been linked to the massive evolutionary success of the group. We suggest that the perciform jaw mechanism may promote rapid evolutionary divergence due to the fact that simple changes in the morphology of this structure can have large ecological effects. Specifically, that altering the relative size of the preorbital region (which includes the oral jaws) can produce pronounced ecomorphological shifts. We have examined the functional morphology of fish feeding in multiple lineages that include a large percentage of the extant perciform species. Our results suggest that changes in the relative size of the preorbital region have been of extreme importance to the evolutionary success of these groups, and that such changes have often evolved with great speed. The alteration of oral jaw size has frequently been associated with diversification along a bentho-pelagic feeding axis, and is associated with divergence in bite force vs. bite speed. Our data suggest that this anatomical region may constitute an evolutionary module, and that changes in the size of this module may be under the control of a small number of genes of large effect. The Perciformes may therefore possess genetic and morphological arrangements such that simple genetic changes can rapidly produce important biomechanical and ecological shifts. This hypothesis has the potential to explain a large portion of the tremendous success of this group, which constitutes one of the largest branches of the vertebrata.

***S7.9*** COSTA, D.P.*; CROCKER, D.E.; GOEBEL, M.E.; FEDAK, M.A.; MCDONALD, B.I.; HUCKSTADT, L.A.; Univ. of California, Santa Cruz, Sonoma State University, AMLR Southwest Fisheries Science Center, Sea Mammal Research Unit; *costa@biology.ucsc.edu*

***Climate Change and Habitat Selection of Seals in the Western Antarctic Peninsula***

Top predators integrate resources over time and space and depending on the particular species they represent different components of the marine environment. The habitat utilization of top predators has been studied using electronic tags to follow their movements and foraging behavior. These data along with studies of diet are informing us on how these important marine predators are likely to respond to climate change. Such changes in foraging behavior will also provide insights into how the Southern Ocean is changing. The Western Antarctic Peninsula has experienced the greatest and most rapidly changing temperature of anywhere in the Southern Ocean. As such changes in the populations of top predators in this region are indicative of changes that are likely to be observed throughout the Antarctic. We examined the habitat utilization and movement patterns of southern elephant seals, Mirounga leonina over five years (2005-2008), crabeater seals, Lobodon carcinophaga over three years (2001-2 & 2007), and Weddell seals, Leptonychotes weddelli (2007) foraging. Southern elephant seals forage over very large distances and breed on land while crabeater seals are limited to foraging along the continental shelf and breed on pack ice. Further, crabeater seals primarily feed on krill and krill is dependent on the seasonal pack ice for habitat. As the climate of the Southern Ocean warms species like elephant seals that forage over a greater range of habitat types and breed on land are likely to expand, while species like crabeater and Weddell seals that forage over a more restricted area and breed on sea ice are likely to decline as their habitat recedes.

***86.3*** COVENY, A.H.*; VICKERS, M.H.; CUPIDO, C.L.; GLUCKMAN, P.D.; RAUBENHEIMER, D.; Liggins Institute, Univ. of Auckland, New Zealand, Massey Univ., Auckland, New Zealand; *a.coveny@auckland.ac.nz*

***Transgenerational adaptation to obesogenic environments in a rodent***

Numerous studies have examined the ways that animals respond adaptively to their nutritional environments either within a generation through phenotypic plasticity, or across multiple generations through genetic evolution. In contrast, there is little information on whether and how animals adapt at intermediate time-scales, across a single or a few generations. We report experiments in which female rats were transitioned at puberty from a grain-based diet to one of three dietary regimes involving synthetic foods differing in their nutrient (protein, carbohydrate and fat) content and ration (*ad libitum* vs. 70% of *ad lib*.). Intake, body composition and reproductive output were monitored over five generations. The first generation exposed throughout development to the synthetic diets (henceforth F0) showed increased caloric intake and adult adiposity compared with non-transitioned rats raised on the grain-based diet. However, the F1 (offspring of F0) rats showed reduced intake and adiposity compared with F0, but to a greater extent when carbohydrate was the main energy source compared with fat. Adiposity was further reduced on the high-carbohydrate diet when rats were restricted to 70% of *ad lib.* intake, with only minor effects on reproductive outcome. Despite the reduction in intake and adiposity, the rats in all treatments either maintained or increased their lean growth across generations by increasing the efficiency with which ingested protein was converted to growth. Reproductive output in all groups was initially poor with reduced survival of F1 neonates, but improved in subsequent generations. Our data provide enticing evidence for transgenerational adaptation to perturbations in the nutritional environment.

***23.4*** COX, Robert M.*; CALSBEEK, Ryan; Dartmouth College; *robert.m.cox@dartmouth.edu*

***The ecology of life-history trade-offs: whole-island manipulations of predation regime in a wild lizard***

A central tenet of life-history theory is that investment in reproduction compromises survival. Here, we use experimental manipulations of reproductive investment to show that reproduction severely compromises survival in a wild population of brown anole lizards (*Anolis sagrei*). In each of three separate years, elimination of reproductive investment via surgical ovariectomy dramatically increased the survival of female anoles, relative to reproductive shams. Gravid females also suffered significant reductions in sprint speed and stamina, suggesting that their impaired locomotor performance may render them more susceptible to predators. To determine whether the survival cost of reproduction is driven by predator-induced mortality, we combined surgical manipulations of reproductive investment with whole-island manipulations of predation regime (via bird exclusion and/or snake addition). Ovariectomized and sham females were released to replicate islands exposed to (1) bird predators, (2) bird and snake predators, or (3) no predators. Exclusion of bird predators did not influence mortality, but addition of snake predators increased mortality. However, surgical treatment groups did not differ in survival under any predation regime, suggesting that the trade-off between reproduction and survival is not driven by extrinsic, predator-induced mortality. Instead, the low survival of reproductive females may reflect the energetic demands of egg production.

***80.3*** CRALL, James D*; DONOUGHE, Seth T; MERZ, Rachel A; COMBES, Stacey A; Concord Field Station, Harvard University, University of Pennsylvania, Swarthmore College; *jcrall@oeb.harvard.edu*

***A Complex Flex: Comparative Functional Morphology of Flexible Vein-Joints in Dragonflies and Damselflies***

The elastic protein resilin has been shown to play an important structural role in the wings of insects belonging to several orders. However, the evolution and diversity of such resilin-containing structural mechanisms in insect wings remains poorly described. We have employed a variety of techniques, including fluorescence microscopy, scanning electron microscopy, and mechanical tests to compare composition (i.e. presence of resilin), structure and shape (i.e. presence and morphology of “spikes” or cuticular protrusions associated with some vein-joints), and mechanical behavior of wing vein-joints across a diverse group of species within the order Odonata. By categorizing different vein-joint types and mapping their distribution within wings, we have characterized a surprising diversity of morphological patterns of vein-joints among different taxa within Odonata. Mechanical testing on fresh wings suggests that these morphological patterns are correlated with different mechanical behaviors of certain wing regions. Interestingly, some of the morphological patterns described are not easily reconciled with previously proposed mechanisms, implying a wider and more diverse role of resilin in the passive deformation of insect wings than has previously been described.

***38.1*** CRESPI, Erica J*; WARNE, Robin W; Vassar College; *ercrespi@vassar.edu*

***Interactions between social stress and resource availability on tadpole growth, development and physiology***

Exposure to stressors during early development have been shown to have important impacts on physiological function, behavior, and fitness during later life stages in vertebrates, but the specific mechanisms that link these early experiences to the expression of later phenotypes are poorly understood. In this experiment, we explored the effects of chronic social stress and resource availability on growth, development, and variation in corticosterone (CORT) content in wood frog (*Rana pipiens*) tadpoles approach metamorphosis. We predicted that chronic social stress (and higher CORT levels) throughout development would alter growth and metamorphic timing, and these effects would be minimized when resource availability is high. To test these predictions, we marked early-staged tadpoles of same age to designate three size classes (i.e., social status) and raised replicate populations of tadpoles (n=51 tadpoles, 16-18/size class) in experimental mesocosms of both high and low food availability (n=6/food treatment). We then measured body length, mass, femur length and CORT content as tadpoles approached metamorphosis (Gosner stage 38-39). We found that high-status tadpoles metamorphosed before the other classes, but food availability had no effect on developmental timing. By contrast, reduced food availability caused tadpoles of lower social status to develop more slowly, which allowed them to metamorphose at a larger body size than high status tadpoles. Their hindlimbs were significantly smaller, however, which may suggest an allocation trade-off that could affect long-term fitness. Assessment of CORT content of these tadpoles at metamorphosis and as juveniles will allow us to determine both proximate and long-term impacts of social status and nutrition on neuroendocrine stress axis function.

***38.6*** CRINO, O.L.*; KLAASSEN VAN OORSCHOT, B.; MALISCH, J.L.; BREUNER, C.B.; University of Montana; *ondi.crino@gmail.com*

***The effects of distance to road, nest site characteristics, and parental stress response on nestling stress response in the Mountain White-crowned sparrow (Zonotrichia leucophrys oriantha)***

Activation of the hypothalamic-pituitary-adrenal (HPA) axis in response to stress is a ubiquitous phenomenon across vertebrate taxa. Glucocorticoid responses in developing animals have been well described in several mammalian and avian species. While glucocorticoid responses may enhance offspring success through increased food availability or accelerated transition to independence, they may also decrease offspring quality and alter life-long patterns of glucocorticoid secretion. To better understand the control of HPA function during development, we examined several factors that may shape glucocorticoid responses in the Mountain White-crowned Sparrow ( *Zonotrichia leucophrys oriantha*) nestlings including: nest proximity to a high traffic road, the ecological characteristics of nest site, and parental stress response. We found that nestling corticosterone titers are negatively correlated with distance to a high traffic road and that nest site characteristic influence nestling stress response. Analysis of the parental stress response and its relationship to nestling stress response is ongoing.

***89.4*** CROLL, R.P.*; STOYEK, M.R.; SMITH, F.M.; Dalhousie Univ; *roger.croll@dal.ca*

***Effects of wall compliance on swimbladder function in zebrafish***

Zebrafish use gas-filled swimbladders to attain nearly neutral buoyancy, contribute to three-dimensional orientation (pitch and roll), and facilitate hearing (via the Weberian apparatus). However, swimbladder volume varies with depth-related pressure according to Boyle's Law and also depends on the viscoelastic properties of its wall. In this study the effects of pressure on swimbladder volume, both in vivo and in situ, were observed along with the behaviour of the whole animal, using pressure chambers to simulation vertical movements to and from a depth of 300 cm within the water column. The anterior chamber was found to be highly compliant with large volume changes accomplished in part through a series of regular pleating of its wall. In contrast, the posterior chamber was found to be minimally compliant. These regional differences in compliance caused significant changes in the distribution of gas within the swimbladder system, but the whole-body pitch angle changed only ±2o over the tested range of pressure tested. Ongoing experiments on zebrafish hearing have shown repeatable increases in swimming activity (arousal) in adult zebrafish during exposure to sound stimuli. Comparison of the results of these tests to zebrafish tested after simulated depth changes will elucidate any effects that changes in swimbladder volume may have on audition. It is assumed that our observations on swimbladder compliance and its effects on function are similar to what zebrafish would experience in their natural environment thereby adding a much needed link to existing experimental knowledge of the zebrafish.

***12.5*** CROSSIN, G.T.*; TRATHAN, P.N.; PHILLIPS, R.A.; WILLIAMS, T.D.; Simon Fraser University (Canada) and Centre for Ecology and Hydrology (UK), British Antarctic Survey, Simon Fraser University; *crossin@interchange.ubc.ca*

***Trade-off between migration and reproduction, and the physiological basis of egg size dimorphism in Macaroni penguins.***

Crested penguins (*Eudyptes spp.*) are unique as they lay 2-egg clutches in which the first egg (A-egg) is much smaller (55-84%) than the second egg (B-egg). Macaroni penguins (*E. chrysolophus*) have one of the greatest degrees of egg-size dimorphism within the genus, and a previous study presented some evidence that inter-individual variation in dimorphism is a function of the amount of time spent in the breeding colony prior to laying. This suggests that the female reproductive system only fully develops after arrival at the colony, and that eggs initiated and developed while still at sea are subject to a constraint imposed by the demands of migration. To address this, we studied the reproductive physiology of Macaroni penguins breeding at Bird Island, South Georgia (54°S), with the aim of describing the physiological mechanisms underlying egg dimorphism. Specifically, we tested the hypothesis that "reproductive readiness", as measured by plasma yolk precursor levels, increases with time after arrival, and that the smaller A-eggs, which begin developing at sea, do so when yolk precursor levels are below maximal relative to the B-egg. We collected serial blood samples from 48 female penguins from the time of arrival at nest sites to just after the laying of their A- and B-eggs. We also took egg measurements. As yolk deposition is driven by the 17β-estradiol-induced production of vitellogenin (VTG, the principal yolk protein), we predicted that concentrations of circulating VTG would increase through time and show strong correlations with egg-size dimorphism. Results are discussed with emphasis on the timing and costs of reproductive preparedness in a migratory species.

***63.10*** CROZIER, Lisa G.; NWFSC, NOAA-Fisheries; *Lisa.Crozier@noaa.gov*

***Using time-series data to partition evolutionary and plastic responses to climate change in Pacific salmon: a case study of the historical shift in run-timing in Columbia River sockeye salmon***

Salmon are highly adaptable and behaviorally complex, and they are responding actively to climate change. Sockeye salmon now migrate up the Columbia River almost 11 days earlier than they did in the 1940s. I explored a combination of plastic and evolutionary mechanisms that could explain this shift, and compared alternative models using an information theoretic approach. Based on recent radio-tracking studies of sockeye salmon migration success, I developed a model of thermal stress-induced mortality. Using ~60 years of daily fish counts and river temperatures, I back-calculated cumulative historical selection pressure. I show that there has likely been consistent selection for earlier migration. Both the long-term trend and annual variation in migration timing are consistent with the effects of ongoing evolution and a plastic response to river flow. Although selection improves the ability of salmon to tolerate long-term climate change, it also exacts a demographic cost (i.e., mortality), which could be significant in small populations. Rising river temperatures are certain to continue as the climate warms, and will affect salmon life histories across their geographic range. Understanding both ecological and evolutionary responses will facilitate conservation of these diverse species.

***30.3*** CSIKAR, E.J.*; VALENTINO, R.J.; WALSBERG, G.E.; ASU, C.H.O.P.; *Ecsikar@asu.edu*
***Correlation between differences in CRF levels and behavior in wild-trapped kangaroo rats***
In laboratory studies in which CRF was administered to animals in a novel environment, animals showed an increase in vigilance, a reduction in ambulatory movement, and increased levels of anxiety. One paradigm for anxiety is the open-field test which contrasts a rat's innate curiosity to explore a novel environment with its desire to remain in a safe situation. In general, the anxiety level of the animal is inversely proportional to the amount of time spent exploring the center of the open field. Another model is the shock-prod paradigm, which measures the response of the animal to a mild electric shock. Generally, behaviors may be divided into two categories: active and passive. These experiments were conducted to examine behavioral consequences of observed differences in CRF in wild-trapped kangaroo rats from contrasting habitats. More specifically, animals from three sites (2 mesic/chaparral and 1 xeric/desert) were trapped, brought into captivity, maintained for 48 hours under standard small rodent housing conditions then individually run in the open field trial. Twenty-four hours after the open field trial, animals were individually run in the shock-prod trial. It was predicted that both groups of mesic animals would both be significantly different from their xeric counterpart; however, the results did not confirm this. Results indicate that animals from the most densely vegetated mesic site spent significantly more time in the center of the arena and spent a greater portion of time digging in the shock trial than animals from the second mesic site and the xeric site. Although unanticipated, the results are generally consistent with other research that indicates a switch from an active to a passive coping strategy when exposed to a chronic or severe stressor.

***92.1*** CUNNINGHAM, Gregory B*; NEVITT, Gabrielle A; St. John Fisher College, University of California, Davis; *gcunningham@sjfc.edu*
***Tuning a nose to forage: Evidence for olfactory learning in a procellariiform chick***
Burrow nesting procellariiform seabirds use olfactory cues for both foraging and nest recognition. As chicks, burrow nesters develop in the dark, but are exposed to both prey-related and individual-specific scents through contact with their parents. This exposure suggests that chicks may have the opportunity to learn odours while still in the nest. In this study, we examined whether exposure to odourants during development might influence olfactory search behaviour expressed later in life. To test this idea, we exposed eggs of thin-billed prions *Pachyptila belcheri* to a rosy-scented novel odour (phenyl ethyl alcohol, PEA) or a control (water) just before hatching; chicks were then tested with these odours in a simple wind tunnel. Prior to fledging, subjects who had received pre-exposure to PEA displayed head sweeps nearly twice as frequently as control birds did when presented with PEA. This study demonstrates that under natural rearing conditions, procellariiforms learn odour characteristics of their rearing environment in the nest.

***S8.7*** CUNNINGHAM, Clifford W*; MIGLIETTA, MariaPia; BUSS, Leo W; Duke University, Pennsylvania State University, Yale University; *cliff@duke.edu*
***Evolution of ontogeny in the Hydractiniidae: Losing jellyfish and committing to the colony stage***
We use a multi-gene phylogeny to study heterochrony and evolutionary variation in the pelagic sexual medusa (jellyfish) and benthic asexual (colony) stages of the hydrozoan family Hydractiniidae. This family shows nearly all the life cycle diversity of the Class Hydrozoa, with a great variety of colony forms, and well-established model organisms such as *Podocoryna carnea* or *Hydractinia echinata*. Using a multi-gene phylogeny of the Hydractiniidae, we study the evolution the ontogeny of the jellyfish stage, which is repeatedly lost through progenesis. This loss of the free-living jellyfish stage is correlated with predictable changes in colony morphology, and with the range of host-specificity. We conclude by asking whether a free-living jellyfish can be regained after it has been lost for a hundred million years or more, with reference to Dollo's law.

***47.3*** D'ORAZIO, Anthony E.*; DALY, Marymegan; Ohio State University; *dorazio.8@osu.edu*
***Mid-intertidal movement: variation among and within clones of Anthopleura elegantissima***
The intertidal sea anemone *Anthopleura elegantissima* has garnered attention for its agonistic behavioral response to conspecific non-clonemates and its division of labor between polyps specializing in either agonistic encounters (“warriors”) or sexual reproduction (“reproductives”). The behavior and resource allocation strategy is inferred to be a response to the constraints of space limitation in the intertidal zone. If this is the case, then movement or expansion by a clone through movement of its constituent polyps should be important to clone success. Because of *A. elegantissima*’s natural history we make two primary hypotheses regarding movement: 1.) Different clones move differently; 2.) propensity for movement differs among members of a clone in a predictable way, related to their role within the clone. We used two experimental situations to explore these hypotheses. In our first experiment, polyps were given the opportunity to move toward clonemates or non-clonemates. There were strong differences in frequency of movement between clones and between warrior-type polyps and reproductive polyps, with the former types moving more often; this result lends support to both hypotheses. Some of the largest differences in movement were between clones that occurred adjacent to one another in nature. We also found that polyps moved in the direction of the clonemate more often than predicted by chance. In our second experiment, we placed groups of clonemates alone or with polyps from another clone and monitored average distance between clonemates over a more extended period (7-23 days) as a proxy for movement. We found added support for differences in movement between clones. These results may help explain how neighboring clones maintain a relatively stable interclonal boundary despite unequal fighting abilities.

***15.11*** DAI, W*; HWANG, PP; DUAN, C; University of Michigan, Institute of Cellular and Organismic Biology, Taiwan; *cduan@umich.edu*

***Exploring the duplicated zebrafish genes: Discovery of a novel role of insulin-like growth factor binding protein (IGFBP)-5 in calcium homeostasis***

Insulin-like growth factor binding proteins (IGFBPs) are high affinity binding partners for IGFs and play important roles in regulating IGF availability and actions. IGFBP-5 is the most conserved member of this gene family. Recently, we have shown that zebrafish have two distinct IGFBP-5 genes, likely resulted from a gene duplication event during teleost evolution. These two genes exhibited distinct spatial and temporal expression patterns. Interestingly, one of the two genes, igfbp-5a, is specifically expressed in epidermal ionocytes surrounding the yolk sac and gill arches. Fluorescent double-labeled in situ hybridization analysis revealed that igfbp-5a mRNA is co-localized with trpv6 mRNA but not with the H+-ATPase atp6v1al mRNA. In fish, the epithelial Ca2+ channel Trpv6-expressing ionocytes are known to be important for calcium uptake. Acclimation of zebrafish embryos to artificial water with altered ion concentrations showed that igfbp-5a mRNA levels are increased in response to reduced calcium concentrations. Low Ca2+ freshwater also increased the number and size of the igfbp-5a-mRNA expressing ionocytes, while it had no effect on the atp6v1al-mRNA expressing ionocytes. To test the role of IGFBP-5a in these cells and in calcium metabolism, antisense morpholinos were used to knockdown IGFBP-5a in zebrafish embryos. Compared with the control embryos, IGFBP-5a knocked down embryos had increased calcium content and calcium influx. Knocking down of IGFBP-5a also resulted in an increase in the number of Trpv6-expressing ionocytes. These findings suggest that IGFBP-5a is specifically expressed in Trpv6-expressing ionocytes and its expression is regulated by environmental calcium concentrations. Our study in zebrafish has also unraveled a novel role of IGFBP-5 in calcium homeostasis.

***75.6*** DALEY, MA*; FISHER, RL; GILES, T; WARNER, S; Royal Veterinary College; *mdaley@rvc.ac.uk*

***Metabolic energy cost of locomotion over uneven terrain in the common pheasant (Phasianus colchicus).***

It has been proposed that a trade-off exists between economy and stability of legged locomotion. However, it is unclear whether this is generally true, because little research exists on the relationship between stability and metabolic energy cost of locomotion. If such a trade-off does exist, animals might adopt different movement strategies when running over uniform *versus* uneven terrain. To test this idea, we have measured kinematics and metabolic cost energy cost of locomotion in five pheasants (Phasianus colchicus) as they ran on an obstacle treadmill. We measured terrains with obstacles at 10, 20, 30 and 40% leg length, with fixed height obstacles at approximately every fifth step. We used open-circuit respirometry with Nitrogen dilution calibration to measure metabolic energy consumption. From kinematics it appears that 60% of the movement strategy can be explained by the birds adopting a more crouched posture to minimise changes in body height over the obstacle. For highest obstacle conditions, there is evidence that the birds increase their body height in anticipation of an upcoming obstacle, whereas in the smaller obstacle conditions, there is little evidence of anticipation. Oxygen consumption increased approximately linearly with obstacle height for the 10-30% leg length obstacle conditions. Surprisingly, there is a sharp reduction in oxygen consumption at the 40% leg length condition. This discontinuity suggests that the birds switch to a different locomotor strategy for highest obstacle heights, and may also suggest that the birds are not optimising their movement strategy for economy at the lower obstacle heights (supported by a Royal Society Research Grant to MAD).

***S8.1*** DALY, M*; RODRIGUEZ, E; Ohio State University, American Museum of Natural History; *daly.66@osu.edu*

***Progress and problems in understanding relationships among sea anemones***

Actiniarian sea anemones are among the most diverse and successful members of the anthozoan subclass Hexacorallia, being found at all depths and latitudes and in all marine habitats. Members of this order exhibit the greatest variation in anatomy, biology, and life history in Hexacorallia, and lack any morphological synapomorphy. Nonetheless, previous molecular phylogenetic studies have found that Actiniaria is monophyletic with respect to extant hexacorallians. Relationships within Actiniaria have been more difficult to elucidate, and those relationships that have emerged conflict significantly with taxonomic concepts at all hierarchical levels. We discuss points of consensus and controversy in Actiniarian phylogeny, exploring the implications of the poly- and para- phyly of major groups.

***26.2*** DALZIEL, AC*; SCHULTE, PM; University of British Columbia; *dalziel@zoology.ubc.ca*

***Evolutionary variation in physiological traits contributes to differences in swimming capacity among migratory and non-migratory threespine stickleback (Gasterosteus aculeatus).***

The threespine stickleback species group contains a number of unique ecotypes, including migratory and non-migratory (stream-resident) populations. The migratory and stream-resident ecotypes show heritable differences in endurance swimming capacity that have evolved in parallel in multiple populations along the coast of British Columbia, suggesting that natural selection has played a role in shaping these differences in performance. To determine which underlying traits may contribute to these differences in swimming performance, and if they too have evolved in parallel, we conducted a common garden experiment using progeny from parental fish collected from two different locations. We raised the progeny of pure stream-resident, pure migratory, and reciprocal F1 hybrid crosses in the lab and tested these fish for differences in swimming performance and underlying physiological and biochemical traits. We have found that migratory sticklebacks, and F1 hybrids that swim as well as pure migratory fish, can achieve significantly higher maximal metabolic rates and have larger pectoral muscles and pectoral fins than do stream-resident fish and F1 hybrids that are poor swimmers. We will present data that further examines the physiological and biochemical properties of the swimming musculature (i.e. muscle size, fiber-type composition, enzyme capacities), and other steps in the oxygen transport cascade (i.e. gill surface area, heart size) to determine which traits are necessary for superior endurance swimming performance.

***16.6*** DANAHER, B.*; MUNRO, E.; SHERRARD, K.; ROBIN, F.; University of Washington; *brooke.danaher@gmail.com*

***Ascidian neural tube morphogenesis proceeds normally following ablation of the notochord***

Ascidian neurulation proceeds through concurrent invagination and extension of a monolayer neural plate. The underlying notochord forms simultaneously through invagination and convergent extension of a monolayer plate into a cylindrical rod. The notochord is a likely candidate for effecting neural morphogenesis: it is the substrate for neural tissue throughout neurulation, and its robust convergent extension is a probable source of extensile force in the ascidian tailbud. Here we use laser ablation at the 64-cell stage and time lapse confocal microscopy to examine neural morphogenesis in the absence of a notochord. We show that neural plate organization, invagination, and neural tube closure all continue normally. Neural tube extension is slightly limited, but neural cells retain normal organization and significant elongation. Our results indicate that neural morphogenesis is a robust process, and suggest alternative driving forces for ascidian tailbud elongation.

***63.11*** DANIKAS, L.N.*; COBB, V.A.; Middle Tennessee State Univ.; *lndanikas@gmail.com*

***Latitudinal Variation in Locomotor Performance of the Northern Watersnake, Nerodia sipedon***

Locomotor performance is arguably one of the most important physiological mechanisms for capturing prey and avoiding predation, and, is thereby generally subject to pressures of natural selection. For ectothermic animals, locomotor performance varies considerably with temperature. Locomotor performance typically increases with temperature, reaching an "optimal" or maximal efficiency level before declining as the critical thermal maxima is approached. Across a broad geographic range with considerable climate variation, the thermal physiology of ectothermic species could vary in a predictable pattern, exhibiting adaptations to regional conditions. The northern watersnake (*Nerodia sipedon*) is one of the most wide ranging snake species in North America, and is exposed to a wide range of environmental conditions, making it a good model species to test latitudinal gradients. We examined the effect of temperature on neonate locomotor performance (maximal crawling and swimming speeds) from two latitudes representing the northern and southern localities for this species. Maximal crawling and swimming speed differed significantly between the two populations, with the southern population exhibiting optimal terrestrial locomotor performance at a temperature 5°C higher than that of the northern population. Aquatic trials exhibit similar curves for both northern and southern populations, however performance differed significantly. Optimal temperatures varied between latitudes only for terrestrial tests, which may suggest differences in habitat use by populations. This pattern of separation between the two populations indicates possible thermal adaptations to regional climatic conditions by ectotherms and could potentially influence selective pressures.

***102.6*** DAVID, Gwendolyn*; ORTIZ-BARRIENTOS, Daniel; SMITH, Michelle; WILSON, Robbie; Univ. of Queensland, Brisbane; *g.david@uq.edu.au*

***I can score more than you! Investigating the importance of skill on whole organism performance in a complex environment***

Skill, the ability to effectively execute a learned motor task, plays a fundamental role in the ecology and evolution of species. Success in important ecological tasks such as foraging, hunting, sexual signalling and male-male competition should be greatly affected by skill. Furthermore, the cognitive ability to learn is determined by genetic and environmental factors, and therefore skill should play a major role in the evolution of many species. However, despite the large body of literature addressing physiological performance and its effect on whole organism performance in nature, little attention is given to the role of skill. Quantifying performance of organisms in ecological tasks in nature is complex because individuals experience many abiotic, intra- and inter-specific interactions. In addition, quantifying skill in non-human model systems can be logistically problematic. Therefore, in this study we measured athletic performance and skill in humans as a model system, and quantified the relative importance of these traits on performance in a highly complex environment. Multiple physiological and skill tasks were measured in male soccer players ex situ, and performance was assessed in competitive, 11 vs 11 soccer matches. Soccer matches are an ideal model system for assessing individual performance in a complex environment. Analogous to nature, soccer matches represent a complex environment in which individuals experience many intraspecific and abiotic interactions, and an individual's performance relies on their underlying skill, athletic ability and morphology. Moreover, many of these interactions can be easily quantified along with whole organism performance. The results of this research are discussed with particular reference to studying the evolution of skill in non-human models.

***67.2*** DAVIS, J.*; JIANG, P.; WILLARD, S.; KOUBA, A.; Rhodes College, Memphis, TN; Memphis Zoo, TN, Memphis Zoo, TN, Mississippi State University; *davisj@rhodes.edu*

***Natural and captive habitat conditions of Chinese giant salamanders***

The Chinese giant salamander (*Andrias davidianus*) is one of three extant species of in the family Cryptobranchidae. All three species are at risk; the Chinese giant salamander is perhaps the most imperiled due to habitat loss and over-harvesting for human consumption. Despite long-term harvesting of natural populations, captive breeding efforts, and government protection, little is known regarding habitat conditions required to sustain giant salamander populations. The purpose of this study was to determine key habitat conditions in natural streams and in captive breeding farms in the Qinling Mountains of China. We tested the hypothesis that environmental conditions at successful breeding farms are more similar to natural conditions compared to conditions at unsuccessful breeding farms. Since the species is strictly aquatic, several water quality indicators as well as light intensity at the water surface were measured at twelve natural sites and eight breeding farms. Analyses indicated that mean water temperature at successful farms (20.7 $^{o}$C) did not differ from natural stream sites (19.8 $^{o}$C) and notably, the mean water temperature at unsuccessful farms (23.9 $^{o}$C) was significantly higher than both natural sites and successful farms ($p < 0.05$). No significant differences were found among sites for other conditions including: pH, dissolved oxygen, salinity, turbidity, or light intensity. Among measured conditions, only water temperature was a significant predictor of breeding success. Improving conditions in unsuccessful breeding farms, through water quality management, may increase breeding success and contribute to reintroduction programs such that sustainable populations of this critically endangered species may be established in nature.

***S8.8*** DAWSON, M.N*; BAYHA, K.M.; GOMEZ DAGLIO, L.E.; COLLINS, A.G.; University of California, Merced, Smithsonian Institution; *mdawson@ucmerced.edu*

***Phylogeny and Ecology of Jellyfish (Scyphozoa) Mass Occurrences***

Most investigations of the mass occurrences of jellyfish continue to focus on the ecological responses of jellyfish to environmental change. Yet still, after two decades of ecological study, "management actions appear to be difficult and uncertain" (Richardson et al. 2009). This difficulty may arise in part because the evolutionary context for modern-day ecological responses are rarely considered. Prior phylogenetic analyses of Scyphozoa have offered a glimpse of the possible value of this perspective: transitions in the evolution of jellyfish mass occurrences – from aggregations to blooms and swarms – coincided with the evolution of a subset of life-history and morphological characters. The inference that these phenotypic characteristics cause or permit mass occurrences, however, remains preliminary due to incomplete taxon sampling, low resolution in some parts of the tree, and a somewhat limited phenotypic character matrix. Here, we revisit the question of "what is behind the evolution of mass occurrences?" using complete family-level taxonomic coverage of Scyphozoa, more rigorous phylogenetic analyses with additional loci, and a more extensive phenotypic dataset (ca. 200 characters). This analysis provides greater confidence in inferences of the evolution of mass occurrences, but for many taxa the phenotypic data remain too sporadic, or simply unavailable in the literature, to fully answer our question. Renewed effort to gather geographically extensive ecological, ethological, morphological, and physiological data describing all stages of all species of Scyphozoa, identified accurately and placed phylogenetically, is a logical and imperative next step to increase understanding of the evolution of jellyfish mass occurrences, thereby enabling development of a more predictive framework.

***33.1*** DE BOEF, M.*; BIEWENER, A. A.; Concord Field Station, Harvard University; *maria.deboef@gmail.com*

***The structure-function relationship in bone microstructure: An experimental study in Helmeted GuineaFowl (Numida meleagris)***

It has been well established that bone macrostructural morphology is strongly influenced by bone function. This relationship is evident not only in the how bones with different functions are structured but also in how bone structure adapts to changes in loading patterns. Several studies have found that this strong structure-function relationship extends to bone microstructural morphology as well. However, the precise relationship between the various microstructure morphologies and types (tensile, compressive or shear) and magnitudes of bone strain has not yet become clear. In this study, Helmeted GuineaFowl (*Numida meleagris*) were exposed to flight and running exercise during development. The types and magnitudes of strain experienced by the humerus and tibiotarsus were quantified and compared to the bone microstructure found in these bones. Bone microstructure was characterized using measures of vascular orientation and osteocyte density. It was found that significant differences in these bone microstructure characteristics existed between skeletal elements and between exercised and control birds. Vascular canals in the tibiotarsus were primarily oriented along the longitudinal axis. In contrast, vascular canals in the humerus were primarily oriented within the plane of section and parallel to the periosteal surface, a pattern often described as laminar. These patterns were exaggerated in the exercised birds. Osteocyte density was higher in the tibiotarsus than in the humerus and higher in the exercised birds than in the controls. There was no correlation between bone microstructure in specific regions of a bone (medial, lateral, dorsal, ventral) and the type or magnitude of strain experienced by that region.

***105.1*** DE MIRANDA JR., M.A.*; CABLE, A.E.; KANATOUS, S.B.; Colorado State University , Colorado State University; *demiranda.michael@gmail.com*

***What does it take to exercise while holding your breath? The underlying secrets of myoglobin regulation in seal muscle cells.***

The purpose of this study was to determine if cultured Weddell seal (*Leptonychotes weddelli*) primary skeletal muscle cells inherently possess adaptations to diving under hypoxia. Weddell seal primary skeletal muscle cells were cultured along side a $C_2C_{12}$ mouse skeletal muscle cell line and differentiated under normoxic (21% $O_2$) and hypoxic (0.5% $O_2$) conditions. Weddell seals cells were grown and differentiated in either low glucose DMEM supplemented with 2.5% lipid mixture or high glucose DMEM supplemented with 5% lipid mixture. After 7 days of differentiation into mature myotubes the cells were harvested and analyzed for differences in myoglobin concentration using a myoglobin assay and 2D gel electrophoresis. We hypothesized that cultured Weddell seal primary skeletal muscle cells would have elevated myoglobin concentrations when compared to cultured $C_2C_{12}$ mouse skeletal muscle cells. Our results indicate that under hypoxia the mouse cells down-regulated myoglobin by 31%. Interestingly under hypoxia, Weddell seal cells up-regulated myoglobin to concentrations 12-fold greater. In addition, myoglobin concentrations increased in Weddell seal cells, under normoxic and hypoxic conditions, as a result of increasing concentrations of lipid supplemented to the growth media. In contrast, lipid supplemented to the growth media of the mouse cells had no effect on myoglobin concentrations in either oxygen condition. Based on our results, we conclude that Weddell seal skeletal muscle cells differentially regulate myoglobin in response to hypoxia as compared to mouse skeletal muscle cells, which may be attributed to inherent adaptations to the low oxygen associated with breath-hold diving.

***98.1*** DEBAN, SM*; LAPPIN, AK; University of South Florida, California State Polytechnic University, Pomona; *sdeban@cas.usf.edu*

***Temperature effects on the motor control of ballistic prey capture in toads***

Elastic structures in musculoskeletal systems can enhance mechanical power output and extend the functional range of muscles. We investigated how elastic recoil mechanisms can also extend the thermal breadth over which ballistic movements can be performed in ectotherms by examining kinematics and motor control of ballistic tongue projection in toads. *Bufo terrestris* were imaged feeding at a range of body temperatures (12-34°C) with simultaneous recording of EMG activity of jaw levator and jaw depressor muscles. Elastically powered movements (rapid mouth opening and tongue projection) were compared to non-elastic, muscle-powered movements (slow mouth opening, mouth closing, and tongue retraction). Temperature had no significant effect on the velocity of elastically powered movements ($Q_{10}$ values of 1.0-1.2) but lower temperatures significantly reduced the velocity of muscle-powered movements ($Q_{10}$ values of 1.4-2.8). Nonetheless, temperature significantly affected muscle activity associated with both elastic and non-elastic movements. With increasing temperature EMG burst duration declined while EMG burst intensity increased ($Q_{10}$ values of 2.9-3.1). Elastically powered movements are thus less thermally dependent than muscle-powered movements, but temperature has similar effects on the motor control of both types of movement. These results accord with a bow-and-arrow model of ballistic movement in which elements with thermally independent elastic properties (e.g., tendons, non-contractile components of muscle) are strained by active muscle contraction in which the rate of tension development is thermally dependent. The thermally independent elastic elements subsequently recoil to power the ballistic movement.

***S7.3*** DEMASTER, David J.*; SMITH, Craig R.; THOMAS, Carrie J.; North Carolina State University, University of Hawaii, Honolulu; *demaster@ncsu.edu*

***Evidence for a Benthic Food Bank in West Antarctic Peninsula Sediments: Radiochemical and Benthic Biological Approaches***

Primary production and organic carbon export flux along the Antarctic continental shelf commonly are characterized by intense boom-bust seasonality. The FOODBANCS Project (FOOD for Benthos on the Antarctic Continental Shelf) conducted 5 cruises between December 1999 and March 2001 to the West Antarctic Peninsula (WAP) Shelf to determine the seasonal variability in organic matter flux to the seabed and to examine the fate of this organic matter on the seafloor and in benthic food webs. Sediment traps, time-lapse bottom photography, video surveys, a variety of coring efforts (mega-, box, and kasten), bottom trawls, and flux core measurements (oxygen, DIC, and nutrients) all support the hypothesis that the near-surface Antarctic sediments are acting as a “food bank”, with sedimentary processes (e.g., particle flux, bioturbation intensity, detritivore food availability, organic matter regeneration) exhibiting substantially less variation than the associated primary production rates in the overlying waters. In 2008 and 2009, FOODBANCS2 explored many of the same biogeochemical and benthic biological processes along an expanded N/S sampling grid on the WAP Shelf extending from 63ºS to 68ºS. This new project is using the gradient in ambient temperatures and ice cover to examine and predict the effects of climate change on Antarctic benthic ecosystem structure and function. The seabed integrates many of the short-term variations occurring in the water column and thus provides a unique perspective of integrated climate change effects in the Antarctic.

***63.4*** DES ROCHES, S.*; ROBERTSON, J.; HARMON, L.; ROSENBLUM, E.B.; University of Idaho; *desr7280@vandals.uidaho.edu*

***Ecological Release in a Geologically Young Community***

Ecological release is a prominent hypothesis in evolutionary ecology regarding colonization of newly available habitats by a population. In the original population, selective pressures maintain ecologically relevant characteristics within an optimal range; however, in the absence of these pressures, individuals are more variable in their use of available niches. I studied the colonization of White Sands, New Mexico, by Sceloporus undulatus. These lizards live two distinct habitats in the Tularosa Basin: White Sand dunes and outside dark soils. I tested three hypotheses regarding whether White Sands Sceloporus undulatus experienced ecological release. First, I examined whether cryptic colouration is an adaptation that allowed the invasion of White Sands using matched and mis-matched clay models to gauge predator attacks. Second, I surveyed competitors and predators across the habitats to determine if their abundance decreased within the dunes. Third, I documented morphology and habitat use to establish whether inter-dune individuals are more variable than their outer-dune counterparts. Although morphologically, individuals inhabiting White Sands were not more variable, they used a greater variety of available habitat than their dark-soils counterparts. I demonstrated that the number of potential competitors is higher in the dark soils habitats than in White Sands; yet, I failed to show evidence of predation being higher on mismatched clay lizards in either habitat. The current absence of significant predation differences between White Sands and dark soils, however, does not indicate that this was previously the case. My results show that evidence of ecological release of White Sands S. undulata may be a result of both the historical and recent relaxation of selective predation and competition.

***4.5*** DESCAMPS, E*; TIAN, H; SANDERS, E; VAN HENGEL, J; VAN ROY, F; ADRIAENS, D; Ghent University, Gent, Flanders Interuniversity Institute for Biotechnology , Gent, Interuniversity Institute for Biotechnology , Gent, Interuniversity Institute for Biotechnology , Gent; *emilie.descamps@ugent.be*

***Perturbations in the E-cadherin/catenin junctional complex in mouse embryos resulting in exencephaly***

The essential role of cell-cell adhesion molecules in morphogenetic processes, particularly for the members of the cadherin protein family, has been acknowledged for years. The best-known adhesion and signaling system is the E-cadherin/catenin complex. The catenins are associated with the cytoplasmic domain of cadherin. We want to investigate the role of defects in cell adhesion molecules and their associated signaling molecules in craniofacial malformations in the mouse. To this end, we are generating tissue-specific knock-out mice for selected members of the cadherin/catenin junctional complex. We aim to find out what modifications are linked to a defect in the E-cadherin/catenin complex. For that, Wnt1Cre;p120ctn$^{fl/fl}$ KO mice were generated, where the floxed p120ctn alleles are eliminated in the Wnt1 expressing cells, mainly neural crest cells. This perturbation often resulted in exencephaly phenotypes. The present study provides a 3D-anatomical characterization of the craniofacial complex of this phenotype. By performing a contour-based shape analysis of the head of early mouse embryos (11.5dpc), a phenotypic characterization is done to determine the regions that are affected. For the description of the internal anatomy, 3D reconstructions of mice at 16.5dpc were made based on images of micro CT-scanning. The first results displayed absence of skeletal parts covering the extruded brain and reduced or displaced skeletal parts in the skull. Supported by the Concerted Research Actions (GOA) of Ghent University.

***59.11*** DEVRIES, M. S.*; HOLBROOK, A. L.; WINTERS, C. P.; JAWOR, J. M.; The University of Southern Mississippi; *Margaret.DeVries@usm.edu*

***Flexibility of the HPG Axis of Female Northern Cardinals (Cardinalis cardinalis): Implications for Behavior and Reproductive Context***

Testosterone’s influence on aggression and parental care has been well studied in male birds, but the relationship between testosterone (T) and female behavior is poorly resolved. The impact of elevated T on female aggression and parental care varies among species and recent evidence suggests that T elevations influencing female behavior could depend upon social context and/or reproductive stage. Using gonadotropin-releasing hormone (GnRH) challenges and simulated nest intrusions (SNIs), we examined the flexibility of the hypothalamic-pituitary-gonadal (HPG) axis of female Northern Cardinals (*Cardinalis cardinalis*) across multiple reproductive periods. Results indicate that female cardinals have the capacity to elevate T before the onset of breeding (via GnRH challenge) and in response to intrasexual intruders at the nest during incubation (SNI). Testosterone levels induced by GnRH challenges did not significantly differ from natural increases in T produced in response to SNIs. However, our findings suggest that the HPG axis of female cardinals is relatively inflexible while females are providing nestling care (e.g., feeding). These results imply that while elevated T might support female aggression in this species, the responsiveness of the HPG axis of female cardinals could be dependent on reproductive context.

***28.1*** DEVRIES, M. S.*; LU, S.; MARTíNEZ DEL RIO, C.; DAWSON, T. E.; Univ. of California, Berkeley, Univ. of Wyoming; *msdevries@berkeley.edu*

***Determining diet over multiple timescales: isotopic turnover in mantis shrimp***

The mantis shrimp species *Neogonodactylus bredini* (Stomatopoda) produces high accelerations and forces with hammer-like raptorial appendages that are thought to be specialized for smashing hard-shelled prey. Yet preliminary observations suggest that *N. bredini* consumes both hard- and soft-bodied prey. Stable isotope analysis (SIA) of different tissue types has been used to track changes in vertebrate diet over time, because different tissues assimilate nutrients, or "turnover," at different rates. We tested whether muscle and hemolymph in *N. bredini* also exhibited different turnover rates. We measured how long it took for a known prey item to assimilate into the tissues by feeding individuals solely a marine snail, *Tegula funebralis* for 290 days and by periodically dissecting out muscle and hemolymph tissues for SIA of carbon and nitrogen. We then fit an isotopic incorporation model to the change in isotopic value for both tissues. A one-compartment model of turnover was well-supported by the data and revealed that average (±SD) incorporation of delta$^{13}$C and delta$^{15}$N was much faster in hemolymph than in muscle but that nitrogen was retained longer than carbon (delta$^{15}$N = 52.3±21.5 days in muscle and 15.2±6.0 days in hemolymph; delta$^{13}$C = 47.9±30.8 days in muscle and 3.8±2.2 days in hemolymph). Carapace length and weight did not change, suggesting that incorporation rates were due to catabolic turnover. To our knowledge, this study is the first to show different turnover rates between two tissue types in invertebrates. Short and long turnover rates allows for determining diet over short and long timescales in one individual. This technique will yield novel insights into whether *N. bredini's* unique appendage morphology narrows or widens diet breadth over time.

***59.9*** DEY, C.J.*; O'CONNOR, C.M.; GILMOUR, K.M.; VAN DER KRAAK, G.; COOKE, S.J.; McMaster Univ., Hamilton, ON, Carleton Univ., Ottawa, ON, Univ. of Ottawa, ON, Univ. of Guelph, ON; *cody.dey@live.com*

***Behavioural and physiological responses of a wild teleost fish to cortisol and androgen manipulations during parental care***

It is widely accepted that the endocrine system plays an important role in the initiation and control of reproductive activities, including parental care. Despite an abundance of studies regarding this relationship, elucidation of the roles of each hormone in relation to specific behaviours has proven difficult. In some parental male fish, androgen hormones are critical in stimulating territory acquisition and nest-building behaviours but their role during parental care is more contentious. Likewise, glucocorticoids have been suggested to play a key role in mobilizing energy reserves required for energetically costly behaviours such as protracted brood care. This study investigated the role of androgens and cortisol in mediating parental care behaviours of the smallmouth bass using exogenous manipulations of hormone titers. Behaviours of parental fish treated with cyproterone acetate, an anti-androgen and those treated with cortisol were examined in the context of parental vigilance, aggressive nest-defence behaviours and nest success and compared to non-treated parental fish. Furthermore, plasma biochemical energetic and nutritional status indicators were measured and related to endocrine titers and parental behaviour. This study revealed that cortisol treatment resulted in a significant decrease in nest success, possibly due to the energetic cost of sustained levels of the hormone. Interestingly, cortisol treatment did not affect other parental care behaviours. In addition, cyproterone acetate treatment decreased nest defence aggression towards a simulated brood predator. Overall, these findings suggest an important role for both androgens and cortisol as proximate mediators of parental care in fishes.

***38.9*** DI POI, C.; ATKINSON, S.*; HOOVER-MILLER, A.; BLUNDELL, G.; University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau AK, Alaska Sea Life Center, Seward AK, Alaska Department of Fish and Game's, Juneau AK; *atkinson@sfos.uaf.edu*

***Presence of the mother influences the stress response in harbor seal pups***

For many species, the presence of a significant social figure down-regulates physiological responses and hence serves to buffer the individual against stressful stimuli. We studied how the presence of the mother regulates both behavioral and endocrinological responses of harbor seal (Phoca vitulina) pups to a stressful event (capture and sampling). Blood samples were taken for circulating cortisol and 5-HT quantification for mother-pup pairs, dependent pups alone (caught without their mother), weaned pups alone and single adult females. Behaviors of pups, vocalisation and agitation levels, were recorded as well. All seals were captured, sampled and released in Endicott and Tracy Arms, Southeast Alaska during the 2009 pupping season. Neither circulating cortisol nor 5-HT concentrations were affected by time passed between the capture and blood collection. Accompanied pups showed significantly higher levels of agitation and vocalisations than both dependent pups alone and weaned pups, possibly due to the close presence of their mother during the sampling. Moreover, vocalizations in harbor seal pups are known to have a role maintaining contact with the mother, while they naturally subside once they have weaned. The presence of the mother significantly reduced the cortisol response of her pup compared to that measured for pups alone (both dependent and weaned pups). The mothers with pups had higher concentrations of cortisol compared to single females. Differences in 5-HT levels observed between pups or females were not conclusive. These results provide the first evidence that the presence of the mother may decrease the magnitude of the glucorticoid stress response in her offspring in phocids.

***58.5*** DIAL, KP; Univ Montana, Missoula; *kdial@mso.umt.edu*

***When kids out-perform adults: Contrasting ontogenetic locomotor performance for two species of Galliform birds***

At hatching, megapods (e.g., brush turkey, malleefowl) are the most well-developed (ie., super-precocial) birds in the world and even possess flight-capable wings. I studied ontogeny of locomotion in Australian brush turkey (*Alectura lathami*) (N=9) spanning age classes from hatchling to adult using field-captured animals brought to the lab. Birds were challenged to ascend steep textured inclines (equipped with a force-plate) and videotaped over a wide-range of angles (horizontal to 110$^{o}$). As found previously for chukar partridge, brush turkeys preferentially employ wing-assisted incline running (WAIR) rather than fly to ascend to an elevated refuge. However, in contrast to all other bird species studied to date, flap-running incline performance in brush turkeys degraded with age. The youngest birds successfully ascend the most aggressive inclines where older animals fail to perform. Wing loading, ground reaction force (parallel and normal), acceleration, and wing-stroke kinematics are compared between the two clades. Within Galliformes, developmental trajectories for locomotion are strikingly different and appear to be correlated with the degree of parental care. NSF 0417176.

***70.6*** DIAL, TR*; CARRIER, DR; University of Utah; *trdial@gmail.com*

***Precocial hindlimbs and altricial forelimbs of developing Mallard ducks: A study of locomotor performance and morphometrics***

The young of some precocial species exhibit near-adult levels of locomotor performance. Waterfowl (Anseriformes) have an unusual developmental trajectory wherein their precocial hindlimbs exhibit the capacity for high levels of aquatic and terrestrial locomotion, whereas their forelimbs undergo a much more altricial trajectory. To gain a better understanding of the functional consequences of altricial versus precocial development I am investigating the locomotor ontogeny of Mallards (*Anas platyrhyncos*, n=80) from day of hatching to adulthood. Using high-speed video, maximal whole-body escape performance (acceleration and velocity) was quantified during running, swimming, flapping descent and takeoff across ontogeny. A growth series of morphological measurements was collected and directly compared to performance data. Long bone mid-shaft diameter and muscle mass scaled to body mass with negative allometry in the hindlimb, but with strong positive allometry in the forelimb. Hatchlings exhibited near-adult levels of hindlimb performance during swimming and running. In contrast, although the aerodynamic forces of excised and dried Mallard wings suggests a potential for early forelimb function, the forelimbs were unable to generate sufficient aerodynamic power for flight until the animals were adult size.

***69.4*** DIAMANT, A.G.*; RIDGWAY, R.L.; Seattle Pacific University; *adiamant@spu.edu*

***Localization of labile zinc in hemocyte lysosomes of the pond snail, Lymnaea stagnalis***

Hemocytes of *Lymnaea stagnalis* maintain normal cellular function when exposed to much higher (up to $10^{-4}$ M) than ambient ($10^{-12}$ M to $10^{-9}$ M) concentrations of $ZnCl_2$. While the ultimate destination of excess $Zn^{2+}$ within the cell has remained an item of debate, previous studies in our lab suggest that $Zn^{2+}$ is initially taken up endocytically in small “zincosomes” which then fuse with and/or mature into late endosomes and, eventually, lysosomes. To substantiate these findings, three competing hypotheses concerning the final site of sequestration of labile $Zn^{2+}$ were tested: 1) exclusively lysosomes, 2) exclusively mitochondria, or 3) some combination of the two. Isolated hemocytes were labeled with FluoZin-3 AM (a membrane-permeant probe that fluoresces green upon binding $Zn^{2+}$) and either LysoTracker Red DND-99 or MitoTracker Red FM (membrane-permeant probes that fluoresce red upon passively diffusing into their respective organelles). We observed and imaged the cells using a spinning disc confocal microscope in order to qualitatively evaluate the degree of co-localization between each organelle and $Zn^{2+}$. To quantify the results, deconvolved images were analyzed and Pearson’s coefficients calculated. Results from a sample of 10 cells per experiment were used to calculate 95% confidence intervals, which suggest co-localization between lysosomes and $Zn^{2+}$ (Pearson’s = 0.85 ± 0.03) and exclusion between mitochondria and $Zn^{2+}$ (Pearson’s = 0.33 ± 0.06). These results support the specific hypothesis that $Zn^{2+}$ is sequestered mainly, if not exclusively in the lysosomes. They also corroborate the more general hypothesis that the endosomal-lysosomal pathway is responsible for maintaining a low level of cytosolic labile $Zn^{2+}$ in these cells. (Funded by a SPU Faculty Research Grant to RLR).

***55.2*** DICKERSON, BH*; HEDRICK, TL; University of North Carolina at Chapel Hill; *bradley.dickerson@alum.swarthmore.edu*

***Accommodation of antennal perturbation in freely flying hawkmoths***

In recent years, studies of animal flight have expanded beyond the basic aerodynamic mechanisms required for flight force generation to include issues of sensory integration and robust flight performance. Sane et al. (2007) demonstrated that the antennae of the hawkmoth *Manduca sexta* act as mechanosensors and detect Coriolis forces, essentially serving as gyroscopes and helping the moths maintain a stable orientation. However, many questions remain regarding the function and capabilities of the antenna-gyroscope, including the degree to which moths may accommodate damage to the sensory apparatus by changing biomechanical properties of the system and the consequences of sub-lethal damage to flight performance. We examined these questions by comparing the vibration frequency, inter-antenna angle and whole body roll-pitch-yaw orientation and temporal variation in these parameters between intact moths and moths with the distal 50% of each antenna amputated. We hypothesized that the loss of mass would reduce vibrational amplitude in treatment moths, leading to deficits in orientation stability marked by greater variation in roll, pitch and yaw. However, we expected the control and treatment moths would maintain similar (and constant) inter-antennal angles. Preliminary data analysis supports the last of these, but also revealed no change in antennal vibration amplitude, suggesting that treatment moths were able to relax the antenna joint to achieve similar bending under a different load regime. Orientation stability at short time scales was also unaffected by partial antennectomy, but treatment moths experienced occasional drastic failures in pitch, indicating that the accommodation to sensor damage was ultimately insufficient to preserve free-flight function.

***57.2*** DICKSON, JM*; WEBB, JF; University of Rhode Island, University of Rhode Island ; *jdickson@mail.uri.edu*

***The development of widened lateral line canals in a Lake Malawi cichlid: Insights into lateral line evolution***

The mechanosensory lateral line system of bony fishes is composed of an array of neuromast receptor organs located in lateral line canals and on the skin of the head and body. The lateral line canals are an important component of the dermal cranial skeleton. Among teleosts there are four types of canal systems - one of these, widened canals, has evolved convergently in only ~12 families. Its taxonomic distribution suggests that it is an adaptation for prey detection and that widened canals evolved from narrow canals. But, what sorts of developmental changes can explain how they evolved? To answer this question the development of widened and narrow canals must be compared quantitatively among related taxa. Species with widened canals that are available for laboratory study are rare, but the Lake Malawi cichlid genus *Aulonocara* provides a unique opportunity for such a study. We carried out the first detailed histological analysis of the pattern and timing of the development of widened canals and canal neuromasts in the cichlid, *Aulonocara baenschi* (5-53 days post fertilization [dpf], <5mm–23 mm SL). Preliminary data show that the mandibular canal is partially formed at 15 dpf (9 mm SL) and canal enclosure is complete more than a month later at 47 dpf (22 mm SL). Simultaneously, canal diameter increases, maximum canal neuromast length triples (from 64 to 224 µm) and neuromast width appears to increase indicating a change in neuromast shape. Ontogenetic changes in canal diameter and neuromast size in *A. baenschi* will be compared to those in several other species of cichlids that have narrow canals in order to assess how the timing of developmental patterns can explain evolutionary change in the mechanosensory lateral line system of teleost fishes. Supported by NSF grant 0843307 to JFW.

***27.3*** DING, Y*; MALADEN, R; KAMOR, A; GOLDMAN, D; Georgia Institute of Technology; *dingyang@gatech.edu*
***Mechanics of subsurface swimming of the sandfish Scincus scincus***
Previous work (Maladen et. al, Science, 2009) demonstrated that the sandfish lizard (*Scincus scincus*) swims within granular media (sand) using axial body undulations without use of limbs and explained the motion with a resistive force theory (RFT) which incorporated measured animal kinematics and an empirical model of granular thrust and drag. Here we use a numerical model of a sandfish moving within an experimentally validated soft sphere molecular dynamics granular media model and experimental x-ray PIV measurements of the velocity field surrounding the sandfish to probe the physics of granular propulsion and to test the assumptions of the RFT including velocity independence of drag due to flow dominated by grain-grain friction, local forces, and non-inertial motion. The numerical model reproduces measured animal kinematics and RFT predictions including the speed-frequency relationship, the independence of wave efficiency on material compaction, and for the latter, the temporally resolved forces and the time averaged thrust to drag ratio on each element. Examination of the granular velocity field surrounding the sandfish in both experiment and simulation reveals that the RFT assumption of force locality is valid because velocities decay rapidly with increasing distance from the body. Particles below the animal are nearly stationary while those above it move rapidly as they refill voids created by body motion. Unlike flow in the vicinity of comparably sized animals in water, vortices are not apparent in the granular flow which confirms that the dynamics are non-inertial.

***2.2*** DITTMAN, Andrew H.*; MAY, Darran; HAVEY, Michelle A.; Northwest Fisheries Science Center, NOAA Fisheries, Seattle, WA, School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA ; *andy.dittman@noaa.gov*
***Odorant-Induced Changes In Olfactory Receptor mRNA Expression In Sockeye Salmon (Oncorhynchus nerka) After Imprinting.***
Pacific salmon are well known for their extraordinary homing migrations from oceanic feeding grounds back to their river of origin to spawn. These migrations are governed by olfactory discrimination of homestream odors that juvenile salmon learn (imprint to) prior to their seaward migrations. Our previous studies have suggested that one component of imprinting may involve long-term sensitization of the peripheral olfactory system to specific odorants. In this current study, we examined the mechanism of peripheral sensitization during imprinting, by exposing juvenile sockeye salmon to L- arginine during several putative imprinting periods. Arginine is a potent salmon odorant for which a candidate olfactory receptor has been identified. We examined full life cycle changes in receptor expression in L-arginine-exposed vs. L-arginine-naïve fish using quantitative PCR. In parallel, we assessed imprinting success of these same exposure groups by behavioral assessments of odorant attraction using maturing adults in two-choice mazes. Fish exposed to L-arginine during appropriate developmental stages demonstrated long-term memory formation for this imprinting odorant ($P \leq 0.05$; two-sample t-tests). Treatment groups that successfully imprinted, as evidenced by adult behavior, also demonstrated increased expression (relative to arginine-naïve fish) of the putative arginine receptor mRNA in the olfactory epithelium during key life stages. Our results suggest that early odorant exposure may affect olfactory receptor expression levels throughout the life of a salmon. Funded by the Bonneville Power Administration and the NWFSC.

***47.1*** DIZNEY, L.*; VARNER, J.; DEARING, M.D.; University of Utah; *l.dizney@utah.edu*
***Behavioral analysis of deer mice with respect to hantavirus transmission***
Sin Nombre virus (SNV) is an emerging zoonosis of concern. SNV is hosted by the deer mouse. Transmission between mice is hypothesized to be through exchange of body fluids during aggressive encounters, though this aspect of hantavirus ecology has been difficult to study. Additionally, species diversity appears to decrease SNV prevalence, but the mechanism underlying this reduction is unknown. The goals of our research were to determine how frequently deer mice engage in aggressive behaviors that could lead to transmission, whether certain demographic groups were more likely to engage in these behaviors and to examine the impact of other species on behavior. To address these issues, we used a novel surveillance system. On a 3.1 ha site in central Utah, we live-trapped all nocturnal rodents for 3 nights every 6 weeks from May through September 2009 (4 sampling periods). We marked all animals with passive integrative transponder (PIT) tags, recorded life history data and collected blood samples from deer mice for SNV analysis. We then observed behavior for 6 nights at 9 surveillance stations consisting of foraging arenas (3 g millet in 1 l of sand), infrared cameras and PIT tag readers. Initial results from the first two sampling periods yielded 1080 hrs of video recording. We observed a total of 807 visits to the stations by 4 species of rodents. In only 3 % of these visits was more than one animal present at a time. Five different behaviors were observed during multi-animal visits: fighting (11%), chasing (31%), avoiding (42%), sharing (8%) and allogrooming (8%). Pocket mice competitively excluded deer mice, and deer mice were never observed to engage in aggressive behaviors with conspecifics. These preliminary results suggest that interspecific competition may alter deer mice behavior thereby lowering SNV transmission rates.

***S10.9*** DONNELLY, M.J.*; WALTERS, L.J.; University of Central Florida; *mdonnelly@knights.ucf.edu*
***Ecosystem engineering in Florida's estuaries: mangrove and oyster ecotones over a gradient of anthropogenic disturbances***
Anthropogenic disturbances have altered the structure and diversity of mangrove and oyster ecosystems. Although not commonly found together, tropical mangroves and reefs of the temperate oyster *Crassostrea virginica* have overlapping distributions in Florida. These two ecosystem engineers create a unique connected habitat, supporting a diverse assemblage of organisms. Here, we discuss what has happened in the Indian River Lagoon where humans have modified topography by increasing reef and marsh elevations, which in turn has eliminated native ecosystem engineers and respective communities and increased non-native invasions. Next, we discuss the effectiveness of restoration on these engineers by leveling both habitats back to pre-disturbance elevations. With oysters, boat wakes create 1m high dead margins composed of disarticulated shells on which aquatic diversity plummets from 149 to 0 species and only terrestrial plants are able to establish. Leveling dead margins and providing recruitment substrate re-established biodiversity to control levels within months. With mangroves, marshes were impounded for mosquito control by creating dikes 1m above mean high water, reducing mangrove recruitment and facilitating terrestrial plant invasions. During restoration, dikes were leveled and all existing vegetation removed. Our 4-year monitoring program documented recruitment of mangroves, fiddler crabs, birds and fishes to restored impoundments. As plant and invertebrate communities develop, increased diversity of birds and fishes was observed. Due to their importance as ecological engineers, restoring mangrove and oyster habitat can have cascading effects throughout the estuarine system and benefit a variety of organisms.

***10.2*** DONOVAN, D.A.*; ELSASSER, P.A.; WITTES, J.W.; Western Washington University, Swarthmore College, Pennsylvania; *donovan@biol.wwu.edu*

***Broad salinity tolerances of the invasive clam Nuttallia obscurata***

*Nuttallia obscurata* was introduced from the Western to the Eastern Pacific Ocean in the late 1980s and has spread rapidly through the Puget Sound and Straight of Georgia. It is commonly found living high in the intertidal zone and in regions of varying salinity. We investigated how *N. obscurata* responds to hyposmotic, hyperosmotic, and thermal stress in order to investigate whether broad physiological tolerances play a key role in its success as an invasive species. Clams were acutely exposed to salinities ranging from 1 ppt to 60 ppt at 10 ºC and 20 ºC and mortality was monitored for two months. Both salinity and temperature significantly affected mortality, although mean survival of clams held at 1 – 50 ppt at 10 ºC was greater than 45 days. In a similar experiment, gill tissue was excised and acutely exposed to 1 – 60 ppt at 10 ºC and 20 ºC and mortality was monitored over two weeks. Both salinity and temperature significantly affected tissue mortality, and there was no interaction between the two variables. However, the gill tissue was surprisingly tolerant of very low salinities. At 10 ºC, gill tissue was able to survive for two weeks at salinities ranging from 1 – 30 ppt. These results are supported by data showing that *N. obscurata* osmoconforms at salinities ranging from 10-50 ppt and osmoregulates at 1 and 5 ppt, and that gill tissue hydration remains relatively stable over the range of salinities.

***67.7*** DORSEY, A. E.*; WILSON, P. S.; California State University, Northridge; *ann.dorsey.88@csun.edu*

***Rarity as a life-history correlate in Dudleya (Plantae: Crassulaceae)***

In this study the life-history tradeoffs and habitats of rare and common species are compared to find how these aspects might affect their geographic prevalences. Nine Dudleya species occurring in and around the Santa Monica Mountains were studied. Five are rare narrow endemics with small localized ranges, one is rare with an intermediate range, and three are common with broader ranges. Life-history traits were studied in wild populations and in cultivated siblings from wild collected seeds. In regard to life-history tradeoffs there were differences in growth and reproduction. The rare species grew to a smaller size and reproduced earlier than common species. The small body size of the rare species resulted in smaller reproductive outputs than the larger-bodied common species. The rare species also tended to have lower seedling survival. Reproductive output and survival affect population size, persistence, and dispersal all of which directly affect species' distributions. Habitat characteristics were recorded in two or three populations of each study species. The habitat requirements of the study species differed in co-occurring vegetation, soil type, and microclimate. The rare species grow in habitats that do not occur as often as those of the common species contributing to their scarcity. To further understand how habitat may play a role in limiting species' distributions, the nine species were grown in an inland and a coastal garden. Plants of all species grown in the inland garden were smaller in size than those in the coastal garden. Moreover, the growth disparity between plants in the two gardens was greatest for the rare species. The rare species have a lower tolerance for hot dry conditions compared to the common species. Differences in life-histories resulting from tradeoffs affect the rarity of the species, as well as specialization on rare habitats.

***67.3*** DOUGLAS, L.E.*; BEAUPRE, S.J.; University of Arkansas, Fayetteville; *ledougl@uark.edu*

***Large scale habitat manipulation influences body condition in adult timber rattlesnakes (Crotalus horridus)***

Identification of methods for monitoring the effects of habitat restoration is of critical conservation importance. We studied the effects of large scale habitat modifications on timber rattlesnakes (*Crotalus horridus*). Thirteen plots ranging in size from 4.2 ha to 18 ha were modified in an effort to restore oak savanna habitat in an upland hardwood ecosystem in Madison County, Arkansas. Plots were manipulated by selective harvest, prescribed burning, or both treatments, or were managed for continued fire suppression as control sites. Modifications were conducted in 2007 and 2008 by the Arkansas Game and Fish Commission, and sites were monitored for two years before and two years after treatments occurred. We analyzed changes in body condition of timber rattlesnakes tracked using radio-telemetry throughout the study period. Body conditions of rattlesnakes foraging on manipulated plots increased or remained unchanged during the study period, while body conditions of snakes foraging in control areas declined following manipulations to levels significantly lower than the body conditions of snakes using manipulated areas. Despite dramatic changes in composition of the vegetation community, density and diversity of snake prey species (small mammals) did not detectably increase at manipulated sites until the second year following manipulations, and then only at sites that were both cut and burned. Physiological changes in *C. horridus* appear to rapidly integrate ecosystem-level changes that may be difficult to detect using other methods (e.g. mammal trapping); therefore we suggest *C. horridus* has potential to serve as an indicator species for forest restoration.

***73.5*** DOUGLAS, Hector/D; University of Alaska Fairbanks, Kuskokwim; *hddouglas@yahoo.com*

***Prenuptial perfume paralyzes ectoparasites - odorant linked to quality in male crested auklets***

Experimental evidence has shown that the citrus-like aldehyde odorant of the crested auklet (*Aethia cristatella*) has a paralytic effect upon auklet lice. Lice briefly suspended over incisions in interscapular integument of crested auklets were immobilized for more than two days while those exposed to incisions in the flank were not paralyzed. Novel structures called wick feathers emit aldehydes into plumage. These are concentrated in the interscapular integument, but have not been found elsewhere in crested auklet integument. Auklet louse mobility and survival were also observed in experiments with synthetic analogues of the crested auklet odorant. Impairment was noted at very low exposures and progressively more acute responses were observed with incremental increases in dosage. Male crested auklets differ in their odorant emissions. Males with larger crest ornaments emit more octanal ($r = 0.37$, $p = 0.04$, $n = 31$). Furthermore, males with a more robust adrenocortical response to acute stress are able to emit more octanal, the most abundant odorant constituent. Alloanointing with the aldehyde odorant is part of courtship and social behavior in crested auklets. Stronger smelling males may be more sexually attractive and more dominant.

***12.9*** DOWNS, C.J.*; WONE, B.; DONOVAN, E.R.; HUNTER, K; HAYES, J.P.; Univ. of Nevada, Reno, Univ. of Nevada, Reno; Univ. of California, Riverside; *downsc@unr.nevada.edu*

***Immune function in mice selected for high metabolic rate***

Life history theory posits that trade-offs exist among energetically expensive activities. Mounting an immune response may be energetically expensive, so a trade-off may exist between metabolic rate and immune function. Indeed, we tested the hypothesis that basal metabolic rate (BMR) is negatively correlated with innate and adaptive immune function in laboratory mice (*Mus musculus*) selected for mass-independent metabolic rates. We artificially selected replicate lines of mice high maximal metabolic rate (MAX), high maximal metabolic rate and low BMR (COR), and maintained replicated control lines (CONT). After 7 generations of selection, BMR of selected mice diverged significantly. MAX lines had BMR ~5% > the CONT lines and the COR lines had BMR ~5% < CONT lines. We tested the ability of mice to mount an innate immune response by injecting them with lipopolysaccharide (LPS), an endotoxin from Gram-negative bacteria. To test adaptive immune response, we inoculated a second group of mice with Keyhole Limpet Haemocyanic (KLH). After each immune treatment, we measured metabolic rate during the immune response and immune indicators in blood plasma. Mice treated with either LPS or KLH used more energy then control sham mice (injected with saline), however, there was no difference in energy used among mice from the selected treatments. This suggests that immune responses are expensive, but that the 5-10% differences in BMR among selection treatments were not great enough to alter the energetics of mounting an innate or adaptive immune response. Supported by NSF IOS 0344994.

***67.4*** DRAKE, K.K.*; NUSSEAR, K.E.; ESQUE, T.C.; BARBER, A.; MEDICA, P.A.; TRACY, C.R.; U.S. Geological Survey, University of Nevada-Reno; *kdrake@usgs.gov*

***Does Translocation Effect Physiological Stress Levels in Desert Tortoises?***

In 2005, the USGS initiated research to understand the physiological characteristics of stress potentially associated with translocation in a population of desert tortoises (Gopherus agassizii) near Fort Irwin, California. We hypothesized that translocation of wild tortoises may cause a potentially chronic physiological stress response in both resident and translocated animals and this response may result in changes in behavior, habitat use, and movement patterns. We predicted this stress response would return to baseline levels within two years after translocation. Blood samples (n=2,220) were collected from 238 individual tortoises for three years (2005-2007) prior to translocation and two years (2008-2009) post translocation to determine whether translocation of tortoises causes any measurable stress response, and the time frame over which animals adjust to translocation. Laboratory analyses were completed for samples (2005-2008) measuring plasma total corticosterone (CORT) using radioimmunoassay. Analysis for 2009 data are on-going. Sex, handling time, time of blood collection, animal body temperature, ambient air temperature, categories of lymphatic fluid (i.e. samples with no lymphatic fluid or samples containing <15% lymphatic fluid) all had a significant effect on levels of CORT. After translocation occurred in spring 2008, differences in CORT were not observed among treatment groups (translocated, resident, and control tortoises) indicating that translocation did not cause a measurable physiological stress response within the first year of translocation.

***66.4*** DUGUID, W.D.; Univ. of Victoria; *willduguid@hotmail.com*

***Reversed asymmetry in lithodid crabs: an absence of evidence for heritability or induction***

The mechanisms controlling development of left-right asymmetries remain an intriguing problem in developmental biology. Individuals exhibiting reversal of directionally asymmetric characters provide an opportunity to study these mechanisms and may also provide insight into evolutionary changes in asymmetry states. King crabs (family Lithodidae) exhibit a dramatic morphological handedness; both sexes have a larger right claw, and the female abdomen is deflected to the right. The first recorded capture of an egg-bearing female lithodid (*Lopholithodes foraminatus*) with reversed asymmetry of the claws and abdomen provided an opportunity to investigate possible heritability or induction of reversed asymmetry in lithodid crabs. A high incidence of reversed claw asymmetry (approximately 25%) was observed for the offspring of both reversed (n = 1) and normal (n = 3) females. Reversed claw asymmetry persisted through development and was correlated with development of reversed abdominal asymmetry in juvenile females. The direction of asymmetry could not be reversed through major claw removal, and the incidence of reversed asymmetry was apparently independent of larval rearing temperature. Reversed mandibular asymmetry was never observed in zoeae, or in either normal or reversed juveniles. This suggests that while the asymmetric development of the claws and abdomen are linked, they are separate from the primary asymmetry of the organism. The apparent absence of heritability for variation in the direction of asymmetry in *L. foraminatus* contradicts expectation. Further research on this subject may challenge assumptions about the evolution and development of bilateral asymmetries.

***15.6*** DUNCAN, C.A.*; COHICK, W.S.; JOHN-ALDER, H.B.; Rutgers Univ., New Brunswick ; *caduncan@eden.rutgers.edu*

***Effects of Food Deprivation on the Insulin-like Growth Factor-I System in Eastern Fence Lizards (Sceloporus undulatus)***

Based on numerous studies involving food deprivation, previous investigators have concluded that nutritional status is a principal environmental regulator of IGF-I. However, discrepancies exist in the literature regarding severity of nutritional manipulation and correlations between nutritional status, hepatic IGF-I message and plasma IGF-I. For example, in hatchling *S. undulatus*, food deprivation decreased hepatic IGF-I by 5-fold, while re-feeding restored hepatic IGF-I to the level of the ad libitum fed group. In yearling *S. jarrovii*, 1/3 ration had no effect on hepatic IGF-I compared to the ad libitum fed group. These data demonstrate that hepatic IGF-I is permissive across a range of food intake and is not continuously scaled to food intake. Thus, the natural significance of nutritional regulation of IGF-I is not well understood, and ecologically realistic levels of nutritional manipulation may not support the conclusion that food is a key environmental regulator of IGF-I. Alternatively, hepatic IGF-I may not serve as a reliable indicator of plasma IGF-I. To test the relationship between hepatic IGF-I and plasma IGF-I, we altered food rations in adult males of *S. undulatus*. Dietary treatment groups were as follows: Fed (F; 6 crickets/d x 15 d), Unfed (U; 0 crickets/d x 11 d), and Re-fed (R; unfed x 11 d and fed x 4 d). During the 15-d treatment period, F consumed 1.8 crickets/d, and during the 4-d re-feeding period, R consumed 3.2 crickets/d. Body condition worsened and expression of hepatic IGF-I was inhibited by 3-fold in U, while re-feeding for four days restored these effects relative to F. Altogether, results from nutritional manipulation in *Sceloporus* lizards are consistent with previous work but suggest that food restriction short of starvation may have little effect on the production of IGF-I. Supported by SICB, Graduate School-New Brunswick and School of Environmental and Biological Sciences.

***98.8*** DUNKIN, R.*; WILLIAMS, T.; WILSON, D.; JOHNSON, S.; JOHNSON, K.; Univ. of California, Santa Cruz, Wildlife Safari, Six Flags, Vallejo, Have Trunk Will Travel; *dunkin@biology.ucsc.edu*

***Are Elephants Obligate Evaporative Coolers?***

Elephants often occupy habitats with sustained high temperatures and low water availability, however, patterns of habitat use suggest they are highly water dependent. Although they lack sweat glands, relatively high rates of evaporative water loss (EWL) have been measured from elephant ears and EWL appears important for heat dissipation. However, it is unknown whether elephants are obligated to use evaporative cooling to maintain thermal balance nor whether they can mitigate water loss through behavioral or physiological mechanisms. We measured heat production and heat loss for 6 African and 6 Asian elephants across ambient temperatures ($T_a$) between 9 and 33°C and after animals were bathed. Skin temperatures, heat flux, and transdermal EWL were measured at 5 body sites and digital images were used to calculate body surface area. Metabolic heat production and respiratory evaporative water loss were measured simultaneously using open flow respirometry. We then modeled heat balance as a function of $T_a$. We found for both species the temperature gradient between the skin and environment approached 0°C at $T_a$ between 25 and 28°C, corresponding to heat flux near 0 W $m^{-2}$. Between 9 and 33°C, non-evaporative heat dissipation accounted for 160 to -20% of resting metabolic heat production (mean ±SD = 1875.8 ± 354.5W). Evaporative cooling increased heat dissipation between 20 and 48% from dry skin and 33 to 105% from wet skin. Evaporative cooling appears essential for heat dissipation above $T_a$ between 28-33°C and during exercise. Elephants do not appear able to reduce EWL and instead rely on mud bathing to mitigate endogenous water loss. Obligate evaporative cooling likely explains elephant water dependence and may represent a liability during drought conditions and with increasing desertification.

***S8.10*** DUNN, CW; Brown University; *casey_dunn@brown.edu*

***A survey of cnidarian transcriptomes- diversity through the lens of next-generation sequencing***

While there is now strong support for many relationships within Cnidaria across phylogenetic datasets and studies, some important relationships of broad interest have remained unresolved. This is the case even with greatly improved taxon sampling in recent studies that consider from one to several genes. To compliment this many-taxon work, the Assembling the Cnidarian Tree of Life project has collected sequence data for thousands of genes from broadly sampled Cnidarian taxa with an Expressed Sequence Tag (EST) approach. This will enable a phylogenomic analysis of the group, aid in gene discovery for other types of studies, including developmental work, and help reconstruct the genomic content of the most recent ancestor of Cnidaria. These sequence data have been collected with a Roche Genome Sequencer FLX Titanium Series Instrument, using cDNA libraries that were constructed with customized adapters that are optimized for this platform. Here we present various diagnostics of sequencing success with this new technology and preliminary phylogenetic investigations of the data.

***72.4*** DURANT, Sarah E*; HAWLEY, Dana M; HEPP, Gary R; HOPKINS, William A; Virginia Tech, Auburn Univ; *sdurant@vt.edu*

***Incubation temperature affects multiple measures of immunocompetence in wood duck (Aix sponsa) ducklings.***

Recent research demonstrates that the temperature of the nest environment can have profound effects on the phenotype of avian offspring (e.g., growth, stress physiology, hatchling body composition). These results suggest that incubation temperature could shape other aspects of a young birds' physiology, such as the developing immune system, that are important to survival. In this study we investigated the effects of incubation temperature on immunocompetence in wood duck (*Aix sponsa*) ducklings. Wood duck eggs were collected from the field and experimentally incubated at temperatures that fall within the range of temperatures of naturally-incubated wood duck nests (35.0, 35.9, and 37.0°C). Following experimental incubation, ducklings were raised under identical conditions. To assess aspects of immunocompetence, ducklings were exposed to one of two immune antigens-- phytohemagglutinin (PHA) or sheep red blood cell (SRBC) -- at six days of age. Ducklings incubated at the lowest temperature had significantly lower swelling (19-21%) in response to PHA injection than ducklings incubated at both higher temperatures. Similarly, day six SRBC antibody titers of ducklings incubated at the lowest temperature were 32-41% lower than antibody titers of ducklings incubated at the higher temperatures. Our results suggest that incubation temperature could play a significant role in determining early immune function of birds.

***40.6*** DYKE, Gareth*; PALMER, Colin; University College Dublin, University of Bristol; *gareth.dyke@ucd.ie*

***The unique pterosaur pteroid bone: wing function in extinct flying reptiles***

Pterosaurs, flying reptiles from the Mesozoic, had wing membranes that were supported by the bones of their arm and a super-elongate fourth finger (the 'wing-finger'). Associated with the wing, pterosaurs also possessed an unique bone – the pteroid – that functioned to support the forward part of the membrane (the propatagium) in front of its leading edge, articulated at the wrist. Because reconstructed orientations for the pterosaur pteroid vary (i.e. lying anterior to the wing leading edge or medial, alongside it) and cause considerable debate, we undertook to provide bounds on its mechanical strength and aerodynamic performance by biomechanical modelling. Finding the most likely orientation for the pteroid is important because its position implies differences in the way that pterosaurs controlled their wings. Our analysis of pterosaur wrist biomechanics and bone cortical thickness shows that an anteriorly orientated pteroid, at least in large ornithocheirid pterosaurs, is highly unlikely. Unless these pterosaurs only flew steadily and low speeds and had very low body masses (another source of contention), their pteroids would have broken if pointed forward (anteriorly) from the wing leading edge. In addition to this structural vulnerability, the degree of pteroid movement required to produce a forward orientation would have required impractically high membrane strains and theresultant leading edge shape would have reduced the aerodynamic performance of the wings. We demonstrate quantitatively that the more traditional medial orientation for the pterosaur pteroid was mechanically much more robust and more aerodynamically efficient and speculate on the evolution of the wing in these remarkable extinct flying reptiles.

***73.4*** EDWARDS, J. R.*; LAILVAUX, S.P.; University of New Orleans; *wherzmysocs@gmail.com*

***Display Behavior and Habitat Use in Single and Mixed Populations of Anolis carolinensis and Anolis sagrei Lizards***

The presence of introduced species can have important effects on the behavior of native species. We compared the display behavior and habitat use of introduced *Anolis sagrei* and native *Anolis carolinensis* lizards across three sites in Southern Louisiana. The chosen sites were similar in that they were all located in urban settings with clumped vegetation. The first site contained primarily *A. sagrei*, the second supported both *A. sagrei* and *A. carolinensis* populations, and only *A. carolinensis* were present at the third site. Thirty adult male anoles of each species (where present) were filmed from each of the sampled populations during the active summer reproductive period and compared for differences in display behavior and habitat use. Consistent with previous studies, our data indicate differences in perch height for both species in the single compared to the mixed populations, and preliminary analyses indicate potential differences in display behavior among sites as well.

***S4.8*** EDWARDS, J.*; WHITAKER, D.L.; Williams College, Pomona College; *joan.edwards@williams.edu*

***Floral Trebuchets, Airguns and Elaters Effect Rapid Spore Dispersal in Low Growing Plants***

Wind-dispersed spores of ground dwelling plants are small with low terminal velocities so they can be held aloft and carried long distances. The height of spore release determines the distance of dispersal. But spores easily carried by wind are also rapidly decelerated when moving through air. Plants growing close to the ground use extraordinary accelerations to achieve even modest heights. We report three ultra-rapid movements that effect spore dispersal. First floral trebuchets of bunchberry dogwood (*Cornus canadensis* ) where pollen is launched from anthers through the release of elastic energy stored in the filaments. We use high-speed video (10,000 fps) to show that pollen held between the thecae of adjacent stamens is vertically accelerated up to 24,000± 6,000 m $s^{-2}$ with speeds of 3.1± m $s^{-1}$ launching pollen to a mean height of 2.5 cm (range 2.2-2.7 cm; n=5). Outdoors in steady wind pollen is carried over 1m and can effect cross-pollination in this obligate outcrosser. Second the exploding airgun capsules of *Sphagnum* moss.). Mature capsules form on pseudopodia up to 20 mm above the moss capitula. In sun capsules dehydrate and shrink transversely increasing pressure and explosively popping the cap free from the capsule vertically propelling spores. We used high-speed video (1,000 to 100,000 fps) to show that the exploding capsules of *Sphagnum* generate vortex rings to achieve launch velocities for the spores of 16.7 m $s^{-1}$ (mean± s.e.m., N = 13, range 7.9 to 29.8 m $s^{-1}$, with a lower bound of acceleration of 1.6 x $10^{6}$ m $s^{-2}$. The spores are propelled to heights of 10.35 ± .64 cm (mean ± s.e.m., N = 10, range 7.39 to 14.35 cm) into the turbulent boundary layer. Third are the elaters attached to (*Equisetum hyemale* ) spores and elaters mixed with the spores of (*Preissia quadrata* ) which effect spore dispersal by moving rapidly in response to changes in humidity.

***48.2*** EERNISSE, D.J.*; CORSTORPHINE, E.; CLARK, R.N.; STRATHMANN, M.F.; Calif. State Univ., Fullerton, Univ. of Guelph, Santa Barbara Museum of Natural History, Friday Harbor Labs, Univ. of Washington; *deernisse@fullerton.edu*

***Seastars across the oceans: Molecules help untangle biogeographic patterns for a species-rich genus, Henricia***

Over 100 recognized or newly discovered species of *Henricia* Gray, 1840 have a globally widespread anti-tropical distribution with especially impressive diversity in the northern temperate latitudes. Although *Henricia* has long been notorious for its taxonomic difficulty, we have made considerable progress by studying morphology while also sequencing portions of the mitochondrial 16S and COI gene regions. By collaborating to pool our separate regional molecular data sets, we have found that *Henricia* diversification extends across ocean basins. Besides our emphasis on both temperate coasts of North America, we have included representatives of *Henricia* from the Aleutian Islands, Japan, England, New Zealand, and South Africa. Some species were found to be widespread, for example along the entire Pacific coast between Baja California and southeastern Alaska, or with a trans-Arctic distribution. In contrast, the Pacific Northwest *Henricia* fauna is comprised of a surprisingly high proportion of co-occurring endemic species. Each of at least two species from New Zealand has a phylogenetic affinity with particular northern hemisphere counterparts, rather than with each other. Perhaps the cool deep-water habitat of the particular particular New Zealand species included has permitted historical dispersal across the tropics. Likewise, our analysis has revealed several intriguing phylogenetic connections across the Arctic with varying levels of genetic divergence.

***47.4*** EGGE, A.R.*; BRANDT, Y; SWALLOW, J.G.; The University of South Dakota, Vermillion; *aegge@usd.edu*

***Sequence analysis of aggressive interactions between male dyads of stalk-eyed flies***

Stalk-eyed flies of the species *Teleopsis dalmanni* are sexually dimorphic with males exhibiting extreme hypercephaly relative to females. In males, eye-span is highly correlated to body length and is an indicator of relative strength and condition. Previous studies have suggested that males use eye stalk length to assess their opponent's fighting ability during resource competition. Such studies have investigated the effects of morphology on the outcome of these agonistic interactions; however, we still lack a detailed examination of the behavior that winners and losers display while competing. Sequential analysis of aggressive behavior reveals behavioral transition probabilities and may provide insights into the significance of such behaviors. In this experiment, we placed two males in a divided arena and starved them for 24-hours. Once starved, the partition was removed and a drop of high-quality food was added. Flies were digitally recorded for 10 minutes to be scored later for aggressive behaviors. Our analysis reveals an emphasis on assessment behaviors during these contests. Furthermore, our analysis reveals that winners more frequently transitioned from high intensity behaviors to pursuit behaviors; conversely, losers more frequently transitioned from both low and high intensity behaviors to retreat. When viewed in light of game theory modeling, these results support the self-determined persistence and war of attrition models because contest duration is based on loser threshold or retreat behaviors. Future studies should include increased size variation between opponents to examine extremes in behavioral patterns.

***35.4*** ELAHI, R*; SEBENS, KP; University of Washington; *elahi@u.washington.edu*

***Diversity, consumer pressure and resource availability on subtidal rock walls***

Resource competition theory predicts an inverse relationship between species richness and resource availability. More species should more fully exploit available resources, decreasing the rate of colonization by both native and exotic species. Space is the limiting resource for sessile organisms on marine rocky substrata, and the availability of space is limited by recruitment and growth and increased through senescence, disturbance and consumption. This study examined the relative importance of sessile species diversity and consumer pressure on space availability in benthic rock wall communities. For two years, we quantified the seasonal abundance of sessile taxa in 72 permanent quadrats installed on six transects at three sites in the San Juan Islands, Washington. Gastropods and other small consumers were counted in quadrats, while large consumers including echinoderms and fish were counted on transects. Within a multiple regression framework, the density of two common consumers, red urchins and chitons, explained 53% of the variation in available space, while sessile richness explained an additional 6%, suggesting that consumers were responsible for the patterns of available space. To test this hypothesis, we used a combination of consumer gut content analyses and field manipulations of urchin and chiton density. Preliminary data suggest that urchins create space by consuming sessile invertebrates and foliose algae, while chitons maintain space by consuming crustose algae and microscopic algal recruits. Together, these results emphasize the need to understand the role of consumers when trying to predict resource availability and invasibility in communities where space is the limiting resource.

***51.6*** ELEKONICH, M.M.*; ROBERTS, S.P.; University of Nevada Las Vegas, Central Michigan University; *michelle.elekonich@unlv.edu*

***The cellular cost of highly metabolic behavior for aging and life histories.***

Cost-benefit models of behavior and its effects on life history traits typically measure cost in terms of whole animal energetic expenditure and loss of opportunities. We will highlight our work on the physiological, functional genomic and biochemical traits of honey bee flight muscle related to aerobic capacity and oxidative stress that suggests that direct cellular level costs also exist and differ between tissues. Young adult honey bees are flightless just after eclosion, but become one of nature's great flying machines exhibiting the highest mass specific metabolic rates ever measured during a genetically-programmed but environmentally-sensitive transition from in-hive tasks to foraging in nature. Once they have been foraging for a short time, honey bee flight performance declines, and this senescence coincides with the loss of diurnally up-regulated antioxidant responses and diminished oxidative capacity in flight muscle. The cellular costs resulting from high temperatures and oxidative stress in flight muscle cells appears to hasten functional senescence and thus limit lifespan.

***25.2*** ELLERS, O*; YOSHIMURA, K; MOTOKAWA, T; JOHNSON, A; Bowdoin College, Tokyo Institute of Technology; *olafellers@suscom-maine.net*

***Why not walk faster, underwater?***

Usherwood (2005) elaborated on the standard inverted pendulum model of walking. He calculated a number that we call the instantaneous Froude number. He showed that the instantaneous Froude number could be equal to one at a wide range of standard Froude numbers, with the instantaneous Froude number determining the walk-run transition. If the instantaneous Froude number is greater than one an animal will no longer be able to maintain a walking gait and will need to start running. Given some constraints on leg swing frequencies, Usherwood showed that the experimental discrepancies between observed standard Froude numbers of 0.5 and the expected number of one at the walk-run transition could be explained by considering the instantaneous Froude number. We have developed a version of Usherwood's instantaneous Froude number for underwater circumstances. In our model, the animal's density, added mass and drag all play a role not relevant in most terrestrial circumstances. In addition to elucidating the walk-run transition, this model makes specific predictions about step frequency and dynamics of walking. In our presentation we will test whether underwater walkers such as sea urchins, crabs and octopuses conform to the dynamic predictions of the inverted pendulum. Essentially, we test whether the dynamics of underwater walkers are governed by inertial forces or whether they are governed by a forcing function driven by muscles as in a stiffness-controlled oscillator.

***73.1*** ELLIS, WA*; FITZGIBBON, SI; ROE, P; BERCOVITCH, FB; WILSON, R; University of Queensland, Australia, Queensland University of Technology, Australia, San Diego Zoo's Institute for Conservation Research, CA; *w.ellis@uq.edu.au*

***Unraveling the mystery of koala vocalisations: acoustic sensor network and GPS technology reveals males bellow to serenade females.***

How animals respond to the vocalizations of conspecifics can provide insights into both the context and content of their acoustic communication. In this way, responsive behaviors can act as biological translators of animal vocalizations. Little is known about the content or biological function of the vocalizations made by koalas, due to their solitary, cryptic and nocturnal behavior. The spatio-temporal and social arrangement of koalas has been the subject of much conjecture, but the acoustic structure and seasonality of natural calls have been poorly described. We constructed a novel acoustic sensor network using cell phone technology and successfully applied this to monitor the vocal behaviour of free-ranging koalas in central Queensland. We paired these recordings with simultaneously acquired location data from collar-mounted GPS units to examine the relationship between their vocal communication and spatial arrangement. We found clear seasonal variations in bellow dynamics that were associated with environmental conditions, indicating a role for koala bellowing as a cue for mating in this species. Male travel distance was unaffected by season, but females travelled more during the breeding season than at other times of the year. Daily travel and bellows were concentrated around midnight and female, but not male, travel distance during the breeding season was positively correlated with bellow occurrence. We conclude that male bellowing may be mediated by seasonal environmental conditions and represents a probable trigger for oestrus in females, which may respond to the dynamics of male vocalisations in order to select a mate.

***101.2*** ELLIS, IE*; KEMPF, SC; Auburn University; *ellisir@auburn.edu*
***Immunohistochemical and Histological Analyses Indicating the Presence of SCP-like Neuropeptides in Larval Crassostrea virginica (Bivalvia)***
The Eastern oyster *Crassostrea virginica* is an important species within both estuarine ecosystems and the aquaculture industry. Investigating how the larval nervous system affects larval behaviors, such as settling, could reveal information to aid in the restoration of declining populations and aquaculture practices. Although a few immunohistochemical studies have been conducted, there has been no documentation to date identifying the location of small cardioactive peptides (SCPs), a common neuropeptide in molluscan larvae. In this study, larvae at the D-hinge, umbo, and pediveliger life stages were purchased from the Dauphin Island oyster hatchery. SCP-like neuropeptide analyses were conducted using two techniques: 1) labeling of SCP neuropeptides via a Diaminobenzidine kit and then embedding the larvae in Epon 812 for histological examination or 2) immunohistochemical labeling to visualize SCP-like neuropeptides using a laser-scanning, confocal microscope. Progressive development of the central nervous system of *C. virginica*, along with investigations of the presence and location of SCP-like neuropeptides were examined. Here, we found SCP labeling at the D-hinge stage, indicating that this neuropeptide is present in the early larval stages of development. Additionally, SCP labeling becomes more predominant as development continues towards competency. Nerve processes containing SCP were found throughout the central nervous system loop, which includes 3 paired ganglia: the cerebro-pleural, pedal and visceral ganglia. At the pediveliger stage, SCP-like neuropeptides were found in 1-2 and 2-3 neuron cell bodies within the cerebral and visceral ganglia respectively.

***105.3*** EME, J; HICKS, J ; CROSSLEY II, D A*; U Cal Irvine, U N Dakota; *dane.crossley@und.nodak.edu*
***Cardiovascular plasticity during development in the American alligator (Alligator mississippiensis)***
The vertebrate cardiovascular (CV) system becomes operational early in embryonic development, and, therefore, must function and continue to mature both anatomically and physiologically. Deviations in the developmental environment may result in challenges that impact CV function and may adjust the pattern of maturation for this critical system. While this is likely a truism across vertebrates, reptilian embryos may be particularly impacted given features of development in these egglaying species. Previously, we have shown that environmental challenges influence the maturation and alter the tonic regulation of baseline CV variables. However, the impact of these challenges on the development of acute regulatory mechanisms, such as a chemoreflex, is unknown. Using stressors that have been previously shown to occur in reptilian nests (reduced oxygen and dehydration), the plasticity of the CV system was assessed in American alligator (*A mississippiensis*) embryos. Developmental challenge altered physiological CV maturation and morphological development, independent of the incubation stress applied. Acute dehydration events and chronic hypoxic-incubation resulted in a bradycardia at 90% of incubation, but differed in the affect on arterial pressure. Assessments of both a hypoxic and chemically induced chemoreflex indicated the maturation of this regulatory mechanism is plastic during embryonic development and blunted by chronic hypoxic-incubation. Further, the role of the sympathetic and parasympathetic nervous systems is altered by incubation stress. The data indicate that the maturation of CV function exhibits a degree of phenotypic plasticity in the alligator. Supported by NSF Career award IBN IOS-0845741 and NSF IOB 04445680/ 0922756 to JWH

***S3.2*** EMLET, R.B.; University of Oregon; *remlet@uoregon.edu*
***Evolution of morphological and functional novelties among invertebrate larvae - opportunities and limitations***
Marine invertebrate larvae are well known for their distinctive forms, many of which typify different clades at various hierarchical levels (e.g. gastropod veliger, asteroid bipinaria, actinotroch of phoronids, ascidian tadpole). Also well known is the flexibility within many groups where feeding larvae are replaced by nonfeeding larvae or encapsulated development. Diagnostic larval forms and their derived relatives represent novelties of various ages and that have a variety of consequences. Larval forms that feed on algal cells vary less within clades than those that feed on larger prey. Transitions to nonfeeding often involve simplification of form, increased swimming speeds, and increases of size at metamorphosis. Convergence is common for nonfeeding forms within clades and also occurs to a lesser extent across taxa.

***45.9*** ENDRES, C*; PUTMAN, N; LOHMANN, KJ; Univ. of North Carolina, Chapel Hill; *endres@email.unc.edu*
***Detection of Airborne Odorants by Loggerhead Sea Turtles***
Sea turtles are known to detect chemical cues, but in contrast to most marine animals, turtles surface to breathe and thus potentially have access to olfactory cues both in air and in water. To determine whether sea turtles can detect airborne chemical cues, captive loggerhead turtles (*Caretta caretta) were placed into a circular, water-filled arena in which odorants could be introduced to the air above the water surface. Air that had passed across the surface of a cup containing food elicited increased activity, diving, and other behavior normally associated with feeding. In contrast, air that had passed across the surface of an identical cup containing distilled water elicited no response. Increases in activity during food odor trials occurred only after turtles surfaced to breathe and peaked in the first post-breath minute, implying that the chemical cues eliciting the responses were unlikely to have been detected while the turtles were under water. These results provide the first direct evidence that sea turtles can detect airborne odors. Under natural conditions, this sensory ability might function in foraging, navigation, or both.*

***67.6*** ENG, M.L.*; LETCHER, R.J.; MACDOUGALL-SHACKLETON, S.A.; ELLIOTT, J.E.; WILLIAMS, T.D.; Simon Fraser Univ., National Wildlife Research Centre, CWS, Univ. Western Ontario, Pacific Wildlife Research Centre, CWS; *margaret_eng@sfu.ca*

***Effects of early exposure to a brominated flame retardant (PBDE-99) on physiology and behaviour in zebra finches***

Polybrominated diphenyl ethers (PBDEs) are a class of brominated flame retardants that have become ubiquitous in the environment. PBDE-99 is one of the most abundant congeners found in environmental samples, yet its long-term effects on avian wildlife are unknown. In birds, early life stages are the most sensitive to environmental conditions, and exposure to contaminants during the nestling period may have critical long-term effects. The objective of this study is to determine the effects of early exposure to PBDE-99 on birds, using the Zebra Finch as a model songbird species. We exposed young for the duration of the nesting cycle to environmentally relevant, sublethal levels of PBDE-99. A preliminary study dosing chicks with PBDE-99 (0-250 ng/g bw/day) for 21-days during the nestling phase showed that there was a strong dose-dependent relationship for plasma PBDE levels at 30 days of age. Furthermore there was a strong correlation between plasma and lipid PBDE levels. Following dosing, we assessed the physiology and condition, including growth, oxidative stress, immune function, and hematocrit for each treatment group. The young were raised to sexual maturity to examine long term effects on physiology, male mating behaviour (including song), female reproductive success, and brain development. Behavioural endpoints were found to be the most sensitive to contaminant exposure, and few effects on growth and physiology were observed.

***43.4*** ESSNER, R.L.*; SUFFIAN, D.J.; REILLY, S.M.; Southern Illinois University Edwardsville, Ohio University; *ressner@siue.edu*

***A Comparison of Jumping Behavior in the Rocky Mountain Tailed Frog, Ascaphus montanus and Fire-bellied Toad, Bombina orientalis***

Rocky Mountain tailed frogs, *Ascaphus montanus* (Anura: Leiopelmatidae) are semi-aquatic anurans belonging to a basal clade that diverged from all other frogs (Lalagobatrachia) at least 170 mya. Leiopelmatids retain a suite of plesiomorphic morphological features, including nine amphicoelous presacral vertebrae, free ribs, epipubic cartilage, and a “tail-wagging” muscle. They are unique among frogs in their use of an asynchronous (trot-like) rather than synchronous swimming gait. Detailed studies of leiopelmatid jumping behavior are currently lacking. However, it has been assumed that all anurans jump in a similar manner (like ranid frogs) by rapidly extending hindlimbs during the propulsive phase and initiating a mid-air rotation during flight in order to land forelimbs-first. Recovery begins near mid-flight by protracting and flexing extended hindlimbs and protracting and extending forelimbs so they are positioned to absorb impact forces. We compared jumping in *A. montanus* with a basal lalagobatrachian, the fire-bellied toad, *Bombina orientalis* using high-speed video at 500 fps. The two frog species differed in the timing of key kinematic events and exhibited dramatically different landing postures. *Bombina orientalis* reflected the general lalagobatrachian condition of early hindlimb recovery and forelimbs-first landings. In contrast, *A. montanus* exhibited delayed hindlimb recovery and avoided forelimbs-first landings. We propose that the jumping behavior of lalagobatrachian frogs is derived and that the unique behavior of *A. montanus* represents the ancestral condition for anurans.

***97.5*** EVANS, N.M.*; CARTWRIGHT, P.; University of Kansas; *evansnat@ufl.edu*

***Phylogenetic Placement of Myxozoa: An exploration of conflict between phylogenomic and rDNA molecular data***

Myxozoa is a diverse clade of microscopic obligate endoparasites, several of which can cause serious disease in a number of economically important fish. Yet despite this significance, myxozoan higher-level classification has proven difficult due to an overall paucity of morphological characters and, more recently, the discovery of this clade’s highly divergent molecular sequences. Currently there exists two competing molecular hypotheses for the placement of Myxozoa. The most recently advanced is based on a phylogenomic approach, which places the long branched myxozoan Buddenbrockia, with Cnidaria. The second hypothesis, based on a larger taxon sampling, but with a single marker, 18S rDNA, supports the placement of Myxozoa as a long-branched clade sister to Bilateria. As part of the Cnidarian Tree of Life Project, we investigated the phylogenetic placement of Myxozoa, evaluating the conflict and support for both hypotheses within and between traditional and phylogenomic datasets. Our efforts include augmentation of traditional 18S data with new 28S rDNA sequences and comprehensive taxon sampling of metazoans, including myxozoans and cnidarians. Effects of missing data as well as alternative amino acid substitution models are explored for the phylogenomic data. Our results suggest caution when interpreting results of long branched taxa due to the vulnerabilities inherent to both traditional and phylogenomic molecular approaches.

***93.3*** FAUCHER,, K.*; PARMENTIER,, E.; BECCO,, C.; VANDEWALLE,, N.; VANDEWALLE,, P.; Univ. of LiÃ¨ge, Belgium; *kfaucher@ulg.ac.be*

***Fish lateral system is required for accurate control of shoaling behaviour***

In teleost fishes, the lateral system is assumed to contribute, among other roles, to maintaining schooling behaviour. Sight is also assumed to play a role in schooling, as fish with a cut lateral line do not stop schooling unless they are also blinded. This conclusion, however, was based on experiments where only the trunk lateral line was inactivated, leaving the head lateral system intact. Here the aim was to test how inactivation of the whole lateral system affects the fish shoaling behaviour. Groups of firehead tetras, *Hemigrammus bleheri*, were video-recorded before and after inactivation of their whole lateral system with aminoglycoside antibiotics (and also in sham-treated specimens). Shoaling behaviour was characterized by: nearest distance to the first, second, and third neighbour, shoal radius, shoal order parameter, and the number of collisions between individuals. SEM observations showed damage to most superficial neuromasts as a result of antibiotic treatment. Importantly, the antibiotic-treated fish proved unable to maintain a shoal. After the end of the treatment, however, they recovered both a normal tissue morphology and normal shoaling behaviour within about a month. The lateral system is thus more crucial to shoaling behaviour than previously believed.

***48.4*** FERNANDES, D.A.O.*; PODOLSKY, R.D.; Grice Marine Laboratory, College of Charleston, SC; *dafernan@edisto.cofc.edu*

***The effects of the association with eelgrass on the embryonic development of the gastropod Haminoea vesicula (Gould, 1855)***

Marine gastropods commonly deposit egg masses in association with photosynthetic organisms. The gastropod *Haminoea vesicula* attaches its egg ribbons to the eelgrass *Zostera marina*. Photosynthesis by such macrophyte can provide significant amounts of oxygen to embryos throughout the egg ribbon. Little is known, however, about the actual benefits or costs to embryonic development of this intimate association. I examined the effects of the association between *H. vesicula* egg ribbons and the eelgrass *Z. marina* on developmental rate and larval shell length. Pieces of *Haminoea vesicula* egg ribbon were pinned into mesh-bottom plastic trays. Half of the egg mass pieces were pinned onto *Z. marina* blades. Embryos were placed in outdoor tanks with flowing seawater and raised under five different light conditions: 0%, 25%, 50%, 75% and 100% blocked sunlight. Embryos attached to eelgrass developed significantly faster under good light conditions, whereas, under poor light conditions, the association with *Z. marina* significantly increased development time. Under moderate light levels (25% - 50% blocked sunlight), development of *H. vesicula* was faster whether embryos were attached or not to the macrophyte. A significant decline in newly-hatched larvae shell length was observed at low light levels. The association with eelgrass did not affect larval hatching size.

***9.5*** FERRER, RP*; ZIMMER, RK; Seattle Pacific University, University of California, Los Angeles; *ferrer1@spu.edu*

***Community ecology, evolution, and molecules of keystone significance***

The keystone species concept is seminal in ecological theory. It involves species whose impacts on communities are far greater than would be predicted from their relative abundances or biomasses. Similarly, select neuroactive compounds function in keystone roles. They are rare within natural habitats but connect such seemingly disparate processes as microbial loop dynamics and apex predation. Outstanding examples draw on four distinct sets of compounds: dimethylsulfoniopropionate (DMSP and metabolites), tetrodotoxin (TTX and its precursor, arginine), saxitoxin (STX), and pyrrolizidine alkaloids (PAs). Introduced into a respective community by one, or only a few, autotrophic or microbial species, these molecules originally function in chemical defense. When borrowed by resistant consumer species, however, they are used either in chemical defense against higher-order predators, or as chemosensory cues that elicit courtship and mating, alarm, and predatory search. Requisite to these multifunctional properties, biosynthetic capacity first evolves with mechanisms for autoimmunity and/or toxin storage in primary producers. Subsequently, consumers evolve resistances or tolerances, and the toxins are transferred through food webs via trophic interactions. In consumers, mechanisms develop for recognizing toxins as feeding cues, and eventually as signals or pheromones in chemical communication within, or between, species. Through convergent evolution, one, or a few, neuroactive compounds thus inform phylogenetically diverse species in a given community. These select molecules initiate major direct and indirect effects, causing potent reverberations and structuring respective communities within terrestrial, freshwater, coastal-ocean and open-ocean habitats.

***93.5*** FERRIER, G.A.*; ZIMMER, C.A.; ZIMMER, R.K.; Univ. of California, Los Angeles; *gferrier@ucla.edu*

***Chemical Communication, Keystone Molecules, and Forces Structuring Natural Communities***

Sensory systems provide critical filters that enable organisms to detect and recognize valuable resources. Trophic cascades, structuring populations and communities, are largely determined by trait-mediated interactions that rely on sensory inputs. Certain molecules, serving as chemical signals, can establish the course of community dynamics at multiple trophic levels. Here, we investigated the roles of surface-adsorbed proteins in mediating predator-prey dynamics on wave-swept shores. For cuticle/shell formation, barnacles (*Balanus glandula*) are required to produce a high molecular weight, insoluble, glycoprotein complex. A primary subunit (~98 kDa) of this protein complex was isolated, purified, and, in field tests, evoked settlement by conspecific larvae. The subunit thereby operates as a seminal recruitment cue. Moreover, the same compound triggered a predatory response in numerically dominant whelk species distributed throughout the eastern Pacific (*Acanthinucella spirata*, *Nucella emarginata*, *N. ostrina*, *N. canaliculatta*, *N. lamellosa*). Such proteins, therefore, simultaneously influence demographic processes that enhance or diminish barnacle populations. As dominant competitors for space, the relative balance between barnacle recruitment and predation mortality has strong direct and indirect effects which influence community dynamics. Furthermore, the ability of all whelks to detect and respond to these signals suggests that the biogeography of barnacles, and their population stability, is affected in comparable ways. The conserved response of many species to the same signal, and the resultant cascading effects across multiple trophic levels, signify barnacle glycoproteins as keystone molecules that structure communities on wave-swept shores.

***32.1*** FERRY-GRAHAM, LA*; HUBER, DR; DEAN, M; CLAES, JM; MALLEFET, J; California State Univ., Univ. of Tampa, Univ. of California Irvine, Univ. Catholique de Louvain; *lfgraham@mlml.calstate.edu*

***Prey processing in chimaeroid fishes***

Holocephalans are uniquely derived for durophagy: the upper jaw is fused to the neurocranium (holostyly), and all chimaeriform holocephalans, extinct and extant, possess tooth plates. Yet, for the three extant families, authors have posited that there has been a gradual transition away from a reliance on crushing benthic prey. The Callorhynchidae (*Callorhynchus*) are the most like ancestral chimaeriforms in their morphology. However, the Chimaeridae (*Hydrolagus* and *Chimaera*) are described as being less suited for crushing, and more reliant on suction prey capture. We set out to quantify differences in morphology and performance between these two chimaeriform groups, and specifically to test the hypothesis that *Callorhynchus* is capable of processing harder prey than *Hydrolagus* or *Chimaera*. Cranial and muscular data were collected from a size range (~10 individuals) of *Callorhynchus callorhynchus*, *Hydrolagus colliei*, and *Chimaera monstrosa*. A PCA on external head measurements suggested that there are differences in head shape, but contrary to predictions, *Chimaera* was different from *Callorhynchus* and *Hydrolagus*. However, MANCOVA, used to compare estimated bite forces among the three species, with head width as a covariate, revealed that *Callorhynchus* tended to differ from *Hydrolagus* and *Chimaera*. Additional statistical exploration of the cranial and muscular variables used to generate bite force estimates further supported such performance differences. Interestingly, CT scans of *Callorhynchus* and *Hydrolagus* revealed only subtle differences in the amount of skeletal calcification (reinforcement), which was slight in both species. Further, *Callorhynchus* appears to possess some red adductor musculature, which, if confirmed, yields significantly lower bite force estimates. Thusly, it remains unclear if the chimaeroid feeding paradigm is supported.

***37.10*** FIERST, Janna L; Florida State University; *jfierst@bio.fsu.edu*

***Sexual Dimorphism Increases Evolvability in a Computational Model of a Genetic Regulatory Network***

The majority of work on genetic regulatory networks has focused around environmental and mutational robustness, and much less attention has been paid to the conditions under which a network may produce an evolvable phenotype. Understanding evolvability, or the ability to produce potentially adaptive variants, is significant because underlying genetic architectures that confer higher evolvability will result in phenotypic traits that respond rapidly to selective pressures. Sexually dimorphic characters often show rapid rates of change over short evolutionary time scales and while this is thought to be due to the strength of sexual selection acting on the trait, it may be that a dimorphic character with an underlying pleiotropic architecture influences the evolution of the regulatory network and results in higher evolvability. I tested this with a computational model of a genetic regulatory network and found that sexually dimorphic characters had higher robustness to mutation, purged deleterious mutations more quickly and had higher evolvability in novel environments. These results indicate that producing two pleiotropically linked characters does not constrain either the production of a robust phenotype or the response to selection. Instead, the genetic system evolves to maximize both quantities. Separate from any kind of sexual selection, the underlying genetic architecture of sexually dimorphic characters may confer a rapid response to selective pressures.

***5.4*** FIGUEROA, Alex*; LAILVAUX, Simon; University of New Orleans; *afigueroa21@gmail.com*

***Use of Prehensile Tails in Cantilevering and Prey Capture in Treeboas, Corallus hortulanus***

Arboreal habitats represent a complex mosaic of functional challenges for snakes. In addition to navigating branches of various size, shape and incline, arboreal snakes are often required to traverse relatively large gaps, a behavior known as cantilevering. Prey capture imposes further functional demands by requiring snakes to hold onto prey to ensure feeding success. Stout-bodied and ambush foraging arboreal snakes (e.g. boids and viperids) possess prehensile tails thought to be used for supporting the body during behavioral activities. Additionally, these snakes immobilize prey by constriction or envenomation. Here, we present data on the functional use of prehensile tails in Corallus hortulanus during both cantilevering and prey capture. We used a high-speed camera to measure the kinematics of snake performance in each ecological context and with both immobilized and unrestrained tails in order to test the hypothesis that prehensile tails play an important functional and stabilizing role in these arboreal snakes.

***14.2*** FISH, F.E.; West Chester Univ., Pennsylvania; *ffish@wcupa.edu*

***Swimming kinematics of manta rays: Oscillatory winged propulsion by a large pelagic batoid***

The batoids swim by undulation or oscillation of their greatly expanded pectoral fins. The largest batoid is the manta ray (*Manta birostris*), that has highly tapered and relatively high aspect ratio pectoral fins, which are oscillated to provide thrust. Due to the large size of these rays and previous lack of availability in aquariums, kinematic descriptions were limited. To examine the swimming kinematics of manta rays, animals were video recorded at aquarium and field sites. Video-recordings were analyzed frame-by-frame. Animals swam at relative speeds up to 0.87 body lengths/s. The pectoral fin tip moved through a sinusoidal trajectory and the fin showed both chordwise and spanwise flexibility throughout the stroke cycle. The frequency of the fin stroke tended to increase with swimming speed and had an average stroke cycle of 0.31 Hz. The peak-to-peak amplitude remained constant with respect to swimming speed and averaged 0.74 body lengths. The body was stable during swimming with little pitching or heaving motions associated with the pectoral fin oscillations. However, manta rays are highly maneuverable and are cable of banking turns, inside loops and barrel rolls. As a large pelagic batoid, the movements of the manta ray display characteristics for stable, efficient swimming and high maneuverability.

***34.4*** FLAMMANG, B.E.; Harvard University; *bflammang@oeb.harvard.edu*

***Functional morphology of the radialis muscle in shark tails***

The functional morphology of intrinsic caudal musculature in sharks has not been studied previously, although the kinematics and function of body musculature have been the focus of a great deal of research. In the tail, ventral to the axial myomeres, there is a thin strip of red muscle with fibers angled dorsoposteriorly, known as the radialis. This research gives the first anatomical description of the radialis muscle in sharks, and addresses the hypothesis that the radialis muscle provides postural stiffening in the tail of live swimming sharks. The radialis muscle fibers insert onto the deepest layers of the stratum compactum, the more superior layers of which are orthogonally arrayed and connect to the epidermis. The two deepest layers of stratum compactum insert onto the proximal ends of the ceratotrichia of the caudal fin. This anatomical arrangement exists in sharks and is modified in rays, but was not found in skates or chimaeras. Electromyography of the caudal muscles of dogfish swimming steadily at 0.25 and 0.5 body lengths per second (Ls–1) exhibited a pattern of anterior to posterior activation of the radialis muscle, followed by activation of red axial muscle in the more anteriorly located ipsilateral myomeres of the caudal peduncle; at 0.75 Ls–1, only the anterior portion of the radialis and white axial muscle of the contralateral peduncular myomeres were active. Activity of the radialis muscle occurred during periods of the greatest drag incurred by the tail during the tail beat and preceded the activity of more anteriorly located axial myomeres. This nonconformity to the typical anterior to posterior wave of muscle activation in fish swimming, in combination with anatomical positioning of the radialis muscles and stratum compactum, suggests that radialis activity may have a postural function to stiffen the fin, and does not function as a typical myotomal muscle.

***44.1*** FLETCHER, Q.E.*; BOUTIN, S.; MCADAM, A.G.; SPEAKMAN, J.R.; HUMPHRIES, M.M.; McGill Univ.; *quinn.fletcher2@mail.mcgill.ca*

***Seasonal energetics of a northern free-ranging mammal in a resource pulse system***

Throughout the year, all animals face energetic demands resulting from allocation to reproduction, in addition to variation in food availability and climatic conditions. The role played by these energetic demands changes seasonally. Thus, to gain critical insight into the underlying factors affecting levels of energy expenditure, we examined seasonal changes in the field metabolic rate (FMR) of a natural population of red squirrels in Yukon, Canada. We focused on levels of energy expenditure during autumn food hoarding, winter, and lactation. Inter- and intra-annual variation in food availability and climatic conditions is extreme at this site. White spruce seeds that are hoarded during autumn are used preferentially to meet the energetic demands of winter and reproduction the following spring; however, seed is only available for a short window during autumn and seed production varies strongly among years. Moreover, the northern location of our study site exposes squirrels to extremely cold temperatures during winter, which potentially increases thermoregulatory demands. Levels of FMR varied strongly across seasons in adult female squirrels. Even though winter ambient temperatures were extremely low, the FMR of squirrels was at its lowest levels. Field metabolic rate was highest when red squirrels were hoarding white spruce seed, and these levels exceeded FMR levels during the peak of lactation. This was surprising because lactation is considered the most energetically demanding period of the year since females must obtain enough energy to meet their energetic demands in addition to those of their offspring. In conclusion, a seasonal comparison of FMR suggests that squirrels expend the most energy while accumulating the food capital that they use for winter and reproduction.

***37.1*** FLY, E.K.*; HILBISH, T.J.; Univ. of South Carolina; *efly@biol.sc.edu*

***Comparing British mussel hybrid zones to a temperature-sensitive hybrid zone on the coast of France***

Warming temperatures associated with climate change have been linked to changes in the geographic distribution of many species, including intertidal species. Hybrid zones between warm and cold-adapted species are thought to be especially sensitive tools allowing for the formation of hypotheses concerning ecological responses to climate change. The blue mussels *Mytilus edulis* and *M. galloprovincialis* are cold and warm-adapted species, respectively, that are found along European coasts, where they form multiple, extensive hybrid zones. The hybrid zone on the Brittany coast in France has shifted northward roughly 125 km in fewer than 10 years. It has been hypothesized that this shift in the hybrid zone is correlated with daily temperatures in January above 10.5 °C. This hypothesis was applied to the *M. edulis-M. galloprovincialis* hybrid zones in Britain to determine whether these hybrid zones are sensitive to the same temperature parameters or whether there may be regional adaptation. If this hypothesis is supported in Britain, we expect to see shifts in species distribution in areas that show corresponding changes in degree days in January. If this hypothesis is not supported, we will see either stasis of the hybrid zones or changes unassociated with degree days in January.

***87.10*** FORSGREN, K.L.*; YOUNG, G.; Univ. of Washington; *klforsg@u.washington.edu*

***The regulatory role of sex steroids during primary growth of ovarian follicles of coho salmon (Oncorhynchus kisutch)***

Studies on the endocrine regulation of oogenesis in teleosts have primarily focused on the later (secondary growth: vitellogenesis and maturation) stages of oocyte development. The regulation of earlier stages of development (primary growth: from chromatin nucleolar stage to cortical alveoli stage) is poorly understood and is of interest because aspects of fecundity and egg quality are thought to be determined during this time. We have developed an in vitro model based on long-term culture of ovarian follicles of coho salmon (*Oncorhynchus kisutch*). Our research to date indicates that sex steroids regulate the early stages of ovarian development, particularly the perinucleolar stage. Late perinucleolar ovarian follicles were cultured with various doses of estradiol-17beta (E2), testosterone (T), or 11-ketotestosterone (11KT) and then analyzed by histology. After 7 days, the highest dose of E2 (30 ng/ml) had only minor effects on oocyte volume. However, long-term culture (21 days) at the same dose resulted in the accumulation of cortical alveoli. 11-KT, a non-aromatizable androgen, significantly stimulated the growth of late perinucleolar oocytes compared to controls even at the lowest dose (0.03 ng/ml). T also stimulated oocyte growth, but was much less effective than 11-KT. Long-term culture with high doses of T (3 and 30 ng/ml) also resulted in the accumulation of cortical alveoli similar to E2. Overall, these results suggest that androgens may be primarily responsible for stimulating growth during the late perinucleolar stage, whereas E2 may be involved in the stimulation of cortical alveoli synthesis. (Supported by National Research Initiative Competitive Grant No. 2003–35203-13602 from the USDA Cooperative State Research, Education and Extension Service)

***64.7*** FOSSETTE, S*; HOBSON, V.J.; GIRARD, C.; KLAASSEN, R.; GASPAR, P.; GEORGES, J.Y; HAYS, G.C; Institute of Environmental Sustainability, Swansea University, Collecte Localisation Satellites, Satellite Oceanography Division, Lund University, Collecte Localisation Satellites, Satellite Oceanography Division, Institut Pluridiciplinaire Hubert Curien, UniversitÃ© Louis Pasteur, CNRS; *sabrina.fossette@googlemail.com*

***Characterizing leatherback's migration pattern from satellite-derived behavioural and oceanographic data: a meta-analysis at the Atlantic Ocean scale***

The critically endangered leatherback turtle, *Dermochelys coriacea*, performs the widest migrations in any sea turtle species, encountering highly diverse environmental conditions worldwide. A comprehensive overview of its different migration strategies at the scale of an ocean basin is notably required for implementing concerted conservation strategies. Yet, to date this overview is still lacking in the Atlantic Ocean where the last world’s major leatherback populations occur. Here, we present the meta-analysis of the migration pattern of 21 satellite-tracked leatherbacks captured throughout the Atlantic Ocean. Using satellite-derived behavioural and oceanographic data, we show that leatherbacks disperse actively without using any migratory corridor, yet highly impacted by surface currents, to reach highly dynamic oceanographic features where biomass but also fisheries concentrate. Three main migration strategies were highlighted: the “round-trip”, the “northern” and the “equatorial” strategy.

***14.6*** FOSTER, K. L.*; HIGHAM, T. E.; Univ. of British Columbia, Clemson University; *fosterk@interchange.ubc.ca*
***Functional morphology and biomechanics of ratfish steady swimming***
The functional morphology and biomechanics of body-caudal fin swimmers, and more recently median-paired fin swimmers have been studied extensively for a variety of chondrichthyan and osteichthyan fishes. However, functional morphology through ontogeny and the kinematics and hydrodynamics of steady swimming is poorly understood among chimaerids, sister group to sharks, skates, and rays. Ratfish are unique in that they swim by employing a flapping, labriform-like pectoral fin motion. To assess whether morphological differences underlie functional differences in pectoral fin use, we compared pectoral fin muscle morphology of spotted ratfish (*Hydrolagus colliei*) ranging from 19 to 53cm with that of 62 to 86cm spiny dogfish (*Squalus acanthias*). Despite the different use of pectoral fins during steady swimming of these two closely related species, no significant difference is found between adductor to abductor muscle mass ratios (P=0.76) or total pectoral muscle mass (P=0.12) relative to body size. The proportion of pectoral muscle projecting distally into the fin, however, is significantly larger in the spotted ratfish (82% and 36% in ratfish and dogfish respectively). This unique arrangement of the pectoral fin muscles in ratfish may enhance fine control over pectoral fin shape and movement. High speed video of ratfish individuals of 39 to 53cm in length swimming steadily at ~45cm/s reveal a constant amplitude of 13.11 ± 1.22cm relative to body length and no significant difference between average upstroke and downstroke velocity (P=0.25). Hydrodynamics of water flow generated by and around the pectoral fins are also analyzed and presented through analysis with particle image velocimetry.

***99.5*** FOWLER, D.A.*; DE BAKKER, M.A.G.; RICHARDSON, M.K.; Institute of Biology Leiden (IBL), Leiden University; *d.a.fowler.2@umail.leidenuniv.nl*
***Posterior HoxA and HoxD Genes in Avian Limb Development***
Comparative studies of regulatory networks and their constituent signaling factors provide a powerful line of study for comparative development. Non-traditional model organisms allow for testing of hypotheses generated in studies of traditional genetic model organisms. The zebra finch, *Taeniopygia guttata*, is an example of one such organism which we use in this study as a foil to traditional model organisms such as the chicken, *Gallus gallus*. The posterior Hox genes are a differentially expressed and necessary factor in the regulatory networks which coordinate the proper development of vertebrate limbs. We conducted a comprehensive survey of posterior HoxA and HoxD gene expression using *in situ* hybridization; these show that in some instances posterior HoxA and HoxD expression differs from current hypotheses. Although many patterns are highly conserved, these differences in expression of the posterior Hox genes occur both between the chicken and the zebra finch and between fore limb and hind limb. For example, zebra finch HoxD11 expression in the hind limb begins only after the autopodial field is established, approximately HH 25, and this expression does not extend into the zeugopodial field. This is in contrast to the chicken hind limb which begins HoxD11 expression prior to HH 17, and zebra finch fore limb which begins HoxD11 expression prior to HH20. Seen as an indicator for zeugopodial development, this result questions the nested role of the posterior HoxD genes. These spatiotemporal differences in HoxD11 limb expression indicate a change in hind limb HoxD cluster regulation independent of fore limb HoxD11 regulation. We are currently examining how these differences are related to condensation patterns and differences in skeletal morphology in the limbs of these birds.

***3.4*** FOX, J.L*; DANIEL, T.L.; University of Washington; *jessfox@uw.edu*
***Motion feature detection in a biological gyroscope***
Sensory systems acquire information from the environment, filter it, and transmit it to the nervous system in the form of action potentials. For mechanoreceptors, the relevant information can take the form of numerous kinds of forces occurring in multiple directions. While it is known that halteres of dipteran insects experience large inertial forces during flight and mediate behavioral responses to perturbations in the flight path, less is known about the neural encoding of such forces. Here, we use band-limited white noise mechanical stimulation combined with single-cell recording to determine the features of the motion stimulus that elicit responses (neural feature selectivity). We recorded >1000 neural spikes from each of 36 cells in 7 animals. We find that two principal motion features, the second of which is the derivative of the first, can accurately predict the spiking activity of haltere neurons. Moreover, these features are similar between cells and differ only in their phases. We posit that a population of haltere neurons with similar feature selectivity and distinct phase responses could encode a variety of inertial forces, including Coriolis forces. During a body rotation, the phase of the wingstroke at which peak strain occurs will shift depending on the magnitude of the body rotation. Thus, the identity of the first neurons activated will also vary with the magnitude of body rotation. The central nervous system could therefore discriminate different force magnitudes by detecting the order in which the primary afferents fire. Our data suggest that this type of place code, supported by a population of fast and highly precise neurons with broad frequency sensitivity and sharp feature detection, may be a viable strategy for encoding the complex inertial forces associated with high-speed flight maneuvers.

***47.5*** FOX, R.A.*; LADAGE, L.D.; ROTH, T.C.; PRAVOSUDOV, V.V.; University of Nevada, Reno; *rfox@unr.edu*
***Behavioral Profile and Aggression in Mountain Chickadees***
Research suggests that individual variation in stable behavioral traits (often referred to as behavioral profiles or temperament) may explain variation in ecologically-relevant behaviors such as the acquisition of dominance. In mountain chickadees (*Poecile gambeli*), a North American parid that lives in dominance-structured winter flocks, individuals' exploratory behavior in an unfamiliar flight room (a commonly used measure of behavioral profile in birds) may predict the outcome of dyadic dominance encounters. Birds that visited fewer locations in a novel flight room (low-exploring birds) are significantly more likely to become dominant in brief, pairwise encounters with birds that visited more locations (high-exploring birds). However, it is unclear whether exploratory behavior directly affects the acquisition of dominance status, or whether it simply covaries with some other behavioral characteristic, such as aggression. In this study, we tested the hypothesis that low-exploring birds are more aggressive than high-exploring birds by measuring individuals' responses to mirror image stimulation. We report on the relationship between individuals' responses to mirror image stimulation, exploration scores, and dominance.

***37.8*** FOX, Alicia*; SCHREY, Aaron; MCCOY, Earl; MUSHINSKY, Henry; University of South Florida; *amfox@mail.usf.edu*

***Genetic Relatedness in the Florida Sand Skink, Plestiodon reynoldsi, in the Scrub of Central Florida***

The Florida Sand Skink, *Plestiodon reynoldsi*, is a fossorial lizard currently listed as threatened throughout its range along the scrub habitat of the central ridges in Florida. Genetic differentiation exists across its distribution, and mark-recapture evidence suggests that the Florida Sand Skink may travel 140m at most; however, little is known about within-population properties. The goal of this study is to investigate the mating system and dispersal of the Florida Sand Skink. Multiple microsatellite loci were screened in individuals sampled from two sites: 1) A large homogeneous scrub near Davenport, Florida, and 2) Archbold Biological Station near Lake Placid, Florida. Numerous small wetlands are found throughout the scrub at Archbold and may act as barriers to dispersal. Samples at Davenport were collected from four sites (less than 2 km apart), each with multiple transects of pitfall arrays, while samples at Archbold were obtained from pitfall traps in drift fence enclosures. Parentage and genetic relatedness were estimated among individuals and sites. Significant genetic differentiation, of low magnitude, was observed among four Davenport sites, while, average relatedness values among individuals were low in magnitude. Low relatedness values may indicate that individuals are dispersing throughout the site. Average relatedness values did not differ between Davenport and Archbold, which suggests that individuals are behaving similarly at fine-scales in both locations. We are currently examining reproductive success for individuals collected in Davenport that have been relocated into enclosures with varying environmental conditions.

***S8.4*** FRANCE, S.C.*; PANTE, E.; BRUGLER, M.R.; VAN DER HAM, J.L.; University of Louisiana at Lafayette; *france@louisiana.edu*

***On the evolution of deep-sea octocorals and antipatharians: Patterns revealed from molecular phylogenies***

The discovery of high species diversity in the bathyal benthos has focused questions on the origin of deep-sea species and the processes that lead to speciation in this comparatively monotonous environment. We are exploring these questions using deep-sea corals as a model system, specifically three families of "gorgonians" (Anthozoa: Octocorallia) - Chrysogorgiidae, Isididae, and Primnoidae - and black corals (Anthozoa: Hexacorallia: Antipatharia), whose taxonomic diversity and abundance reach a maximum at depths >200 meters, although shallow-water representatives are known from each group. Phylogenetic analyses of DNA sequences reveal both the Chrysogorgiidae and Isididae are polyphyletic, but it is the inclusion of shallow-water taxa in these families that appear to be the cause: the strictly deep-sea genera cluster on robust monophyletic clades. The Primnoidae are monophyletic (except for the genus *Acanthoprimnoa*, whose placement on the tree may be affected by very long branch lengths), with shallow-water emergence at high latitudes for some species. The relationships among the deep-water clades from the different families remain unresolved due to short internal branch lengths in the phylogeny, an indication of a relatively-rapid radiation in the past coupled with the low substitution rate observed among octocorals. Among the black corals, the two families whose species are restricted to bathyal depths group as a monophyletic clade, distinct from families dominated by shelf-dwelling species. Our dataset still suffers from incomplete taxon sampling - a reflection of the difficulty of obtaining rare deep-sea specimens - but provides support that evolutionary radiations from deep-sea ancestors are common among these corals.

***62.9*** FRANCIS, JR., A.W.; Armstrong Atlantic State Univ., Savannah, GA; *austin.francis@armstrong.edu*

***Impact of an Elevated Sea Level Anomaly on Fish Recruitment to a Georgia Estuary***

The occurrence and abundance of fish species in shallow coastal waters and estuaries is generally determined by atmospheric and oceanographic processes coupled with fish behavior. It was the goal of this investigation to identify temporal and spatial patterns of fish recruitment in a Georgia estuarine nursery area. Larval and juvenile fishes were collected using an ichthyoplankton net deployed during night flood tides when larvae were most likely to be suspended in the water column. All sampling was conducted at the Moon River, a tidal stream of Skidaway Island that empties into Wassaw Sound. Samples were collected once a week from April 9, 2009 until July 28, 2009 and fixed in 10% formalin. Environmental conditions were assessed by recording air and water temperature, salinity, and current speed. Additional meteorological data, including fraction of moon illuminated, atmospheric pressure, wind speed, cloud cover, and precipitation, were obtained from U.S. Naval Observatory and National Oceanographic and Atmospheric Administration databases. In the laboratory, ichthyoplankton was sorted and identified to lowest possible taxon. Over a period of 16 weeks, a total of 13,994 fish were collected, representing 25 species from 14 families. Several species had not been previously described as occurring along Georgia's shallow coastal waters or estuaries. The dominant species in most samples was the bay anchovy, *Anchoa mitchilli*, representing 94.2% of the total catch. The greatest numbers of fishes were collected during the new moon. In late June, an elevated sea level anomaly contributed to a recruitment event more than 30 times the recruitment observed before or after the anomaly. Stochastic physical processes that elevate coastal sea level appear to enhance recruitment for at least some fishes.

***51.1*** FRANK, CRAIG L.*; REEDER, DEEANN; HICKS, ALAN; RUDD, ROBERT; Fordham Univ., Armonk, NY, Bucknell Univ., Lewisburg, PA, NY DEC, Albany, NY Rabies Lab., Albany; *frank@fordham.edu*

***The effects of White Nose Syndrome (WNS) on bat hibernation***

Six bat species found in the Northeast hibernate during winter. Hibernation consists of multi-day periods of torpor. The energy source during hibernation is stored body fat, increasing from 7% to 27% in early fall. White Nose Syndrome (WNS) greatly increases bat mortality during winter. It was first observed in New York during the winter of 2006-07, and has since been found at 65 different sites located in 9 states. Bats with WNS cluster near the entrances of cave/mines during hibernation, and fly outside during daylight in January. Bats with WNS have a white fungal growth on their muzzles and wings. WNS affects 5 hibernating bat species. We predicted that the increased mortality associated with WNS is due to: a) more frequent arousals from torpor during hibernation, which produces, b) a premature depletion of body fat. We tested these hypotheses by analyzing the carcasses of *Myotis lucifugus* collected throughout the winter in New York, and measuring the torpor patterns of free-ranging *M. lucifugus* at these sites during hibernation via radio telemetry. The mean torpor bout length for *M. lucifugus* hibernating in WNS sites was 7.5 d, less than the 12.4-19.7 d periods previously reported for this species. Bats with WNS also had a mean body fat level of 11.0 % by 31 Jan., and it further decreased to 7.5 % by 26 Feb. Mean body fat levels of bats without WNS, in contrast, did not decrease to 7.5 % until late April. Our results thus support the hypotheses that bats with WNS prematurely deplete body fat reserves by arousing from torpor more frequently.

***S7.10*** FRASER, William/R*; SCHOFIELD, Oscar/ME; KAHL, Alex; MARTINSON, Douglas/G; PATTERSON-FRASER, Donna/L; Polar Oceans Research Group, Institute of Marine and Coastal Science, Rutgers University, Lamont-Doherty Earth Observatory of Columbia University; *bfraser@3rivers.net*

***The Distribution of Adélie Penguins in the Western Antarctic Peninsula Region: Causal Mechanisms and Implications to Research in the Southern Oceans.***

Marine top predator populations do not occur randomly in oceanic environments. An extreme example of this heterogeneity is observed in the breeding distribution of Adélie penguins (Pygoscelis adeliae) on the Western Antarctic Peninsula (WAP). Adélie penguins are flightless, an evolutionary feature that severely constrains the spatial scales over which they can forage, and which led to the hypothesis that populations were likely restricted to marine regions where production was predictable over ecological time scales. Progress in testing this hypothesis was achieved by incorporating new technologies within the context of an integrated scientific approach that considered the annual to millennial time scales of the processes affecting the Antarctic lithosphere. Thus, integrated research contributing to a mechanistic understanding of the observed patterns has thus far included geology, glaciology, paleoecology, prey and phytoplankton ecology, marine circulation and ice mass and sea level changes. The WAP is changing due to climate warming, presenting researchers with an unprecedented opportunity to identify and understand how interactions between physical and biological processes drive ecosystem responses. Research on the distribution and population dynamics of marine top predators such as Adélie penguins provides a model for the types of questions that can be developed to bridge the gaps between disciplines whose contributions will be essential to understanding the complexity of the processes involved.

***64.2*** FREEMAN, R M*; DEAN, B; KIRK, H; PHILLIPS, R; ROBERTS, S; PERRINS, C; GUILFORD, T G; Animal Behaviour, Department of Zoology, Oxford Univeristy & Microsoft Research Cambridge, Animal Behaviour, Department of Zoology, Oxford Univeristy, British Antarctic Survey, Cambridge, Information Engineering, University of Oxford, Edward Grey Institude, Department of Zoology, University of Oxford; *robin.freeman@microsoft.com*

***Machine Learning approaches to understanding the migratory behaviour of a small seabird, the Manx Shearwater (Puffinus puffinus)***

Accurately determining the behaviour of individuals during their migration often requires expensive and relatively heavy telemetry devices. As such, research has necessarily focused on larger species and on smaller numbers of individuals. Here we explore the possibility of using data gathered from lower-cost, lightweight devices already widely deployed on smaller species (geolocators) to infer behaviour during migratory routes. Using methods from machine learning and pattern recognition to find patterns that correspond to those observed during summer foraging we are able to predict previously unseen marine stop-overs in a small Procellariiform, the Manx Shearwater (*Puffinus puffinus*). We will then discuss the potential for such analysis on wider datasets, explore the role of these interdisciplinary approaches and discuss some of our more recent findings.

***56.5*** FRONSTIN, Raime B*; WILLIAMS, Tony D; Simon Fraser University, Burnaby; *rbf1@sfu.ca*

***Investigating the costs of reproductive anemia associated with egg-production in European Starlings***

Costs of reproduction are widely considered to be a driving force in shaping the evolution of life history traits. Although costs of increased egg production have been well documented experimentally in birds (e.g. decreased survival, chick-rearing ability) the physiological mechanisms underlying such costs are largely unknown – indeed this is true more generally for all costs of reproduction. Egg production in birds is associated with reproductive anemia, defined as a reduction in hematocrit, hemoglobin, and red blood cell number, which can persist beyond clutch completion. It has been suggested that reproductive anemia might provide a “non-resource based” mechanism underlying costs of egg production. For example, if anemia persists through offspring rearing this might reduce a females’ aerobic capacity and flight performance providing an explanation for reduced provisioning ability and decreased reproductive success. We are testing this hypothesis in a free-living population of European starlings (*Sturnus vulgaris*) by experimentally manipulating hematocrit in egg-laying females using the drug phenylhydrazine (PHZ). We characterized the hematological status of both control and experimental females through repeat measurement of hematocrit and hemoglobin concentration at various stages of breeding. We then assessed potential costs of increased anemia through measurement of timing of reproduction, clutch size, egg size, incubation duration, offspring quality and offspring sex-ratio, maternal and paternal provisioning efforts, and fledging success.

***64.1*** FUDICKAR, A.M.*; WIKELSKI, M.; PARTECKE, J.; Max Planck Institute for Ornithology, Dept. of Migration and Immuno-ecology; *afudickar@orn.mpg.de*

***Accuracy of Light Level Loggers for Tracking Forest Dwelling Short-Distant Migratory Birds***

In order to stop the decline of populations of migratory animal’s world wide it is necessary to identify events encountered by individuals throughout their annual cycle. Until recently, tracking individual migratory birds has been limited to large species capable of bearing the load of heavy tracking devices. Geolocation via light level loggers has recently provided the opportunity to track small songbirds. Geologgers have been successfully used in artic sea birds and long-distant migrants. However, whether this technology can also be reliably used in forest dwelling short-distant migratory species is still unknown. In order to test the accuracy of light level loggers for tracking forest dwelling short distant migratory songbirds to their wintering grounds, we collected location data from 30 stationary light loggers at 15 forest sites over 800 km from December to March in Western Europe. Additionally, we monitored the movement of non migratory songbirds fit with light loggers over the same time frame to compare their known locations with locations estimated by light level loggers. We found that different calibration methods can significantly alter location estimations and that the appropriate calibration method for light level loggers is species specific. Additionally, by comparing light loggers on multiple individuals at known locations and corresponding stationary loggers we identify an affect of individual behavior on location estimation. These results indicate that the appropriate application of light level loggers for tracking songbirds requires prior knowledge of individual behavior during migration on their wintering grounds.

***75.2*** FULLER, P.O.*; HIGHAM, T.E.; CLARK, A.J.; Clemson University; *pfuller@clemson.edu*

***Digital enhancement: three-dimensional locomotor kinematics of two species of padless geckos***

Locomotion of pad-bearing species of geckos has garnered considerable interest from researchers. However, many groups of geckos include species that lack toe pads, and thus lack adhesive capabilities. A key question is whether all species of padless geckos exhibit similar locomotor kinematics and performance. Both *Teratoscincus scincus* (frog-eyed gecko) and *Eublepharis macularius* (leopard gecko) lack adhesive toe pads, and both species are terrestrial. We examined three-dimensional locomotor kinematics of both species using two synchronized high-speed video cameras (dorsal and lateral view) operating at 500fps. Lizards ran along a 1-meter raceway with a surface covered with 300-grit sandpaper for traction. Several points on the hindlimb and tail were digitized including the hip, knee, ankle, toe, base of the tail, tip of the tail, and snout. In terms of locomotor performance, *T. scincus* exhibited much faster running speeds than *E. macularius*, although *T. scincus* was more variable. Despite having relatively comparable values of duty factor, stride duration was shorter for *T. scincus*. The posture of *T. scincus* appears to be more upright than *E. macularius*, which likely has implications for locomotor dynamics. Morphological data will be incorporated to assess the relationship between form and function in these geckos.

***83.5*** FURUYA, W.*; MOHSENI, K.; University of Colorado; *mohseni@colorado.edu*

***A Care and Testing Facility for Squid Propulsion and Flow Visualization***

This paper discusses the drafting process and trade studies that were used to design a care and testing facility to investigate the hydrodynamics of squid locomotion. This design process includes the selection of the squid species that would be used for the flow visualization, the living conditions of the squid, the tank design concepts, the filtration system design and configuration, the prey organisms, and the expected costs of each subdivision as well as the estimated overall cost of the project. The preliminary flow visualization on Sepioteuthis *lessoniana* is also presented.

***S4.9*** FULOP, D; KRAMER, EM; DUMAIS, J*; Harvard University; *jdumais@oeb.harvard.edu*

***Pollinarium ejection and the evolution of hypervariable male flowers in Catasetum orchids***

Orchids possess an exquisite suite of characters to support pollination. Among the most remarkable of these characters is the forcible pollinarium discharge of the genus *Catasetum*. When ejected from a male flower, the pollinarium attaches precisely to the dorsum of the visiting bee, which will, upon visiting a female flower, deposit the pollen-bearing pollinia into the stigma, thus achieving pollination. The fast release of the pollinarium and precise targeting to the bee's dorsum are critical for successful pollination in the genus; yet these features have received only limited attention in the literature. Here we show that the impulse that propels the pollinarium comes from the elastic energy stored in the stipe and that subsequent interaction with the flower column guides the pollinarium toward the bee. This active pollination mechanism stands in sharp contrast with pollination in the majority of orchid genera where floral architecture must ensure that the pollinator comes in direct contact with the static pollinarium. In *Catasetum*, the pollinarium guidance mechanism and remote triggering via the action of the antennae have relaxed this structural constraint in the design of flowers. This innovation, we propose, has enabled the exceptional diversification of male flower morphology in the genus. To support this claim, we show that one major axis of diversification – the degree of flower opening – correlates precisely with the key biomechanical parameter for pollinarium guidance. Our results give new insight into the evolutionary mechanisms behind the staggering morphological diversity found in orchids.

***S5.5*** GAHN, Forest J*; BAUMILLER, Tomasz K; Brigham Young Univeristy-Idaho, University of Michigan; *gahnf@byui.edu*

***Evolutionary morphology of regenerative abilities among crinoids: a paleontological perspective***

The fossil record demonstrates that crinoids have had the capacity to regenerate lost body parts since the Ordovician. This ability has been recognized in all parts of the crinoid skeleton. Most regeneration is indicated by an abrupt change in the size of adjacent ossicles. Completed regeneration is difficult to recognize, but the carbon and oxygen isotopic composition of ossicles may be used to distinguish fully healed skeletal elements. Although crinoids have possessed regeneration abilities since their origin, the distribution of regeneration sites within and among crinoid clades has changed through time. Examples of this are specialized autotomy articulations in the arms (syzygies) and stalk (synostoses) for minimizing loss and maximizing recovery potential. Most Paleozoic crinoids lacked such articulations as evidenced by fixed stalks and random patterns of longitudinal arm regeneration. However, syzygies and muscular arm articulations are found among the cladids by the Mississippian, and the most diverse post-Paleozoic crinoids (articulates) shared these traits. The presence of these characters in extant crinoids facilitates mobility and predator avoidance. The frequency of regenerated crinoid arms has also changed through time. Spatiotemporal changes in regeneration frequency are best explained by differences in sublethal predation. Notable patterns include a significant increase in regeneration frequency during the Middle Devonian, a time of dramatic evolutionary radiation among durophagous predators. Moreover, at the community-level, the most abundant species have the highest regeneration frequencies. According to apparency theory and escalation, taxa with higher rates of sublethal predation should also exhibit greater predator-avoidance potential, a testable prediction with both paleontological and neontological data.

***8.4*** GARTNER, Gabriel E*; JAYNE, Bruce C; GARLAND JR., Ted; University of California, Riverside, University of Cincinnati; *ggart001@ucr.edu*

***Comparative Analysis of Axial Musculature in Snakes***

Locomotion is a critical selective factor in shaping both the morphology and physiology of animals. Although snakes share a limbless body plan, they have considerable diversity in their types of locomotion, habitat use and axial musculoskeletal morphology. Despite recent advances in higher-level snake phylogenies, no previous study has used modern quantitative phylogenetic methods to analyze this diversity. Here, we use phylogenetic multiple regression to analyze patterns of interspecific diversity in the spinalis muscle of snakes using a data set of 133 species in 13 taxon groups (monophyletic groups on our tree, often representing more than one family) from both the literature and original data. A phylogenetic tree was constructed from the literature, and data on relative length of the spinalis muscle were analyzed using both conventional and phylogenetic statistics. Non-nested models incorporating either log10-transformed numbers of body vertebrae, habitat type, and “clade”—and various combinations therein—were used to examine their effects on several dependent variables associated with the spinalis muscle. Initial results indicate that the single best predictive model is non-phylogenetic (i.e., assumes a “star” phylogeny) and includes habitat and clade as predictor variables, thus indicating an effect of habitat (or ecology) and that phylogenetic signal, the tendency for related species to resemble one another, is present at the level of differences among major clades of snakes.

***91.10*** GAVELIS, Gregory*; MASLAKOVA, Svetlana; Oregon Institute of Marine Biology; *gavelis@uoregon.edu*

***Comparative Anatomy of Planuliform Nemertean Larvae***

Nemertean developmental studies have focused primarily on the pilidium larva of the pilidiophoran group, with little attention to the planuliform larvae of the palaeonemertans or hoplonemerteans. Morphogenesis of the proboscis, cerebral organs, and digestive system have conflicting descriptions in the light-microscopy-based literature for hoplonemerteans. We reassessed larval development of the hoplonemertean *Emplectonema gracile*, and also described for the first time early development of the palaeonemertean *Procephalothrix spiralis* using confocal microscopy. The proboscis in *E. gracile* developed from an internal mass (as in *Paranemertes peregrina*) rather than a distinct invagination (found in *Pantinonemertes californiensis*). Paired antero-lateral invaginations described in development of other species (and homologized with either rudiments of the nervous system or cerebral organs) were observed in early development of both *P. spiralis* and in *E. gracile*, however, their ultimate fate is yet to be determined. As in many hoplonemerteans, *E. gracile* was found to possess a “transitory epidermis” of large cleavage-arrested cells which were gradually replaced by the definitive epidermis. In *P. spiralis*, the epidermis of newly hatched larvae of *P. spiralis* was composed of relatively few large cells, similar to the other studied palaeonemertean *Carinoma*, larvae of many hoplonemerteans, and pericalymma and test larvae of some mollusks. In *Carinoma* these large cells are derived from the trochoblast lineage and form a vestigial prototroch, which suggests that nemerteans ancestrally possessed a trochophore type larva. Because palaeonemerteans are paraphyletic and *Procephalothrix* is basal to *Carinoma* (Thollesson and Norenburg 2003) the fate of these cells in *P. spiralis* is of particular interest to hypotheses concerning the evolution of larval development in nemerteans.

***12.8*** GEBCZYNSKI, AK*; SADOWSKA, J; KONARZEWSKI, M; Univ. of Bialystok, Poland; *andgebcz@uwb.edu.pl*

***Basal Metabolic Rate (BMR) of parents is positively correlated with postnatal growth rate of offspring in laboratory mice***

One of the postulated evolutionary advantages of high basal metabolic rate (BMR) is its positive association with the rate of reproduction, which includes positive association with high individual growth rate. The latter may stem from (1) more effective parental care of parents characterized by high BMR, (2) higher growth rate of offspring having high BMR or (3) both. To test (1-3) we compared growth rates of mice from two lines divergently selected for high (H-BMR) and low (L-BMR) BMR. This long-term selection resulted in over 30% between-line difference in mass-corrected BMR and related traits, such as the mass of internal organs associated with energy assimilation rate. To discriminate between the effect of line-specific growth rate and parental care we swapped pups between litters and lines, thus creating 86 litters of 8 pups (each of 4 pups from L-BMR and H-BMR line) nourished by 44 and 42 mothers from H-BMR and L-BMR line, respectively. When litters were nourished at ambient temperature of 23°C, there was no effect of mother’s line affiliation on growth rate of foster offspring. However, independent of the line affiliation of the foster mother, pups from H-BMR line grew faster than those from L-BMR line, which supports (2). It is also possible, that the advantages of high BMR of parents becomes apparent only under metabolically stressful conditions. To test this, we repeated the above described experiment on another batch of 30 litters exposed to an ambient temperature of 17°C. Independent of the line of origin, pups nourished by L-BMR mothers grew slower than their counterparts. Still however, growth rate of pups of H-BMR line was higher than that of L-BMR line. Taken together our results showed that high BMR is positively associated with both the quality of parental care and the rate of individual growth

***32.3*** GEERINCKX, Tom*; HERREL, Anthony; ADRIAENS, Dominique; Ghent University, Belgium, MusÃ©e National de l'Histoire Naturelle, France; *tom.geerinckx@ugent.be*

***Suckermouth armoured catfishes crack the paradox between respiration and suckermouth attachment***

Suckermouth armoured catfishes (Loricariidae) use their suckermouth for respiration, feeding, and attachment to substrates. The combination of respiration and suction attachment appears paradoxal, as a properly functioning suction device would need a suction disc without leakage (yet inspiration must occur via the sucker), and continuous subambient pressure in the sucker cavity (even during expiratory mouth floor elevation). In the loricariid *Pterygoplichthys disjunctivus*, the anatomy of the suckermouth structures was examined, and a kinematic analysis was performed to acquire insights into how these functions are combined. High speed video recordings of external and internal structures (using X-ray equipment) of several specimens were analysed to determine how respiration is adjusted or constrained during weak or powerful suction onto substrates. These recordings show that suckermouth attachment does influence respiratory parameters such as cycle length, excursion amplitudes of the mouth floor and wall, and the way water enters the mouth. Respiration, however, continues during attachment and is not impaired. Our data show that a muscular oral valve can actively separate the buccal cavity from a pre-buccal cavity formed by the lip suction disc. Volume changes of this pre-buccal cavity assure sucker function, and are mediated by the lower lip, the lower jaws, and the oral valve. The maxillary barbels control lateral inflow openings, and can do so unilaterally. These loricariid head structures can be clearly linked to the station-holding capacities of loricariids, even on smooth, inclined surfaces. Morphological and kinematic data also show that the suspensorium has a minor share in the buccal volume changes, and that the opercle is anatomically and functionally decoupled from the gill slit ventilation mechanism.

***84.3*** GEORGE, Matthew N*; SWANSON, Brook O; Gonzaga University; *mgeorge3@gonzaga.edu*
***Allometry and Correlated Evolution in Fiddler Crab Major Claw Morphology***
For males of many animal species, diverse and opposing selective pressures influence the morphology and function of secondary sex characteristics. In the genus Uca, male fiddler crabs exhibit a single enlarged claw used not only in the context of male-female signaling, but also in male-male combat. This dual utility of a single appendage presents an opportunity to study variation across species and investigate how the appendage's dual roles as a weapon and a visual signal shape morphology. In this study morphology, and structural properties (resistance to puncture) of the major claw and carapace were sampled for 23 species within the genus. An estimation of claw closing force was also determined using these measurements. Our results show large variations in all morphological and structural variables across species, even after correcting for body size. The resistance to puncture of the major claw appears to scale as mass to the 2/3 power. Claw force production on the other hand shows positive allometry, scaling as mass to the 1.1 power. Correlations of size corrected, phylogenetically independent contrasts show a positive relationship between claw-closing force and resistance to cuticle puncture (species with forceful claws have resistant cuticles), suggesting that these are evolutionarily correlated traits. However, mass corrected claw area (an estimate of signal size) is inversely correlated with claw force production, suggesting an evolutionary trade-off between signaling and fighting.

***20.5*** GEORGE, N.T.*; DANIEL, T.L.; Univ of Washington, Seattle, Univ of Washington, Seattle ; *ntgeorge@u.washington.edu*
***Mechanical energy gradients arise as a consequence of temperature gradients in the flight muscles of Manduca sexta***
The inherent inefficiency of muscle contraction leads to significant heat production. Many insects use this energy byproduct to raise their thoracic temperature to achieve near maximal contraction rates. However, an elevated core temperature combined with surface heat loss invariably leads to a temperature gradient throughout the muscle. In the dominant flight muscles of *Manduca sexta*, (dorsolongitudinal muscles: DLMs), we measured a strong gradient in the dorso-ventral direction with a mean difference of 6.4 °C. Together with the temperature dependence of muscle force generation, this thermal gradient suggests the energy output of more dorsal subunits will differ from deeper and warmer muscle subunits. To test this hypothesis, we isolated the cooler dorsal subunits and the warmer ventral subunits and recorded both single and 25 Hz (wing beat frequency) isometric contractions at a range of temperatures. At 25 °C, the dorsal subunits had a rise time 1.5 ms longer than the ventral subunits at 35 °C. In addition, at 25 Hz, the cooler dorsal subunits contracted in an unfused tetanus, whereas the warmer ventral subunits produced isolated twitches. Furthermore, EMG recordings of the DLM subunits showed no separate activation that would align contraction peaks. The presence of an unfused tetanus in the dorsal subunits indicates that work output varies significantly throughout the DLMs. To test this hypothesis, we used temperature controlled work-loop methods. Results show the total amount of work lost by the system decreased as temperature increased; net work differed by at least a factor of 2 from 25 °C to 35 °C. Thus, the existence of a temperature gradient produces a mechanical energy gradient in muscles.

***101.7*** GERMAN, RZ*; CROMPTON, AW; KONOW, N; THEXTON, AJ; Johns Hopkins Univ, Harvard Univ, Brown Univ, King's College, London; *rz.german@jhmi.edu*
***Sensory Stimulus and Reflex Response in Mammalian Swallowing***
Several sensory stimuli can elicit the reflex motor response of a mammalian pharyngeal swallow. Some, such as direct stimulation of a sensory nerve, are not within the range of normal stimuli an animal would experience. Of normal stimuli, bolus volume is the most frequently cited stimulus, although its exact role, and threshold is unknown. Our understanding of the swallow reflex is further complicated by the fact that the pharynx is a midline structure and several side-to-side sensory/motor brainstem connections exist. We tested the hypotheses that 1) stimuli other than bolus volume can elicit a swallow and 2) that unilateral stimuli are sufficient for a normal reflex response. Working with our infant pig model system and an automated feed delivery system, we measured the impact of non-pathologic stimuli on the initiation and frequency of swallowing. While bolus volume was one factor in eliciting a swallow, frequency of delivery, a stimulus to the anterior oral cavity was also significant. Further, some aspects of the motor response in feeding, such as frequency of intra-oral transport, are independent of changes in stimuli. When sensory nerves on one side are ligated, contralateral stimulation is sufficient to produce a kinematically normal swallow. These results are a first step to answering the question "what makes a swallow happen?".

***S9.6*** GHARBIAH, M; NAKAMOTO, A; NAGY, L*; University of Arizona; *lnagy@email.arizona.edu*
***The role of the polar lobe and intracellular signaling in cell fate specification of the mud snail Ilyanassa.***
The early embryo of the mud snail *Ilyanassa* is characterized by the presence of a polar lobe, a large anucleate structure protruded during the meiotic and first two cellular divisions. The contents of the polar lobe are exclusively partitioned into one cell, the D macromere, the descendants of which function to organize polarity within the larvae. Removal of the polar lobe results in larvae with radially positioned head structures as well as disruption of positional information along the anteroposterior axis. The polar lobe was assumed to house localized determinants required to establish axial polarity. We find that the polar lobe is necessary but not sufficient to establish polarity. The D quadrant macromere requires a signal from the micromeres to function as the organizing center of the embryo. Perturbations that disrupt cell contacts and gap junctions prevent organizer activity. In addition, early Notch and Wnt signaling are required to appropriately establish embryonic pattern. Treatment with selective inhibitors of these pathways result in larvae with severe defects in internal organs and cell fate specification. A reappraisal of the literature suggests evidence for additional early signaling to pattern the shell and endoderm. We use this data to build a model for a sequence of signaling events that regulate early embryonic development in *Ilyanassa*. When examined comparatively, the data suggests that underlying the conservative patterns of cleavage and fate maps within phyla with spiralian development is a surprising degree of diversity of molecular mechanisms specifying cell fate.

***32.4*** GIBB, A.C.; ARENA, A.*; Northern Arizona University; *alice.gibb@nau.edu*

***Prey acceptance and feeding kinematics in native and non-native fishes from Colorado River tributaries, or "My what a big mouth you have!"***

The American Southwest is home to a diverse fish fauna that has been imperiled by the introduction of non-native species. We examined native and non-native fish occupying two trophic guilds in Colorado River tributaries: top predators, roundtail chub (*Gila robusta*) and smallmouth bass (*Micropterus dolomieu*), and benthic omnivores, Sonora sucker (*Catostomus insignis*) and common carp (*Cyprinus carpio*). Fish were presented with six ecologically-relevant prey types to assess prey acceptance, quantify feeding movements, and address the following specific questions. Do species at the same trophic level consume the same array of food items? Do species capture different food items via similar or distinct feeding behaviors? From our laboratory studies, several patterns emerge. (1) Natives consume a broader array of food items, relative to non-natives. (2) Species at a given trophic level demonstrate similar feeding behaviors: for example, roundtail chub and smallmouth bass bite and tear benthic attached prey using their jaws, but immediately engulf midwater prey into the buccal cavity. (3) Three of four species modulate mouth gape in response to different prey items; Sonora sucker, however, show an "inflexible" feeding behavior, whereby gape and other kinematic variables are not modified in response to different food types. (4) Non-native species consistently produce a larger gape then their native counterparts, and gape is a function of cranial morphology. This last finding has two significant ecological ramifications: (a) prey items included in the diet of non-natives may be excluded from the diet of natives because they are too large and (b) non-natives may be able to consume similarly-sized native fish, while the converse is highly unlikely.

***85.4*** GIBBS, A.G.*; DE OLIVEIRA, C.C.; RAJPUROHIT, S.; ETGES, W.J.; Univ. of Nevada, Las Vegas, Univ. of Arkansas; *allen.gibbs@unlv.edu*

***Ecological genomics of host plant adaptation and stress in desert Drosophila***

Geographically isolated populations of the desert fruitfly, *Drosophila mojavensis*, complete their life cycles on different species of cacti. Previous studies have demonstrated that temperature and growth on different hosts affect development time and cuticular hydrocarbons (CHCs). CHCs modulate water loss through the cuticle and serve as mate recognition cues, suggesting that host plants can affect both environmental stress resistance and courtship behavior. Based on the recently released whole genome assembly for *D. mojavensis*, the only desert organism with a sequenced genome, we developed Nimblegen 12-plex microarrays containing probes for all predicted genes. We reared flies from Baja California and Sonoran populations on two host plants at different temperatures identified co-expressed gene sets that differ between sexes and populations reared under different conditions, and assessed responses in expressed CHCs. These gene sets are in the process of annotation, and will then provide candidates to identify physiological processes allowing host plant shifts and adaptation to desert conditions. Supported by NSF award 0723930 to A. G. Gibbs and W. J. Etges.

***90.8*** GIGNAC, P.M.*; ERICKSON, G.M.; Florida State University; *pgignac@bio.fsu.edu*

***Ontogeny and the biomechanics of feeding in the American alligator (Alligator mississippiensis): Developmental changes to muscle physiology contributes to niche transitions in a large-bodied vertebrate***

The American alligator, *Alligator mississippiensis*, undergoes a substantial resource shift to increasingly more durable prey throughout development. In addition to its size, this taxon utilizes absolutely high bite forces to capture and subjugate these food resources. For large mammalian prey drowning is the main mode of subjugation wherein *A. mississippiensis* uses its high bite forces to maintain a purchase on the prey item as it is pulled underwater. With struggling prey this process can last tens of minutes. Vertebrate skeletal muscle, however, is unable to sustain high-force contractions over long periods of time. Therefore, how this taxon is physiologically capable of executing such a critical behavior is unknown. Analysis of the jaw adductor musculature throughout ontogeny shows that developmental changes to the colors of some adductors indicate a physiological transition from glycolytic to oxidative muscle fibers. Additionally, bite force measurements in *A. mississippiensis* show that sub-adult and adult individuals maintain a 6-8% hold (of maximum bite force) in between periods of peak bite-force generation. Together these observations suggest one way *A. mississippiensis* gains access to large prey, namely through developmental changes to muscle physiology. To test if these changes can account for the holding behavior, we used a recently established biomechanical model of bite-force generation to address the ability of the developmentally plastic jaw adductors to generate appropriate hold forces. Our results show that the model accounts for the observed forces in relative and absolute comparisons and points towards physiologically important changes to the jaw adductor system of crocodilians that have not been considered previously.

***36.2*** GILMAN, Sarah; Friday Harbor Laboratories, University of Washington; *sgilman@jsd.claremont.edu*

***Climate change and species interactions: predicting indirect effects***

Average global temperatures are expected to warm by 1.4-5.8C over the next century. Although the direct effects of temperature on individual performance are well-documents for many species, less well understood is how these direct effects of temperature will influence interactions among species within a community. The barnacle *Balanus glandula* is one of the major space occupying organisms in rocky intertidal habitats in the San Juan Islands region of Washington, and is preyed upon by the intertidal whelk *Nucella ostrina*. Temperature is predicted to alter both the growth rate of *B. glandula* and the foraging activity of *N. ostrina*. To examine the cumulative effect of these changes, I separately manipulated body temperature and prey size distribution of *N. ostrina* and observed changes in growth rate and foraging behavior. Experiments were conducted in an outdoor tidal mesocosm system that allowed for two high tides and two low tides each day. Snails were assigned to one of three temperature treatments and one of two prey size treatments. Snails ate more barnacles when presented with smaller prey, but energy consumption (calories) declined. Warm temperatures reduced both snail growth and survival, particularly for the smallest snails in the experiment. When larger snails, were fed on the larger prey treatment, their growth and survival under the warmest temperature treatment was not reduced relative to controls. These results present a complex picture of the effect of temperature: changes in the prey size distribution altered the predator's performance under thermal stress.

***59.2*** GLEDHILL, Michael R*; TRAN, Michael C; TSUKIMURA, Brian; California State Univ., Fresno; *mrgledhi@csufresno.edu*
***Regulation of Methyl Farnesoate Esterase during development of the tadpole shrimp, Triops longicaudatus***
Methyl farnesoate (MF), a putative crustacean hormone, is well documented as the precursor to juvenile hormone in insects. In crustaceans, MF promotes juvenile morphology, with low MF levels being necessary for development (Laufer and Biggers, 2001). In juvenile tadpole shrimp, *Triops longicaudatus*, MF decreased ovary weight and oocyte number when incorporated into food pellets (Tsukimura et al., 2006). MF is metabolized by the enzyme methyl farnesoate esterase (MFE). The purpose of this experiment was to determine the base rate of MFE at days 4, 8, 12, and during oocyte development, plus determine if tadpole shrimp in response to dietary MF (6 µg/g), modulate their MFE rates. Enzymatic rates were determined by incubation of tadpole shrimp tissue with the radio-labeled substrate, $^{3}$H-MF. The polar products of the digestion were separated from the remaining non-polar MF by hexane, acetonitrile, and saline water (Laufer et al., 1987). There was an overall decline in the rate of MFE with age. Sexually immature animals, characterized by a lack of cysts in brood sacs, had an average MFE rate of 23.2 ± 3.2 (pmol MF/mg protein/min) compared with sexually mature animals with a MFE rate of 12.1 ± 1.4. The transition appeared to be rapid and around the first expansion of vitellogenesis. When given dietary MF, animals appeared to respond by decreasing their MFE rate as juveniles (Control: 25.3 ± 3.5, MF-treated: 16.1 ± 3.9) and as adults (15.6 ± 1.5 vs. 7.3 ± 2.0). These data support the hypothesis that MF must be cleared from the organism before it can develop into a sexually mature animal. However, the decline in MFE rate observed in animals receiving exogenous MF could potentially be due to toxic level doses of MF.

***49.1*** GOLDBOGEN, J. A.*; CALAMBOKIDIS, J. ; OLESON, E. M.; POTVIN, J.; SCHORR, G.; SHADWICK, R. E.; Univ. of British Columbia, Cascadia Research Collective, Univ. of California, San Diego, Saint Louis University; *jgoldbogen@gmail.com*
***Big heads, big gulps and high drag: mechanics and energetics of rorqual lunge feeding***
Rorqual whales are not only some of the largest animals to have ever lived, but they also exhibit one of the most unique feeding methods among aquatic vertebrates. To investigate the mechanics and energetics of rorqual lunge feeding, we deployed high-resolution acoustic tags to three rorqual species that differ in average body size (blue, fin and humpback whales). We determined instantaneous body speed during lunges from the level of flow noise measured by the hydrophone within the tag. These kinematic data were then integrated with morphological data into an unsteady hydrodynamic model to estimate engulfment volume, drag, and work. Maximum lunge speed, engulfment volume and filter time increased with body size, but relative to body size there was no significant difference. In contrast, both the absolute and mass-specific work against drag increased with body size, which suggests a relatively higher cost of a lunge for larger rorquals. This hypothesis is corroborated by dive profile data which show a decrease in the number of lunges that are performed per dive and a relatively higher increase in post-dive recovery time following lunges at depth. Given these scaling patterns, I discuss the ecological and evolutionary implications of lunge feeding, including the energetic requirements of, and physical limits to, big body size in rorquals.

***32.2*** GONZALEZ, P; CAMERON, CB*; UniversitÃ© de MontrÃ©al; *c.cameron@umontreal.ca*
***Filter feeding in hemichordate worms and the evolution of the vertebrate adenohypophysis***
Observations on the hemichordate worm Protoglossus graveolens demonstrate that the gill slits, pre-oral ciliary organ and the lining of the cylindrical pharynx are used in filter feeding. Pumping of water is generated by cilia that line the lateral gill bars and the pre-oral ciliary organ directs water from the dorsal surface of the proboscis to the mouth. Particles are trapped and concentrated on the primary and secondary gill bars and transported ventrally and posteriorly by cilia that line the pharynx. Particles that passed freely through the gill pores were maximum 1.28 µm and water entered the pharynx at a rate up to 4.05 mm.s-1. The Reynolds number and propulsive efficiency of the filter-feeding structures is similar to other filter feeders. Structural and functional similarities with the cephalochordate pharynx suggest that a wheel organ/ pre-oral ciliary organ and a filter-feeding pharynx may have been present in the common ancestor to the deuterostomes. Immunohistochemical studies using antibodies against Pit1 and FSH further suggest that the adenohypophysis of vertebrates evolved from an enteropneust-like pre-oral ciliary organ/ cephalochordate wheel organ.

***52.3*** GOULDING, T*; COHEN, S; Romberg Tiburon Center for Environmental Studies, San Francisco State University; *tc.goulding@yahoo.com*
***Examining genetic variation of the Acanthocephalan Profilicollis altmani parasitizing mole crabs (Emerita spp.) in North America***
Parasites are often an overlooked component of marine ecosystems despite their abundance and importance in food webs. This is especially true of acanthocephalans or “spiny-headed worms”, a small phylum (~1150 species) of parasitic worms that can infect a variety of hosts from marine, freshwater and terrestrial habitats. Mole crabs (*Emerita spp.*), found in the intertidal zone of sandy beaches around North America, serve as the intermediate host for the acanthocephalan *Profilicollis altmani* which develops in their hindgut. Although *P. altmani* is abundant in host populations, the conserved morphology of acanthocephalans can confound species identification. Using genetic techniques, we compare different populations of *P. altmani* to determine if morphologically cryptic species are present. In this study, multiple species of mole crabs were collected from the Pacific and Atlantic Coasts, as well as the Gulf of Mexico. DNA was extracted from the parasites and two loci were sequenced: the Internal Transcribed Spacer (ITS) and Cytochrome Oxidase Subunit I (CO1). Analysis showed that ITS was not variable between populations of *P. altmani*, so a phylogeny was constructed using Bayesian analysis of CO1. This phylogeny shows that genetic variation among the parasite *P. altmani* from different *Emerita spp.* is low, potentially the result of long-range dispersal of their eggs between populations by birds and ocean currents.

***72.8*** GRAHAM, Sean P.*; FIELMAN, Kevin T.; MENDONCA , Mary T.; Auburn University; *grahasp@auburn.edu*
***Thermal ecology of the cottonmouth (Agkistrodon piscivorus) immunity complement system.***
Complement, an immune protein cascade involved in pathogen lysis, was discovered as a temperature-labile component of vertebrate plasma. However, investigations of the vertebrate complement system in the context of thermal ecology have not been common. We investigated two thermal properties of the complement system of an ectothermic model, the cottonmouth snake (*Agkistrodon piscivorus*). We tested the hypothesis that snake complement conforms to the thermal reaction norm pattern commonly observed in thermal performance studies. Specifically, we predicted that complement efficiency would be maximal at or near the cottonmouth's preferred body temperature determined from measurements of wild-living snakes (i.e., ~24°C). We also tested whether thermal acclimatization of this protein cascade occurs in this snake, by developing temperature/performance curves from field-collected plasma samples obtained during spring, early summer, and late summer. We found no evidence for the predicted thermal reaction norm of this snake's complement system using a functional bacterial lysis assay within a range of ecologically relevant temperatures. Complement efficiency exhibited a significant, positive correlation with temperature, and continued to increase in efficiency well past the field body temperatures preferred by this snake. This pattern was observed in all three seasons we tested, and there was no difference in mean complement efficiency or the slope of the complement/temperature relationship between these periods, suggesting no thermal acclimatization occurs in the complement system of this snake. These results suggest that ectothermic complement may exhibit poor immune performance at cooler temperatures, however, performance could be enhanced at a low energetic cost via behavioral thermoregulation.

***S9.10*** GRANDE, Cristina; Centro de BiologÃ−a Molecular Severo Ochoa; *cgrande@cbm.uam.es*
***The left-right axis. Generating asymmetries in snail development.***
Although most animals are bilaterians, many develop specific asymmetries along the left-right axis like the asymmetric placing of single organs, directional asymmetry in appendages and the coiling of the snail shells. Despite its key role in animal development, comparatively little is known about the molecular mechanisms and processes involved in establishing this axis. Results from studies in deuterostomes suggest that a cascade of lateralized signaling is involved in specifying left-right morphological asymmetries and also that the breaking symmetry event differs among taxa. Comparative developmental and genomic studies in other organisms like arthropods and snails have revealed both differences and similarities in the gene pathways and molecules involved in left-right determination. These findings provide valuable information to understand the origin and evolution of left-right patterning in Bilateria. Here, I discuss recent progress in this field and the relevance of gene pathways, cytoskeletal structures, and ion flows on left-right asymmetry determination in snails in an evolutionary context.

***93.4*** GRASON, Emily*; MINER, Benjamin/G; Western Washington University; *grasone@students.wwu.edu*
***Non-consumptive effects in a marine food chain with both native and invasive species.***
Top-down effects by predators are important in structuring marine ecosystems, and predators control prey densities and distributions via consumptive and non-consumptive effects. However, in food chains with invasive species, the magnitude of non-consumptive effects is not yet well studied, and might be different from chains with native species due to different evolutionary histories. In particular, invasive species might not have evolved inducible defenses or offenses to native predators, which should reduce or eliminate non-consumptive effects. We tested whether predator effluent from a native crab altered the avoidance behavior and feeding rates of two invasive oyster drills (the marine whelks *Urosalpinx cinerea* and *Ocinebrina inornata*) to determine if non-consumptive effects occur in this system. In both species of drills, individuals increased their avoidance behavior three to five-fold and decreased their feeding rate by 48% - 77% in response to chemical cues from native rock crabs eating conspecific drills. This suggests that rock crabs could help preserve a commercially and ecologically important resource (oysters) through both a consumptive- and non-consumptive trophic cascades. However, the existence of an avoidance response may grant the drills a refuge from predation that prevents the crabs from acting as an effective biotic control. The specificity of the non-consumptive effects was further explored with experiments that attempted to determine what elements of the cue were eliciting a behavioral change. Cue response specificity is particularly relevant in invasive species, as it may help managers predict how novel species will likely incorporate into native communities.

***77.2*** GREENE, MJ; Univ. of Colorado Denver; *michael.greene@ucdenver.edu*
***Harvester Ant Foraging Decisions are Informed by Cues Present in Cuticular Hydrocarbons Detected During Social Interactions***
The regulation of worker activity by social insect colonies is performed in a non-hierarchical manner. No one entity, including the queen, has the ability to control the precise activity of the other colony members. Instead, workers make individual behavioral decisions informed by the assessment of local cues. Colony-wide changes in behavior reflect the many individual behavioral decisions of the workers. Social interactions can provide important local cues. In harvester ants (*Pogonomyrmex barbatus* ), foraging is stimulated by the return of a different task, patrollers, to the nest. Colonies are responsive to the rate of patroller return and when patrollers are prevented from returning to nest, foraging will not begin by the colony that morning. Foragers recognize patrollers returning to the nest using cues present in patroller cuticular hydrocarbons. Cuticular hydrocarbons are a mixture of long-chain n-alkanes, methyl-branched alkanes, and n-alkenes which serve in communication, prevention of abrasion to the cuticle, and prevention of water loss. Harvester ant workers that work outside the nest, such as patrollers and foragers, have a higher amount of n-alkanes as compared workers that spend short amounts of time outside of the nest, such as nest maintenance workers. In this study, I tested the hypothesis that high relative abundance of n-alkanes in cuticular hydrocarbons acts as a cue that allows foragers to identify patrollers during social interactions important in the regulation of colony foraging. I removed patrollers to prevent foraging and returned ant mimics to the nest, small glass beads coated with hydrocarbons, and then measured foraging levels. My data supported the hypothesis; when nest maintenance workers were supplemented with n-alkanes hydrocarbons, colonies responded with foraging in a similar fashion as the return of patroller hydrocarbons.

***99.2*** GREENFEST-ALLEN, E*; KINGSLEY, P; PALIS, J; STOECKERT, CJ; Univ. of Pennsylvania, Philadelphia, Univ. of Rochester, Rochester; *allenem@pcbi.upenn.edu*

***Investigating conservation and differentiation in related developmental gene regulatory networks***

A central question in the study of biodiversity is how to resolve conservation of phylum-level traits with the changes that occur within phyla and the continuous modification of characters that leads to speciation. One explanation is that constraints progressively limit developmental flexibility, reducing evolvability through increasing integration of developmental pathways to the point that any deviation is catastrophic. Yet, increasing integration can also augment evolvability by improving redundancy and robustness. These opposing effects imply a hierarchical regulation of developmental whereby a conserved integrated framework regulates and links sets of tightly integrated interactions that act as a coherent unit (modules). Here we evaluate this hypothesis within a small-scale model system: the development of red blood cells (RBCs). In mammals, there are two types of RBCs: primitive and definitive, produced through three developmental lineages. In each, progenitors progress through comparable developmental stages and produce functionally equivalent, but phenotypically distinct RBCs. Accordingly, we expect the lineage-specific regulatory networks contain shared and unique sets of interactions. We integrate multiple data sources (e.g., co-expression, binding, pathways) to infer and weight interactions and estimate the regulatory network for each lineage. Modules and key genes are identified through computational analysis of the individual network topologies and are then compared to identify conserved and unique sets of interactions. We then assess the distribution of these interaction sets within the network graph to evaluate whether the structure affects the likelihood of conservation.

***66.6*** GREENWOOD, A.K.*; PEICHEL, C.L.; Fred Hutchinson Cancer Research Center, Seattle WA; *agreenwo@fhcrc.org*

***How the stickleback gets its stripes***

Pigment patterns exhibit striking variation in nature and are used for a diversity of functions, such as avoiding predators and attracting mates. Juvenile threespine sticklebacks from marine and freshwater populations exhibit divergent pigmentation patterns that likely provide crypsis in open water vs structured environments. Juveniles from marine environments are silver in appearance, a coloration pattern that reflects light and serves to confuse predators in an open water environment. In stark contrast, sticklebacks from freshwater lakes and streams exhibit a pattern of vertical stripes, which enables fish to blend in to a visually complex shoreline environment. We have investigated both the developmental and genetic basis of this variation. Repeated imaging of the developing pigment patterns of individual fish for two months revealed that differences in the patterning and abundance of two types of neural-crest derived pigment cells—black melanophores and silver iridophores—underlie the divergent pigment patterns. We performed genetic linkage analysis in a freshwater by marine F2 intercross to identify the genetic basis of this divergence. We identified two genomic regions underlying extent of vertical striping. We are currently using the stickleback genome assembly to identify and analyze candidate genes within these genomic regions to gain insight into the genes and pathways that are altered to yield divergent pigmentation patterns in the wild.

***87.9*** GRONE, B.P.*; LEE, M.; FERNALD, R.D.; Stanford University; *bgrone@stanford.edu*

***NPY and GnRH Systems Respond to Food Deprivation in a Mouthbrooding Cichlid***

Astatotilapia burtoni, a mouthbrooding cichlid native to Lake Tanganyika, is a model organism used for studying reproductive physiology and behavior. After females become gravid and spawn, they carry their developing fry in their mouths for two weeks before releasing them. During these two weeks, females do not feed and they experience significant metabolic changes. Females also experience metabolic changes as they recover from mouthbrooding and become gravid again. In order to understand how the brain responds to the food-deprivation experience during mouthbrooding, we have compared the effects of mouthbrooding- and non-mouthbrooding-related food deprivation on neuropeptide systems involved in feeding and reproduction. We used quantitative RT-PCR to measure levels of Neuropeptide Y (NPY) Receptors and Gonadotropin-Releasing Hormone (GnRH) mRNA in the A. burtoni brain. A. burtoni express three GnRHs: GnRH1, GnRH2, and GnRH3. Only GnRH1 was regulated by mouthbrooding: mouthbrooding females' brains had significantly lower GnRH1 than gravid females'. By contrast, food deprivation significantly decreased GnRH1, GnRH2, and GnRH3 mRNA levels in the brain. NPY is the most potent orexigenic neuropeptide in teleosts. Teleosts have two closely related NPY Receptor Y8 (NPYR Y8) forms: Y8a and Y8b. We found that food-deprived A. burtoni have significantly more NPYR Y8b mRNA in their brains than fed animals do. Levels of NPYR Y8c were not different between fed and food-deprived groups. Our findings suggest involvement of Y8b but not Y8c in response to food deprivation. Overall, we describe reproductive and orexigenic neuroendocrine profiles that distinguish simple food deprivation from the food-deprived reproductive state of mouthbrooding.

***S3.1*** GROSBERG, RK; VERMEIJ, G*; University of California, Davis; *rkgrosberg@ucdavis.edu*

***Does life evolve differently in the sea?***

Between 85% and 95% of all living macroscopic species dwell on land; the rest are mainly marine. We argue that the extraordinary diversity on land is geologically recent, dating from the mid-Cretaceous period, about 110 million years ago. We suggest that the necessity and ability to be rare—that is, to maintain populations at low density—are critical to the attainment of high diversity. Fundamental differences in the physical properties of terrestrial and marine environments, notably the low cost of mobility to consumers on land, make it possible for terrestrial organisms to persist at far lower densities and achieve higher diversity than marine organisms. Increasing productivity beginning in the mid-Cretaceous led to an increase in the survival of populations at low density and to an increase in the intensity of selection for that ability, as well as for high mobility and habitat specialization. The preeminence of terrestrial as compared to marine diversity is therefore an historical phenomenon that is best explained by selection-related changes in mobility, dispersibility, and the evolution of partnerships.

***S6.4*** GUGLIELMO, Christopher G; Univ. of Western Ontario; *cguglie2@uwo.ca*

***Move that fatty acid: fuel selection and transport in migrating birds and bats***

My title emphasizes the great importance of fatty acid transport to successful non-stop migratory flight. Although fat is the most energy dense metabolic fuel, the insolubility of its component fatty acids makes them difficult to transport to working muscles fast enough to support the highly aerobic exercise required to fly. I will discuss recent evidence that migratory birds appear to deal with this by expressing large amounts of fatty acid transport proteins on the muscle membranes (FAT/CD36 and FABPpm) and in the cytosol (H-FABP). There is also evidence that through endogenous mechanisms and/or diet selection, migratory birds may alter the fatty acid composition of the fat stores and muscle membranes to improve endurance flight performance. I will review the evidence regarding fatty acid chain length, degree of unsaturation, and placement of double bonds (n-6 and n-3) on the rate of mobilization of fatty acids from adipose tissue, utilization of fatty acids by muscles, and whole animal performance. Protein stores are also very important to sustained migratory flight because they are catabolized for gluconeogenesis, key metabolic intermediates, and water. I will discuss the conditions under which protein stores can limit flight duration before fat stores are exhausted. Migratory bats provide an interesting example of evolutionary convergence with birds. I will discuss their potential similarities and differences in physiology and behaviour with birds, and recent attempts to study their migration physiology.

***97.1*** GUSMAO, Luciana C.*; DALY, Marymegan; Ohio State University; *Gusmao.1@osu.edu*

***Genetic diversity within Calliactis polypus (Cnidaria: Actiniaria), a widespread species of sea anemone symbiotic with hermit crabs***

Originally described from the South Pacific Ocean, *Calliactis polypus* is the most widespread species of anemone symbiotic with hermit crabs. Its range spans the Pacific Ocean, Indian Ocean, Atlantic Ocean, and the Red Sea. This wide distribution is the result of difficulties in the assessment of species boundaries due to morphological plasticity and taxonomic synonimies of distant populations. The slow rate of molecular evolution in Anthozoa, the class to which anemones belongs, renders sequence-based studies less effective within and between populations, even those isolated by 3000 km or more. For this reason we amplified and cloned DNA sequence data from the ribosomal ITS/5.8S region as it has provided resolution at and below the species level in plants and animals. We evaluated levels of genetic diversity within and between four populations of *C. polypus* from Japan, Hawaii, Guam, and South Africa. We used this data to confirm the taxonomic status of morphologically based varieties of this species and to determine whether genetic structure follows geographical, bathymetric, or host-associated patterns.

***102.5*** GUTMANN, A.K.; BERTRAM, J.E.A.*; University of Calgary; *annegutmann@gmail.com*

***Explaining the $1/t_c$ relation to locomotion cost in terms of constrained optimization or How metabolic cost rate can appear to both increase and decrease with time of force application***

Kram and Taylor (1990) hypothesized that 'the rate of energy consumed by the muscles of a running animal per Newton of body weight is inversely proportional to the weight-specific rate of force application'. This implies that the weight-specific metabolic cost rate for running should be inversely proportional to contact time since, on average, an animal must produce a vertical ground reaction force equal to its body weight. And, indeed, this hypothesis fits nicely with data obtained from a wide variety of species running on a treadmill. But, if this hypothesis is based on general principles that are widely applicable to other types of locomotion, one would expect that it should also hold for hopping, especially since hopping and running appear to be mechanically similar activities. However, detailed metabolic data for human hopping show the opposite trend—metabolic cost decreases with decreasing contact time. How can such evidence be reconciled? In this talk we show how imposing constraints on locomotion (e.g. having animals run on a treadmill at fixed speeds) limits our observations to one small cross-section of the metabolic cost landscape, and how the apparent conflict between Kram and Taylor's results and our hopping data can be resolved by evaluating a more complete cost function under certain constraint conditions.

***57.3*** HACISKI, S. Insley*; WEBB, Jacqueline F.; University of Rhode Island; *haciski@mail.uri.edu*

***Structural Organization and Ontogeny of the Lateral Line System in Embryos of the Little Skate, Leucoraja erinacea***

The mechanosensory lateral line system of elasmobranchiomorph and osteichthyan fishes differs with respect to certain aspects of the canal morphology and distribution. In batoids (skates and rays), the lateral line system is composed of a set of canals similar to those in sharks, but includes additional canals (with uncertain homologies) that extend onto their laterally expanded, wing-like pectoral fins. We took advantage of the availability of eggs/embryos of the little skate, *Leucoraja erinacea*, to analyze the structural organization of its lateral line system as a representative batoid and elasmobranchiomorph. We mapped canal distribution on the dorsal and ventral surfaces of the body, canal diameter, tubule length and diameter, and the size and distribution of the canal neuromasts in embryos (37-80 mm total length [TL]) using histological analysis and vital fluorescent staining. Preliminary data indicate that the lateral line canals on the head and pectoral fins start forming in embryos less than 50 mm TL, as the pectoral fins are fusing to the head. The tubular lateral line canals (~50-75 µm diameter in a 65 mm TL specimen) have epithelial walls, sit in soft tissue (not cartilage), and are connected to the environment via tubules (~30-35 µm diameter in a 65 mm TL specimen) with terminal pores. Vital fluorescent staining clearly shows that multiple canal neuromasts sit between adjacent tubules and that their size and distribution are unlike that which has been described previously in elasmobranchiomorphs. Further analysis will determine the timing and pattern of canal morphogenesis, which we hypothesized will be distinct from that observed in osteichthyan fishes.

***92.3*** HADDOCK, SHD*; FIGOSKI, L; WATTS, M; SWEENEY, AM; DUNN, CW; Monterey Bay Aquarium Research Inst., MBARI, Univ. of California, Santa Barbara, Brown University; *haddock@mbari.org*

***Experimental evidence for the role of fluorescent proteins (GFPs) in prey attraction***

Autofluorescence is common in the ocean, where a variety of molecules can re-emit absorbed photons as light of a longer wavelength. Common fluorescent molecules include chlorophyll, phycobiliproteins, porphyrins, chitin, and green-fluorescent proteins (GFPs). In many cases, fluorescence seems to be a byproduct of the molecule's chemistry, and not the primary reason for its presence. In the case of GFP-type fluorescent proteins, however, which are found in cnidarians, crustaceans, chordates, and ctenophores, the proteins are assumed to be present primarily *because* of their fluorescence. In most cases, the functions of GFP remain unclear: it has been suggested that the functions are related to the expression of bioluminescence, or that they serve to modulate the light environment of algal symbionts, in the case of non-luminous Anthozoa. To test the hypothesis that fluorescent proteins might serve to attract prey, we conducted laboratory experiments using non-luminous fluorescent hydromedusae and juvenile fishes, their natural prey. Under lighting conditions where fluorescent structures on the jellyfish tentacles were visible, fishes were significantly more attracted to the medusa than they were to a jellyfish mimic or to the medusa under non-fluorescent lighting conditions. Additional *in situ* evidence supported these findings by showing a wide range of fishes attracted to a supernormal visual stimulus. Our results may help explain the presence of fluorescent structures in a diverse range of animals.

***31.5*** HADFIELD, M. G. *; CROLL, R. P.; University of Hawaii, Dalhousie University; *hadfield@hawaii.edu*

***Formation and fate of the musculatue in larvae of the nudibranch Phestilla sibogae***

Developmental programs for many marine invertebrates include the assembly of muscular systems appropriate to functions of swimming and feeding in pelagic larvae. At the end of larval life, metamorphosis brings about the loss of larval specific structures and emergence of juvenile-specific structures. Metamorphosing larvae of marine gastropods undergo destruction of the velum, a swimming and feeding organ specific for pelagic life, together with its intrinsic nerves and muscles. In shell-bearing snails, much of the larval musculature is retained to allow the juvenile snail to retract into its shell and move on the benthic substratum. However, nudibranch gastropods, such as *Phestilla sibogae*, lose their shells at metamorphosis, rendering the larval muscles that were attached to the shell functionless and raising questions about the fate of most larval muscles. To investigate muscle development and loss in larvae of *P. sibogae*, they were relaxed and fixed at successive stages, labeled with rhodamine-phalloidin, which binds to muscle F-actin, and examined with a laser-scanning confocal microscope. 3-dimensional reconstructions of the confocal images of larvae after shell loss revealed nearly complete in situ dissolution first of the right (larval) retractor followed shortly thereafter by the left (pedal) retractor. As the retractor muscles dissolved, oblique and circular muscle fibers in the body wall and longitudinal fibers in the foot became more numerous and prominent to provide movement to the small slug. Simultaneously, the buccal musculature enlarged to support post-metamorphic predatory feeding.

***6.1*** HAEN, K.M.*; LAVROV, D.V.; Iowa State University; *khaen@iastate.edu*

***Conflicting Evolutionary Hypotheses from the Analysis of 10 Glass Sponge Mitochondrial Genomes***

Although progress has been made toward understanding the phylogenetic relationships among the early branching metazoan clades (the Porifera, Cnidaria, Ctenophora and Placozoa), the resolution of their relationships has been fraught with difficulty due to biological and evaluative factors. These include sparse taxonomic sampling, unequal rates of evolution across lineages and mutational saturation (computationally, the long branch attraction artefact). The analysis of mitochondrial (mt) genomes is useful for investigating animal relationships but is also interesting from a more general evolutionary perspective. Mt genomes can contain rare genomic changes that are believed to be valuable for phylogenetic inference. These include gene rearrangements, variations in the genetic code, differences in the secondary structures of encoded transfer and ribosomal RNAs, overlapping genes, and the presence of ribosomal frameshifting sites in protein coding sequences. Glass sponges (Class Hexactinellia, Phylum Porifera) have represented one of the final frontiers for mitochondrial genomic data in the context of the early branching metazoa. We have increased the number of hexactinellid complete mt genome sequences from the three previously published genomes to 10, including individuals from six taxonomic families in our sampling. Here we present well-supported, but confounding, topologies at the base of the phylogenetic tree when evaluating the position of glass sponges within the metazoan tree of life. We then discuss the observation that many apparently "rare" genomic changes found in the mitochondrial DNAs of glass sponges and distantly related taxa seem to be prone to convergence.

***88.3*** HAGEY, TRAVIS*; HARMON, LUKE; AUTUMN, KELLAR; University of Idaho, Lewis and Clark College, Portland, OR; *thagey@vandals.uidaho.edu*

***Predicting adhesive capabilities in Anolis and Phelsuma lizards via the frictional adhesion model and critical detachment angle***

Geckos are capable climbing rapidly on nearly any surface using branched microscopic setae on the pads of their toes. Previously, based on results from the tokay gecko (*Gekko gecko*), Autumn et al (2006) proposed the frictional adhesion model. In this model, adhesion occurs only when setae are dragged along their natural curvature; the adhesive force (Fn) is anisotropic and controlled by the shear force, $Fs \geq -Fn/\tan \alpha^*$, where $\alpha^*$ is the critical detachment angle of the seta. In tokays, $\alpha^*=30°$. Thus, to generate 1N of adhesion, a tokay gecko must produce $1N / \tan 30° = 1.7N$ of shear force. This model may allow us to predict the adhesive abilities of other seta-bearing lizards. To test the generality of the frictional adhesion model, we measured the detachment angle in two lizard genera, *Phelsuma* geckos that have similar setal morphology to that of tokays, and *Anolis* lizards, which have smaller, unbranched setae. Like tokays, *Phelsuma* climb well on vertical and even inverted surfaces with apparent ease. While *Anolis* are agile climbers on inclined and vertical surfaces, they are found only infrequently on inverted surfaces. We measured $\alpha^*$ species averages between 27° and 35° in *Phelsuma*, similar to that of tokay. By contrast, $\alpha^*$ varied from 16° to 20° between *Anolis* species, yielding shear:normal force ratios from 3.4:1 to 2.7:1. To adhere, some *Anolis* lizards must produce nearly 250% of the shear force required by particular gecko species. Our results suggest that the frictional adhesion model may apply broadly to seta-bearing animals. The low critical detachment angle in *Anolis* may limit their habitat choice to non-inverted surfaces. NSF-DEB-0844523 (LH). NSF-IOS-0847953 (KA), NSF-NBM-0900723 (KA).

***S7.7*** HALANYCH, KM; Auburn University; *ken@auburn.edu*
***Phylogeography, larval dispersal and recent history of Antarctic continental shelf fauna***
Separation of the Antarctic and South American continental plates formed the Drake Passage roughly 30-35 MYA. This event lead to the establishment of the Antarctic Circumpolar Current (ACC) and the Antarctic Polar Front (APF) which have been repeatedly invoked to explain biogeographic patterns such as high endemism and circumpolar species in Antarctica. Genetic tools, in particular mitochondrial DNA sequence data, are being employed to test whether recent gene flow into and out of the Southern Ocean has been possible. To date, we have been able to examine nine continental shelf species that are found in Antarctic waters. Results indicate that isolation has occurred in the past between the South American and the Antarctic continental shelves, but much more recently than dogma contends. Additionally, mtDNA sequence data reveal cryptic speciation in several species, implying that 1) connectivity of ancestral populations that spanned the ACC and APF taxa was intermittent, and 2) Southern Ocean biodiversity is vastly underestimated. These recent findings will be compared and contrasted to information from other Antarctic habitats and organismal groups.

***94.3*** HALEY, W.A.*; WILSON, P.S.; California State University, Northridge; *wynhaley@yahoo.com*
***Hummingbird choices at artificial flowers made to resemble bird- versus bee-pollinated flowers***
Certain floral characteristics are associated with specific pollinators. For example, hummingbird-pollinated flowers are usually red, lack a landing platform, lack color patterns on the perianth, and contain a high amount of dilute sucrose-rich nectar compared to bee-pollinated flowers. The goal of this study was to test hypotheses concerning the reasons for these characters as they involve hummingbird behaviors. Arrays were set up that contained 16 “inflorescences,” each with five artificial “flowers.” In Experiment I, flowers were made that differed only in color, and birds showed very little preference, slightly preferring red over other colors. In Experiment II, color was made to be associated with nectar offerings, and birds learned to visit flowers of the color that provided much more nectar (6 versus 2 uL but not 4 versus 2 uL). In Experiment III, birds were offered different sugars (sucrose versus hexoses) as well as different sugar concentrations, and birds did not prefer the nectars that were similar to natural bird-adapted flowers. In Experiment IV, birds were offered flowers with and without a landing platform, and birds preferred flowers that lack a landing platform. In general, the preferences of birds fall far short of explaining the natural phenomenon of bird- versus bee-pollination syndromes.

***21.5*** HAMEL, Jennifer A.*; COCROFT, Reginald B.; University of Missouri; *jahtf7@mail.missouri.edu*
***Receivers, functions, and costs of parent-offspring signaling in treehoppers (Hemiptera: Membracidae)***
In species in which parents defend offspring against predators, communication between parents and offspring may facilitate defense. Understanding signal function in this context is challenging, because signals may have evolved to influence the behavior of family members or of predators. *Platycotis vittata* are oak-feeding treehoppers in which mothers defend offspring from invertebrate predators. During predator encounters, offspring produce repetitive, synchronized vibrational signals. Mothers also produce vibrational signals during and after the predator encounter, in addition to actively defending their offspring. For offspring signals in *Platycotis*, one function is to elicit the mother’s defense, but it is also possible that they influence predator behavior. For maternal signals, we hypothesize that they function to ‘reset the alarm’ after a predator encounter by inhibiting offspring signals. However, it is also possible that maternal signals are directed toward the predator. We used playback experiments to test these hypotheses with a generalist walking predator in the laboratory and with naturally occurring treehopper families in the field. Predators moved less during offspring signals, suggesting that predators may be attracted to signaling offspring. Predators oriented away from maternal signals, suggesting they may be deterred by signaling females. Nymphs did not stop signaling in response to maternal signals. Offspring signals, then, appear to have evolved to influence the mother’s behavior, at the cost of attracting vibration-sensitive predators. Maternal signals may have evolved to influence predators rather than offspring.

***77.6*** HANES, S. D.*; KEMPF, S. C.; Auburn University; *hanessd@auburn.edu*
***Elevated autophagic activity during hyperthermic stress in the common anemone, Aiptasia pallida: A novel cellular mechanism during bleaching.***
Coral bleaching involves the loss of symbiotic dinoflagellates from host gastrodermal tissues, which occurs as a result of elevated temperature/light stress. Previous studies examined histological snapshots of bleaching tissues that suggested several different methods of symbiont loss, including multiple forms of host and/or symbiont cell death, which may co-occur to facilitate bleaching. Although this phenomenon has gained much attention in recent years, little is known of the cellular events driving these potential mechanisms. In this study, light and transmission electron microscopy (TEM) were utilized to examine anemone tentacle histology/ultrastructure in the common anemone, *Aiptasia pallida*, while undergoing progressive bleaching. Bleaching was induced by exposing specimens to hyperthermic conditions of ~32.5ºC for 12 hours of light followed by 12 hours of darkness at ~21.5ºC, which mimicked thermal stress conditions observed in the field. Examination of heat stressed tissues revealed numerous residual bodies (RBs) throughout both the symbiotic gastrodermal layer and the non-symbiotic epidermal layer. The abundance of RBs increased with extended length of thermal treatment, and noticeable cellular degradation in the form of “cleared” areas of less dense cytoplasm and organelle debris was observed. After ~12 hours of thermal treatment, several individual symbionts were observed in membrane bound cytoplasmic protrusions pinching off or detaching from the apical end of degraded host gastrodermal cells in a apocrine-like manner. These findings indicate that significant autophagic lysosomal degradation of host tissues occurs during thermal stress and is an active cellular mechanism during bleaching.

***3.1*** HANNAFORD, S.J.*; FOSTER, R.L.; BOSSART, C.; Univ. of Puget Sound; *shannaford@ups.edu*

***Age, but not task-specialization, is associated with differences in brain structure in bumblebee, Bombus huntii, workers***

Social insects vary tremendously in colony size, with some as small as 10 individuals and others with more than 100,000. Polymorphisms among individuals covary with colony size. These include greater physical and behavioral differences between queen and worker castes and even within worker castes for large colony species. Most studies of neural correlates of social behavior have been done in insects characterized by large colony size (i.e. honeybees, ants). In this study we measured the volumes of several regions in the brains of worker bumblebees, *Bombus huntii* , whose colonies typically range in size from 10 to 100 individuals. Worker bumblebees carry out a diversity of tasks, including those that occur in the hive (e.g. brood care and nest maintenance) and foraging for pollen and nectar outside the hive. Previous studies on the highly eusocial insects have linked differences in brain structure to task specialization. In contrast, our results from bumblebees showed no significant differences in the volumes of structures associated with smell (antennal lobes), vision (optic lobes), or learning and memory (mushroom bodies) between the brains of workers specializing in in-hive versus foraging tasks. We did, however, observe striking differences in the brains of mature workers versus newly emerged worker bees. Within the mushroom bodies, the brains of newly emerged bumblebee workers showed distinctly smaller neuropil regions and larger Kenyon cell regions relative to their older nestmates. These age-related differences are comparable to those seen in highly eusocial insects.

***98.3*** HARDY, KM*; LEMA, SC; KINSEY, ST; Univ. of North Carolina Wilmington; *kristin.hardy@gmail.com*

***The metabolic demands of swimming behavior influence the evolution of skeletal muscle fiber design in the brachyuran crab family Portunidae***

We investigated the influence of intracellular diffusion on skeletal muscle fiber design in several swimming and non-swimming brachyuran crabs. Species with the capacity for sustained swimming behavior had aerobic dark fibers subdivided into small metabolic functional units, creating short diffusion distances necessary to support the high rates of aerobic ATP turnover associated with endurance activity. This dark fiber design was observed in all swimming species including *Ovalipes ocellatus*, which has apparently evolved swimming behavior independently of other Portunidae. Additionally, we observed fiber and subdivision size-dependent differences in organelle distribution. Mitochondria, which rely on oxygen to function, were uniformly distributed in small fibers/subdivisions, but were clustered at the fiber periphery in larger fibers. The inverse pattern was observed for nuclei, which are not oxygen dependent, but rely on the transport of slow diffusing macromolecules. Phylogenetically independent contrast analysis revealed that these relationships were independent of phylogeny. Our results demonstrate cellular responses to diffusion that were necessary for the evolution of swimming and that are likely to be broadly applicable.

***29.2*** HARMON, S.; BURTON, P.M.*; Wabash College; *burtonp@wabash.edu*

***How many mouths are too many? Induction of oral fates in the cnidarian Nematostella vectensis.***

Although embryogenesis, regeneration, and asexual reproduction are all common developmental modes within Metazoa, data directly comparing these modes remains sparse. The sea anemone *Nematostella vectensis* is capable of embryogenesis, complete bidirectional regeneration, and asexual reproduction, providing a unique opportunity to understand how a single genome can accomplish three discrete developmental modes. We are currently focused on the mechanisms of regeneration in order to compare them to new and currently available embryonic data. Our previous studies have shown that that some developmental patterning genes (*otx* and *Hox-like*) are expressed in distinct ways across developmental modes. Current investigations include pharmacological agents that act on the *Wnt* pathway to promote or repress oral development in a variety of life history stages. Alsterpaullone induces oral fates in undifferentiated cells (e.g. blastemas and embryonic cells) without substantial increases in cell proliferation. LiCl represses oral development without increased levels of apoptosis. By investigating these findings across developmental modes and comparing them to existing embryonic data, we begin to clarify the relationship between all three developmental modes.

***52.4*** HARMON, Luke J.; University of Idaho; *lukeh@uidaho.edu*

***A Semiparametric Method to Test for Correlated Evolution in a Phylogenetic Context***

Here I describe a new nonparametric comparative method, the phylogenetic rank correlation (PRC) test. This test, based on the correlation of ranks of independent contrasts on a phylogenetic tree, is robust under several models of trait evolution, and has power comparable to standard independent contrasts and much greater than the contrast sign test, another nonparametric comparative method. The PRC test provides a robust alternative to parametric methods such as PGLS and independent contrasts.

***79.1*** HARRISON, J.F.*; VANDENBROOKS, J.M.; Arizona State University, Tempe; *j.harrison@asu.edu*

***A Proposal for a National Variable Atmosphere Laboratory (VAL) for Climate Change Research***

Many aspects of the Earth's climate and atmosphere are changing rapidly today in response to industrialization. Over the planet's history, these changes have been even more dramatic in magnitude (though not in rate). The recent Intergovernmental Panel on Climate Change (IPCC) report suggests that the resilience of many of Earth's ecosystems will be compromised by climate change in the coming century, leading to decreased cereal grain productivity, increased water stress in semi-arid regions dependent on snowmelt, and widespread human health effects including malnutrition and increased deaths from cardio-respiratory and insect-borne diseases. However, key uncertainties remain in understanding the effects of atmospheric and climatic change on ecosystems and health. Existing facilities for studying the effects of such environmental variation are limited in their ability to distinguish cause and effect due to lack of capacity for large-scale, replicated experimental manipulation of multiple variables. Results of two NSF-sponsored workshops have supported the construction of a national Variable Atmosphere Laboratory (VAL) composed of multiple miniworlds that: 1) allow regulation of multiple atmospheric gases and environmental conditions, 2) are sufficiently large to enable housing of small ecological communities, 3) accommodate animals, 4) allow measurement of net fluxes of key molecules between communities and the environment, and 4) are sufficiently replicated to allow rigorous statistical evaluation of hypotheses concerning the effects of climate change on biological and geological processes. VAL would provide a national interdisciplinary facility for generating critical information necessary for rational planning of a sustainable Earth. Supported by NSF IOS 0748882 and NSF IOS-0929344 to JFH.

***S3.10*** HART, M.W.*; MARKO, P.B.; Simon Fraser Univ., Clemson Univ.; *mwhart@sfu.ca*

***It's about time: divergence, demography, and the evolution of developmental modes in marine invertebrates***

Differences in larval developmental mode are predicted to affect ecological and evolutionary processes ranging from gene flow and population bottlenecks to rates of population recovery from anthropogenic disturbance and capacity for local adaptation. The most powerful tests of these predictions use species comparisons to ask how phylogeographic patterns are correlated with larval developmental mode. An important and largely untested assumption of these studies is that species with similar spatial patterns of genetic variation have similar underlying temporal histories of population divergence and gene flow (and that species differences in spatial variation are driven by different historical processes). Teasing apart these temporal and spatial patterns may be important for understanding the causes and consequences of evolutionary changes in larval developmental mode. New analytical methods that use the coalescent history of allelic diversity can reveal the temporal pattern of variation in gene flow, effective population size, and population divergence time. These estimates can be used to identify population histories that are congruent with each other and with predictions based on species differences in larval form, and to distinguish such patterns from examples of dissimilar population histories that underlie similar patterns of spatial variation (phylogeographic pseudocongruence). We briefly review some of these recent analytical developments, and show their potential for refining ideas about the correspondence between the evolution of larval developmental mode, population divergence, and spatial genetic variation.

***18.4*** HARTKE, T.R.*; ROSENGAUS, R.B.; Northeastern University, Boston; *hartke.t@neu.edu*

***A Couple or a Crowd? Factors influencing founding group size in the termite Nasutitermes corniger***

Mature nests of the highly-derived, neotropical termite *Nasutitermes corniger* have been found to contain multiple unrelated queens and kings. Nest dissections have indicated that these primary reproductives are the same age, suggesting colonies may be founded by multiple reproductives rather than solely by monogamous pairs as in most other termite species. The frequency with which these multiple founding associations (MFAs) occur, and the factors influencing their formation, have yet to be studied. Our research explores the preferences of *N. corniger* reproductives during mate choice and the first 60 days of colony development under semi-natural conditions. Microcosm experiments were conducted with uniform nest site availability under four population densities; mesocosms were under a full factorial design with three nest site levels and two population densities. Results indicate that reproductives from certain parental colonies more frequently founded incipient colonies in MFAs. Higher population density increased the proportion of colonies founded by groups rather than pairs. These results indicate the possibility of a genetic basis for group colony foundation, as has been found in fire ants. Ecological conditions encountered by dispersing reproductives, including heterospecific and conspecific competition for limited nesting sites, may further promote MFAs.

***S3.11*** HARVELL, C.D.*; HEWSON, I.; Cornell University; *cdh5@cornell.edu*

***Climate Change and Invertebrate Microbial Interactions***

A frontier of invertebrate biology is the interaction between micro-organisms and their hosts. These interactions span the range from symbiotic to parasitic, and even a single microbe-host interaction can change depending on its environment. Some of the best known microbial associations of invertebrates include the surface microbial community of corals, light producing symbionts of cephalopods, and chemical producing symbionts of sponges, cnidarians and bryozoans. These associations with bacteria highlight symbioses that likely exemplify much greater dependence on microbial partnerships across the entire invertebrate spectrum. I will focus on the ecology of surface microbial interactions of invertebrates and how these associations are shaped by constraint and contingency, although admittedly we are poised on a frontier with many knowledge gaps. Surface microbial symbionts appear particularly susceptible to changing climate and stresses of warming temperatures and acidifying oceans. I will give examples of our work with surface microbial communities of littorine snails and gorgonian corals and how these are impacted by changing acidification.

***51.3*** HAUSSMANN, M.F.*; MAUCK, R.A.; Bucknell Univ, Lewisburg, PA, Kenyon College, Gambier, OH; *mfh008@bucknell.edu*

***Energy, growth and oxidative stress in Leach's storm-petrels (Oceanodroma leucorhoa)***

Limitation in energy allocation is the main force underlying life history trade-offs. Aerobic species have evolved the capability to use oxygen for efficient energy release. A consequence of this process is the formation of free radicals, which can damage biological tissues and modulate the aging process. This places oxidative stress as a potentially important mechanism driving life history evolution. We manipulated food availability to nestling Leach's storm-petrels to investigate the interplay between energy, growth, and oxidative stress. Control nestlings (N = 20) received food from parents normally over the entire 65 day nestling period. Restriction nestlings (N = 20) received approximately half that during the Early Nestling Period (ENP; hatch to day 40), then approximately twice normal amounts during the Late Nestling Period (LNP; day 40 to day 60). We monitored chick growth parameters daily and collected blood samples at hatch, day 40, and day 60. Catalase activity differed between Control and Restriction birds ($P < 0.01$). While catalase levels in Control birds increased in both the ENP and LNP, Restriction birds showed no change in catalase during the ENP and an increase to control levels over the LNP. Lipid peroxidation (LPO) differed between Control and Restriction birds ($P < 0.01$). LPO levels decreased during the ENP in Control birds and remained low through the LNP. In Restriction birds, LPO increased during the ENP, then decreased during the LNP to reach levels similar to those of Control birds. Our results provide strong evidence for the effect of food availability on oxidative stress. Because oxidative stress underlies physiological health and aging, nutritional stress early in development may impact an individual's life history trajectory.

***65.3*** HAWKINS, M.B.*; CRUZ, A.; STOCK, D.W.; University of Colorado, Boulder; *michael.hawkins@colorado.edu*

***Have teleost barbels evolved by the co-option of fin developmental mechanisms?***

Understanding how complex structures can emerge repeatedly in distantly-related lineages is an important goal of evolutionary biology. A striking example of such convergent evolution is provided by the barbels of fishes. Barbels are taste bud-covered sensory organs that project from the snout of numerous disparate lineages of fishes, ranging from nurse sharks to minnows. Co-option of pre-existing developmental genetic mechanisms is one possible explanation for the apparent ease of barbel origin, and paired appendage development provides candidate mechanisms. Like paired appendages, barbels are outgrowths from the body that are supported by skeletal elements and, in some cases, associated musculature. In addition, the barbels of some species display anterior-posterior polarization, as is seen in paired appendages. We tested this co-option hypothesis by analyzing the expression and function of paired appendage-associated genes during barbel development in the channel catfish (*Ictalurus punctatus*). As in limb and fin buds, the developing barbels express *shh* in a polarized pattern across the anterior-posterior axis, and further similarities were found in the expression of Bmp, Dlx, and Fgf family members. Treatment with chemical inhibitors of hedgehog signaling or with retinoic acid reduced barbel outgrowth, an effect similar to that reported for limbs and fins. In contrast, *dach*, a transcription factor involved in patterning the proximal-distal axis of limbs and fins, is absent from developing barbels. We conclude that barbel development is regulated by similar, but not identical, mechanisms to that of paired appendages.

***67.5*** HAZARD, L.C.*; KWASEK, K.; VIG, D.; Montclair State University., NJ; *hazardl@mail.montclair.edu*

***Interspecific variation in behavioral aversion of amphibians to road deicers***

Winter road deicers (primarily NaCl, but also $CaCl_2$ and other alternatives) may contaminate local watersheds to levels high enough to potentially impact amphibian populations. Amphibians that migrate to vernal pools early in the spring, when salt levels could still be high, may be especially vulnerable. We exposed adult wood frogs (*Lithobates sylvaticus*), green frogs (*Lithobates clamitans*), eastern newts (*Notophthalmus viridescens*), and Couch's spadefoot toads (*Scaphiopus couchii*, used to validate methods) to salt solutions to determine whether they could detect and avoid high concentrations of road deicers. Animals were mildly dehydrated to induce thirst, then placed in a shallow dish containing 0-500 mM NaCl or $CaCl_2$. Location (in or out of the dish) and behavior (moving, standing, sitting, or water absorption response) were recorded during a 10-minute trial. A behavioral control trial using distilled water was conducted immediately after each trial; if an animal showed aversion to both the test solution and the control solution the trial was considered unsuccessful and was not used in analyses. Both spadefoot toads and newts showed behavioral aversion to elevated salt concentrations. Green frogs showed a strong escape response during trials, and no successful trials were completed for this species. Wood frogs showed no aversion to NaCl, remaining in even 500 mM solutions despite significant mass loss due to osmotic water loss, and showed aversion to $CaCl_2$ only at the highest concentration. Breeding Wood Frogs may not be capable of evaluating pond salinity, leaving eggs and tadpoles potentially vulnerable to increased mortality or subtler sublethal effects due to road salt runoff.

***15.2*** HEALY, J.E.*; OSTROM, C.E.; GEARHART, C.N.; FLORANT, G.L.; Colorado State University; *jehealy@rams.colostate.edu*

***Effects of peripheral ghrelin injections on food intake and behavior of golden-mantled ground squirrels (Spermophilus lateralis)***

Mammals that hibernate (hibernators) undergo a circannual cycle of body mass gain and loss mediated primarily by food intake, but the pathways controlling food intake in hibernators have not been fully elucidated. Ghrelin is an orexigenic hormone that is known to increase food intake and adiposity in all mammals studied so far, but no published studies exist on the effect of ghrelin in hibernators. In order to determine the effects of ghrelin injection on food intake, body mass, and activity levels in hibernators, we peripherally injected ghrelin (intraperitoneally) into eight *S. lateralis* at various times of the year and at different stages of their hibernation season. We measured food intake and changes in body mass for the six hour period following injections, and remotely monitored behavior with the aid of a direct-streaming video recorder. We found that food intake increased with ghrelin injections; even some animals injected while hibernating at low tissue temperature aroused from torpor and ate, which is unusual for *S. lateralis*. There was also an increase in activity levels in all animals injected with ghrelin, especially in behaviors involving feeding and thermoregulation (such as food seeking behaviors and nesting). This study is the first to show an effect of injected ghrelin on a hibernator. We believe that ghrelin is involved in control of food intake in summer-active *S. lateralis*, and may be implicated in the behavioral changes that occur in these animals prior to the hibernation season. This research supported by a Sigma Xi Grant-in-Aid of Research to JEH and by an NIH grant to GLF R25DK067017.

***17.1*** HEATH-HECKMAN, E.A.C.*; MCFALL-NGAI, M.J.; University of Wisconsin - Madison; *heathheckman@wisc.edu*

***Chitin as a Component of the Invertebrate Immune System***

*Euprymna scolopes*, the Hawaiian bobtail squid, is a useful model for the study of the invertebrate immune system. Recent analyses have demonstrated that chitin breakdown products have a significant role in communication between *E. scolopes* and its bacterial symbiont *Vibrio fischeri*. To determine the source of chitin in the initiation of the association, we used a commercially available chitin-binding protein conjugated to fluorescein (CBP) to label the chitin. The only cells in contact with the symbionts that labeled with the probe were the macrophage-like hemocytes, an unexpected result; the occurrence of chitin has not previously been reported in the immune cells of any mollusc. To confirm the identity of the substrate being stained, we treated the hemocytes with a commercially available chitinase, which markedly altered the staining patterns of the chitin-binding protein, providing additional evidence that the hemocytes contain chitin. CBP labeling localized to granules in the hemocytes that also label with a halide peroxidase antibody and lysotracker, a lysosomal vital dye. In addition, hemocytes produced mRNA coding for a chitin synthase, suggesting that these cells synthesize chitin. Finally, a wide variety of invertebrate hemocytes exhibited CBP labeling patterns similar to that of *E. scolopes*, though vertebrates that we sampled did not. These results show that chitin can be found in invertebrate hemocytes in close proximity to canonical immune proteins and structures, providing evidence that this polysaccharide may play a conserved role in host-microbe interactions. Supported by NIH RR12294, NIH AI50661, NSF 0817232, and a NIH training grant to E.H-H.

***S6.3*** HEDENSTRöM, Anders; Lund University, Sweden; *anders.Hedenstrom@teorekol.lu.se*

***Testing migration theory: the utility of integrative approaches using field experiments and wind tunnels***

The process of migration typically involves periods of energy accumulation followed by migratory flight. For an animal that strives to migrate as fast as possible (a time minimizer), we can expect physiological and behavioral adaptations to achieve this goal. But what do recover to separate a time minimizer from an energy minimizer? To answer this question we derive the expected behavior(s) and then we design an experiment to test the prediction(s). In migrants we can test the theory for either the energy accumulation phase, or the for the energy consumption phase (flight). I review different laboratory and field based approaches that have, and can, be used to test components of current (optimal) migration theory. Due to logistical problems not all questions can practically be addressed in the field, which is the reason we use rather sophisticated wind tunnels to measure aerodynamic properties and energy consumption during flight. In combination, field and laboratory studies provide useful information about migration strategies.

***42.3*** HEDRICK, T.L.; ROBINSON, A.K.*; Univ. of North Carolina at Chapel Hill, California Institute of Technology; *thedrick@bio.unc.edu*

***Voluntary and perturbed free flight yaw maneuvers in hawkmoths***

A recent study of low speed maneuvering flight in animals ranging across 6 orders of magnitude in body size showed that animals engaged in low-speed yaw turns experience substantial damping of angular velocity (Hedrick et al., 2009). However, that prior study was not able to examine how this damping functions in practice in a free flying animal. Here we examined hawkmoths (*Manduca sexta*) engaged in continuous, voluntary, free-flight yaw maneuvers while tracking (but not feeding from) a nectar source. Flights were recorded using 3 calibrated high speed cameras and subjected to kinematic analysis. Maneuvers lasted up to 20 wingbeats and covered up to 270 degrees of total yaw, with peak whole-wingbeat yaw velocities up to 500 degrees $s^{-1}$. These continuously turning moths only accelerated into the turn during downstroke; upstrokes were purely deceleratory. Upstroke deceleration was consistent with the damping through the flapping counter-torque (FCT) model put forth in Hedrick et al. (2009), with angular velocity dropping to approximately 65% of its initial value by the end of upstroke. In a separate set of recordings, hovering hawkmoths were subjected to physical perturbation sufficient to create yaw angular velocities of up to 1200 degrees $s^{-1}$. Perturbed moths typically reduced their angular velocity in all axes to zero within 3 complete wingbeats; rapid deceleration began immediately at the end of perturbation. The first recovery wingbeat was consistent with a purely FCT deceleration, reducing angular velocity to approximately 48 percent of its initial value. Subsequent wingbeats from both station-keeping and escape moths did not fit the FCT deceleration profile; the moths appear to begin actively maneuvering from the second and subsequent wingbeats.

***76.3*** HEGEMANN, A*; VERSTEEGH, MA; DE GRAAF, M; TIELEMAN, BI; MATSON, KD; University of Groningen, The Netherlands; *a.hegemann@rug.nl*

***No seasonal modulation in the acute phase response of a temperate zone bird, the Skylark (Alauda arvensis)***

We studied the interactions between energy balance and different indices of the immune function to shed light on how birds cope with different seasons. If certain seasons are particularly challenging in terms of energy availability, then free-living birds may be forced to compromise some immune functions because they cannot otherwise meet their total energetic requirements. Alternatively, overall immune function might shift towards a mix of components that is energetically less costly. To investigate these possibilities, we studied the energetic costs of an immune response throughout the annual cycle of the Skylark (*Alauda arvensis*), a widespread and typical temperate zone species. We caught birds in five distinct seasons (spring migration, breeding, moulting, autumn migration and winter), and we experimentally-induced acute phase responses through injection of lipopolysaccharide (LPS). We measured metabolic rate, body temperature, body mass loss, and blood sugar and ketone levels during the acute phase response period and compared LPS-injected birds and un-injected control birds. These comparisons revealed that all measured traits were significantly higher in birds that were undergoing an LPS-induced acute phase response, indicating that the acute phase response is costly. At the same time, and more surprisingly, we found no significant interaction between season and LPS-injection for any of the measured parameters. Thus, the cost of an acute phase response is high throughout the annual cycle, and the costs are not seasonally modulated.

***S10.7*** HEIMAN, Kimberly*; MICHELI, Fiorenza; Muhlenberg College, Stanford University; *kheiman@muhlenberg.edu*
***Non-native ecosystem engineer alters estuarine communities***
Many ecosystems are created by the presence of ecosystem engineers which play an important role in determining species composition. Additionally, a mosaic environment of engineered and non-engineered habitats has been shown to increase biodiversity. Non-native ecosystem engineers can be introduced into environments without similar species, resulting in dramatic impacts on native community composition. Yet, little is known about how non-native ecosystem engineers interact with non-natives already present in the environment and whether non-native engineers are associated with increased local diversity. Through a removal experiment, we explore the effects of a non-native reef-building tubeworm, *Ficopomatus enigmaticus*, on community composition in the central Californian estuary, Elkhorn Slough. We show that assemblages living in the reefs are significantly different from assemblages in nearby mudflats, with the reefs providing habitat for many non-native polychaetes and amphipods, including *Monocorophium insidiosum* and *Melita nitida*. Infaunal assemblages under *F. enigmaticus* reefs show very low species abundance. Once reefs are removed, the newly exposed mudflat is populated by opportunistic non-native species, such as the polychaete *Streblospio benedicti* and *M. insidiosum*, making reef removal a questionable control strategy. There is some indication that the addition of the non-native reefs to the mudflat environment may enhance local species richness. Habitat provision by the non-native ecosystem engineer may be a mechanism for invasional meltdown in Elkhorn Slough.

***10.3*** HEINRICH, E.C.*; KLOK, C.J.; HARRISON, J.F.; FARZIN, M.; MCKINLEY, B.; Arizona State University; *erica.heinrich@asu.edu*
***Mechanisms of hypoxia effects on body size of Drosophila melanogaster***
Low atmospheric oxygen concentrations decrease the size of many animals including the vinegar fly, *Drosophila melanogaster*, but the mechanisms of this effect remain unclear. We tested for a critical period when hypoxia effects body size by rearing flies in 10% oxygen only during the egg, larval, or pupal stage, and by rearing flies continuously in either 10 or 21% oxygen except for 24 h periods when the oxygen level was switched. These studies revealed that hypoxia exposure during any developmental stage causes smaller adults, and in most cases, hypoxia at different stages or durations led to similar size reductions. We compared wing size, wing cell size and wing cell number in flies exposed to hypoxia during different developmental stages. Exposure to hypoxia during the egg phase reduced the number of cells, while exposure to hypoxia during the pupal phase reduced the size of cells. We tested for potentially critical role-specific sensing pathways in epithelial cells during the hypoxic response using RNAi to reduce epithelial gene expression of eight genes in putative hypoxia-sensing pathways. Reduction of expression of these eight genes had no effect on the hypoxic-reduction of body size, suggesting that the targeted pathways may be redundant or not in the epithelial cells. The only significant effect of RNAi treatments on size was that knockdown of tango (homolog to mammalian HIF-beta) caused flies reared in 21% to be significantly larger, suggesting that the HIF pathway expression in epithelial cells may reduce body size of normoxic flies. In summary, our data suggest that developmental plasticity causes flies to develop into a target size associated with that oxygen level via multiple redundant mechanisms. Supported by NSF IBN 0419704 and NSF EAR 0746352 to JFH.

***S9.9*** HEJNOL, A*; PASSAMANECK, YQ; MARTINDALE, MQ; Sars International Centre for Marine Molecular Biology, University of Bergen, Norway, Kewalo Marine Laboratory, University of Hawaii, Honolulu, 96813, USA, Kewalo Marine Laboratory, University of Hawaii, Honolulu, 96813, USA; *andreas.hejnol@sars.uib.no*
***Understanding the non-spiral members of the clade Spiralia: The development of the digestive system of the brachiopod Terebratalia transversa***
Recent molecular phylogenies delivered a more detailed view on the phylogenetic relationships in the clade Spiralia (=Lophotrochozoa). Nested within the traditional spiralian taxa such as Platyhelminthes, Mollusca, Annelida and Nemertea are animal taxa that probably have modified the spiral cleavage program (e.g. Gnathifera, Bryozoa). One such group is the Brachiopoda, which is prominent in the Cambrian fossil record. Brachiopods appear to be closely related to spiral cleaving nemerteans, together forming the Kryptrochozoa. We have studied the expression of genes that are affiliated with bilaterian digestive system development (foregut, midgut and hindgut) in the brachiopod *Terebratalia transversa*. Genes such as GATA4/5/6, Cdx, brachyury, FoxA, hedgehog and otx appear to be involved in regional specification along the anterior-posterior axis of the alimentary canal. The expression patterns of 'foregut' genes such as brachyury and FoxA, during gastrulation show that the oral ectoderm is specified independently from the position of the blastopore. Furthermore, bilaterian 'hindgut' genes (e.g. Cdx, WNTs, Evx) are also expressed in regions distant from the blastopore. However, the expression of these genes decays during later development, reflecting the evolutionary loss of the hindgut in terebellid brachiopods. Our results show the independent specification of oral and hindgut ectoderm from the blastopore, and draw into question a developmental connection between the blastopore and the digestive openings.

***61.2*** HENNINGSEN, J. P.*; IRSCHICK, D. J.; U. of Massachusetts Amherst; *justinh@bio.umass.edu*
***Performance prevails over signal size during staged dominance encounters between male green anole lizards***
Animals use signals to convey information to conspecifics, but the information content and reliability of a signal in a given context are often unknown. Green anole lizards (*Anolis carolinensis*) have a brightly colored dewlap that is displayed to conspecifics during agonistic encounters and courtship. There is a significant and size-independent positive correlation between dewlap size and maximum bite force in green anoles. This suggests that dewlap size may be used as a reliable signal of bite force in this species. However, it is unclear in what contexts (territorial advertisements, aggressive interactions, etc.) the role of the dewlap as a reliable signal of bite force is relevant. Using a novel technique to surgically manipulate dewlap size, we tested whether dewlap size affects the outcome of staged dominance interactions. By manipulating dewlap size, we decouple signal size from performance, thus testing the relative role of the two traits on the outcome of staged interactions. Our data show that dewlap reduction did not influence dominance relationships, whereas bite force performance was the most important factor in the outcome. These results are consistent with the view that dewlap is used as territorial advertisement of male quality but performance is the more important trait during aggressive interactions.

***S9.2*** HENRY, JJ*; PERRY, KJ; University of Illinois; *j-henry4@illinois.edu*

***Cell and molecular mechanisms involved in the establishment of the D quadrant in the Gastropod, Crepidula fornicata***

In spiralian embryos cells of the D quadrant play a key role in establishing the dorsoventral axis and in organizing subsequent development of other cell quadrants. Laser ablation experiments were undertaken to characterize the timing of cell interactions involved in the specification of the D quadrant and its subsequent organizer activity in the snail, *Crepidula fornicata*. As is the case in other equal-cleaving sprialians, the dorsal, D quadrant is specified by animal-vegetal inductive interactions early during development. Unlike the case in other spiralians, however, it is the fourth quartet micromere derived from the D quadrant, (i.e., the mesentoblast, 4d) that serves as the key organizer for subsequent development in this species. Functional molecular analyses suggest that specific elements of the TGF-beta super family are involved in the specification of the D quadrant in *C. fornicata*. Furthermore, 454 pyro-sequencing, PCR and RACE reactions were undertaken to recover clones encoding numerous BMP, TGF-beta, nodal, ALK receptor, Smad, and Smurf proteins, as well as other elements of various TGF-beta signaling pathways. In situ RNA hybridization reveals that many of these messages, as well as others, exhibit specific patterns of localization to particular embryonic cell lineages during early development, which also appear to be consistent with roles of these factors in establishing specific cell fates during development.

***13.4*** HERMANSON, J.C.*; PEYER, S.M.; JOHNSON, J.A.; USFS Forest Products Laboratory, Univ. of Wisconsin-Madison, Univ. of Washington; *jhermans@wisc.edu*

***Determination of Lift and Drag Coefficients of Zebra and Quagga Mussels using an Inverse Method***

The probability of dislodgment of a mussel in flow depends on the hydrodynamic load it experiences relative to the resistance strength of its byssal threads. Hydrodynamic loading is a function of lift and drag coefficients, which have been determined for mussels, but typically in an artificially attached state. The goal of this study was to use load-resistance factor design (LRFD) analysis to calculate lift and drag coefficients of zebra and quagga mussels in their natural, byssally attached state. Mussels attached with byssal threads within a flume for 24 hours in no flow (0 m/s) and then were subjected to water velocities of 0, 0.5, 1.0 and 1.8 m/s for 8 hours. We determined the percentage of the mussels that dislodged in flow at each velocity and the resistance force required to mechanically detach mussels in shear and tension after 32 hours of attachment in no flow. We used an inverse LRFD method to calculate lift and drag coefficients from the hydrodynamic load that must have been imposed on a mussel in flow to yield the observed percentage dislodgment. Thus far, our inverse LRFD method yielded lift coefficients that were roughly 2 times higher for quagga than for zebra mussels. These lift coefficients were 2 to 4 times higher than those of other species of mussels in which lift force was measured directly on artificially attached mussels. The higher lift coefficients that we calculated for zebra and quagga mussels might have resulted from different boundary conditions of byssally relative to artificially attached mussels. Our inverse LRFD method was useful in determining lift and drag coefficients of mussels attached under natural conditions and demonstrated novel fluid dynamics that might influence their colonization of new habitats.

***71.1*** HERMANSON, J.W.*; ALTENBACH, J.S.; Cornell Univ., Ithaca, Univ. of New Mexico, Albuquerque; *jwh6@cornell.edu*

***Primary Downstroke Muscle Activity and Shoulder Movements in Free-tailed Bats.***

We explored several hypotheses about primary downstroke muscle function and skeletal motion in free-tailed bats (*Tadarida brasiliensis*). Bats were implanted with 0.2 mm diameter stainless steel pins in the proximal humerus and acromial process of the scapula to visualize skeletal motions. EMG analysis followed protocols described in our previous studies (J. Zool., 205:157) and used a 16 mm high speed cine recording system. All bats were recovered and released afterwards. Kinematic analysis revealed the dorsal scapulo-humeral interlock was maintained during the first half of the downstroke and that clavicular adduction is nearly synchronous with wing adduction. The caudal division of the serratus ventralis muscle was not anatomically suited to contribute to adduction of the humerus as has been hypothesized in previous studies. Although free-tailed bats are rapid, long-distance fliers, several of their downstroke muscles exhibited a biphasic recruitment pattern similar to that found in some other bats that fly in cluttered environments, including *Artibeus jamaicensis* which fly under and within the forest canopy. The onset and termination of primary EMG activity in serratus ventralis precedes the onset and termination, respectively, of the pectoralis muscle. By opposing the caudal component of force exerted by the pectoralis muscle, the caudal division of serratus ventralis facilitated ventrolateral displacement of the clavo-scapular articulation and effected clavicular adduction. These actions may reduce the excursion of the pectoralis and may contribute to its efficiency during flight.

***25.6*** HERRMANN, MH*; JAYNE, BC; University of Cincinnati; *Herrmamp@mail.uc.edu*

***Perch size and structure have species-dependent effects on the arboreal locomotion in rat snakes and boas***

Arboreal habitats create many challenges for locomotion, such as balancing on or gripping narrow cylindrical surfaces with variable inclines and branching density. Although hundreds of phylogenetically diverse species of snakes climb trees, comparative data on arboreal locomotor performance are lacking. We studied the arboreal locomotion of similar-size juveniles (snout-vent length ~ 60 cm) of two distantly related species: the red rat snake, *Pantherophis guttatus*, and *Boa constrictor*. We determined the kinematics and performance of snakes moving horizontally and up vertical and 45° inclines on cylinders with seven diameters (1.7 - 108 mm). We added pegs to simulate more complex branching structure, and we varied the friction of surfaces. Both species were fastest on intermediate diameters and used lateral undulation on surfaces with pegs. Pegs enhanced speed and allowed climbing on surfaces that were otherwise impassable. On cylinders without pegs, rat snakes only used concertina locomotion, whereas boas used lateral undulation on small-diameter horizontal surfaces and concertina in all other circumstances. Although concertina locomotion always involved periodic stopping and gripping, the kinematics of this gait differed between species. The boas were generally faster and slipped less than the rat snakes on surfaces without pegs, whereas the rat snakes were often faster on surfaces with pegs. Boas could traverse larger diameters than the rat snakes. The unexpected ability of both species to move on very narrow cylinders included an ability to cope with rolling about the long axis of the cylinder. The use of a balancing gait rather than a gripping gait by boas was also unexpected in light of their apparently superior gripping ability.

***48.6*** HEYLAND, Andreas*; GOODALL, Sophie; SOHN, Dosung; LEYS, Sally; MOROZ L., Leonid; University of Guelph, Department of Integrative Biology, The Whitney Laboratory for Marine Biosciences, University of Florida, The Whitney Laboratory for Marine Biosciences, University of Florida, University of Alberta, Biological Sciences; *aheyland@uoguelph.ca*

***Neurotransmitter functions in the placozoan Trichoplax adherens***

Trichoplax adhaerens is an enigmatic disk-like animal consisting of only four morphologically identifiable cell types arranged into 3 layers – surface, middle and lower. The animal lacks anterior-posterior polarity, but shows distinct dorsal-ventral surfaces through intriguing righting behavior, and the presence of gland cells with digestive function in the ventral epithelium. In the absence of sufficient morphological characters its phylogenetic placement has long been controversial and recent molecular data have not been able to resolve the issue. The recently released genome reveals several genes coding for neurotransmitter synthesis enzymes and neuroendocrine signaling molecules. Thus the study of placozoans may provide insights into the early evolution of the nervous system. Using electron and light microscopy we characterized cell types by morphology, and we used histochemical markers for tubulin, actin and neuron-associated genes to identify cells with neuron-like properties. We also used cell cycle markers to identify regions of active cell division to identify the progenitors for each cell type. Studies to assess the involvement of specific cells in coordinating behaviours in the whole animal are in progress and will provide a better insight into how this basal animal functions.

***91.7*** HIEBERT, Laurel/S*; MASLAKOVA, Svetlana/A; Oregon Institute of Marine Biology; *lhiebert@uoregon.edu*

***Axes and organs in nemertean larvae: Development of a hoplonemertean***

Nemerteans display two major modes of larval development: via a juvenile-like planuliform larva, found in the paleonemerteans and hoplonemerteans, and via the unique planktotrophic pilidium larva, which is restricted to the pilidiophoran clade. Planuliform larval development is relatively poorly understood. Here, we describe the larval development of the hoplonemertean *Pantinonemertes californiensis* using confocal fluorescence microscopy, providing the foundation for future studies of developmental gene expression patterns. We discover that by 48 hours after fertilization, the planuliform larva develops two pairs of epidermal invaginations that disappear by day four. The anterior pair resembles the cerebral organ rudiments of other planuliform nemertean larvae, while the homology of the posterior pair is uncertain. Similar to several other hoplonemerteans, *P. californiensis* posesses a transitory larval epidermis. We observed shedding of the cells of the larval epidermis on day five of development. All major organ rudiments are present in the five-day-old larva, including the gut, the cerebral ganglia, the lateral nerve cords and the proboscis. Finally, we present preliminary data on the expression of *Hox* genes in development of *P. californiensis* and the pilidiophoran *Micrura alaskensis*, which may help illuminate how the pilidium evolved from the planuliform larva found in basal nemerteans.

***65.5*** HIERONYMUS, TL*; THEWISSEN, JGM; GEORGE, JC; Northeastern Ohio Universities College of Medicine, Department of Wildlife Management, North Slope Borough; *thieronymus@neoucom.edu*

***Lateral inhibition systems in baleen development***

Baleen is a key adaptation of keratinized palatal tissue that has allowed mysticete cetaceans to specialize as plankton-feeders. The lingual surfaces of major baleen plates are lined by a fringe that grossly resembles hair, but both fringe and the larger plates that contain it are histologically distinct from most other mammalian integumentary appendages. Instead, fringe and baleen plates show the greatest similarity to large keratinized epidermal structures such as horse hoof, bovid horn sheath, and rhinoceros horn. Although the morphological development of baleen has been documented, neither the signaling systems involved nor the tissue-level homologies of baleen are known. Fetal bowhead (Balaena mysticetus) palatal and skin tissues were screened for morphogens that have been implicated in palate and hair follicle development (BMP2/4, SHH, FGF-7&10) by immunohistochemistry. Preliminary results suggest that the initial arrangement of baleen epithelial placodes proceeds by lateral inhibition. An inhibitory signal transmitted by relatively high concentrations of BMP2/4 on the lingual side of the developing baleen ridge may limit the size of the developing baleen placodes in that region. This may lead to the mediolateral morphological gradient of fringe, minor baleen plates, and major baleen plates seen on the posterior palate in adults. Morphological and developmental similarities suggest that baleen may be homologous to typical mammalian palatal structures, with baleen arising as an exaptation of existing palatal morphology in primitive mysticetes.

***75.3*** HIGHAM, T.E.*; RUSSELL, A.P.; Clemson University, University of Calgary; *thigham@clemson.edu*

***Gecko tails flip out: modulated motor control and variable movement following autotomy***

Many lizards are notable for their ability to self-amputate their tail during an encounter with a predator. The autotomized tail subsequently moves without control from higher centers and serves to distract the predator while the lizard escapes. Whereas the energetic, ecological and functional ramifications of tail loss for many lizards have been well-studied, little is known about the behavior and neuromuscular control of the autotomized tail. Once shed, the tail moves in ways not seen as an attached structure, indicating that suppressed movements are unleashed once the tail is severed. We used electromyography (EMG) and high-speed video to quantify the motor control and movement patterns of autotomized tails of leopard geckos (*Eublepharis macularius*). In addition to the movements immediately following autotomy, we quantified the changes in motor patterns and movements of tails until they stopped moving. We observed rhythmic swinging for the entire time following autotomy and complex movement patterns, including acrobatic flips up to 3cm in height, for only a brief time following autotomy. Unlike most central pattern generators (CPGs), muscular control of the tail is variable and can be arrhythmic. Although these complex patterns may arise in response to sensory information from the animal's environment, multiple overlapping CPGs may also be responsible for such a pattern. The autotomized tails exhibited a decrease in mean spike amplitude, but an increase in burst duration as time elapsed following autotomy, suggesting that fast-twitch muscle fibers are being fatigued. We suggest that the gecko tail is well-suited for studies involving CPGs, given that this spinal preparation is naturally occurring, requires no surgery, and exhibits complex modulation

***40.5*** HINIC-FRLOG, S*; MOTANI, R; Carleton University, Ottawa, Univ. of California, Davis; *shinic@earthsci.carleton.ca*
***Aquatic locomotion in fossil birds and early avian transitions from aquatic to terrestrial environments***
Evolutionary transitions of secondarily aquatic organisms to terrestrial habitats are rare; however, birds represent a notable exception. A study of such transitions in birds requires incorporation of extinct ornithurans which may have made the earliest shift from aquatic to terrestrial realm. Here, we quantitatively evaluate whether basal birds were truly aquatic and identify possible adaptive reasons for their transition back to terrestrial environments. We sampled predominant mode of locomotion and measured 32 osteological characters in 245 species of extant birds in order to examine whether mode of locomotion is statistically detectable based on morphology. Regularized discriminant analyses shows that osteological measurements successfully separate diving birds from surface swimmers and also discriminate among different underwater modes of swimming. Using statistical predictions of the multivariate analyses, we confirm qualitative assessments that Hesperornithiformes were foot-propelled underwater swimmers. We predict that *Gansus yumenensis* was not an underwater diver. We provide strong support that all living birds had a common aquatic ancestor in the Cretaceous. Hesperornithiformes had a reduced range of motion around the knee and a poor alignment of the hip with the center of mass. These attributes made walking and transition back to land very difficult. On the contrary, *Gansus* was not as limited in locomotion: at least skimming or surface swimming was possible. Both of these locomotor modes are associated with easier exploration of terrestrial environments. Among aquatic birds, it is only the birds which are restricted to the surface of the water with morphologies overlapping with those of non-swimmers that are more likely to transition back to terrestrial habitats.

***3.2*** HINTERWIRTH, A.J.*; DANIEL, T.L.; University of Washington; *ahinterw@u.washington.edu*
***Visual rotation stimuli drive activity of intrinsic antennal muscles in Manduca sexta***
Mechanosensory functions of insect antennae play vital roles in flight control by acting as air flow sensors or as gyroscopic organs that detect rapid body rotations via Coriolis forces. There are, for example, proposed reafferent circuits that drive antennal muscles in response to wind stimuli, keeping the antennal posture independent of flight speed. Similarly, mechanical stimulation of antennae drive reflexive steering motions of the abdomen. There is, however, no evidence to suggest that visual stimuli have a direct effect on antennal mechanosensory systems during flight. As with halteres in Diptera, such stimuli could be implicated in the flight control pathway. We use a combination of behavioral and electrophysiological approaches to show that visual motion generated during body rotations has an effect on antennal position. While presenting visual pitch stimuli to a tethered animal, we measured antennal position with high-speed videography. Additionally, we recorded EMG signals from intrinsic antennal muscles in the scape that influence antennal position (N=4 animals). A downward visual pitch motion stimulus causes the firing rate in the intrinsic muscle to increase, which leads to a backwards movement of the antenna. Therefore, by directly affecting the mechanical signal perceived at the base of the antennae, visual input from the eyes feeds back to antennal mechanoreceptors, which we have shown influence abdominal flexion. This eye-antenna feedback does not, however, depend on downstream circuits of the thorax or abdomen, and can be elicited in an isolated head preparation. Visual control of mechanosensory information could be used to tune antennal responses to body rotations.

***21.3*** HOBBS, N. J.*; FERKIN, M. H.; University of Memphis; *nhobbs@memphis.edu*
***Dietary protein content affects top-scent preference in meadow voles***
Encountering over-marks, the overlapping scent marks of two different conspecifics, is a feature of olfactory communication for most terrestrial mammals. Previous studies have shown that when exposed to a same-sex over-mark, meadow voles, *Microtus pennsylvanicus*, show a preference for the scent mark of the top-scent donor to that of the bottom-scent donor. This preference suggests that voles attach a higher value to the message found in the top-scent mark relative to the bottom-scent mark. However, the message contained in these signals as well as their meaning can be affected by the sender's and the receiver's diet and nutritional state, which may affect the receiver's preference for the top-scent mark. Because dietary protein is involved in the behaviors that support reproduction and mate attraction in mammals, including voles, we tested the hypothesis that the dietary protein content of both senders and receivers affects the preference for the top-scent donor. In Experiment 1, we altered the protein content of the diet of the receiver by feeding them either a 9%, 13%, or 22% protein diet. In Experiment 2, we altered the protein content of the two senders' diets, by feeding them either a 9% or 22% protein diet. In Experiment 1, male and female voles fed a 22% protein diet showed a preference for the mark of the top-scent donor, but voles fed either a 9% or 13% protein diet did not show this preference. In Experiment 2, male and female voles showed a preference for the top-scent donor if it was fed a 22% protein diet. However, female but not male voles showed a preference for the top-scent mark if the donor was fed a 9% protein diet. Overall, dietary protein content of both the sender and receiver affects the preference of meadow voles for the top-scent donor over the bottom-scent donor of a same-sex over-mark.

***23.6*** HOCH, JM*; LEVINTON, JS; Stony Brook University; *jmatthoch@gmail.com*
***Experimental tests of sex allocation theory in two species of simultaneously hermaphroditic acorn barnacles***
Sex allocation theory predicts that for simultaneous hermaphrodites, allocation to male-specific function should increase as competition for mates increases. Eric Charnov developed a local mate competition model (LMC) that makes specific predictions of relative allocation to the sex roles (specifically the proportion of reproductive resources allocated to male function) for simultaneously hermaphroditic acorn barnacles competing for mates (1980). We tested these predictions using field experiments with two acorn barnacle species, *Semibalanus balanoides* on Long Island, NY, and *Balanus glandula* on San Juan Island, WA. In Charnov's model, barnacles are predicted to allocate resources according to the number of individuals in the mating group. Our previous results show that barnacles alter the morphology of their penises in response to aggregation density- that is, how close neighbors sit to each other, independent of their numbers. We used a full-factorial design to separate the effects of the number of potential mates within the reach of the penis and the density at which those barnacles are crowded. For both species, we did not observe the relative sex allocation (proportion male) predicted by the LMC model. However, when each sex role was looked at separately, we saw that absolute allocation to male function did increase with increasing aggregation density, but not number of individuals in the mating group. Female function was tightly associated with body size and did not appear to tradeoff with investments in male function. Overall, our results suggest that allocation to the male role does increase with increased competition for mates (perceived by the barnacles from density of crowding) and allocation to female function is limited by the ability to produce and brood eggs.

***77.4*** HOCHBERG, Rick; University of Massachusetts Lowell; *rick_hochberg@uml.edu*

***The epidermal glands of gastrotrichs: ultrastructural insights and hypotheses of function***

Despite more than a century of research, the phylum Gastrotricha remains as enigmatic as ever. Intensive collection efforts by scientists across the globe have uncovered substantial new biodiversity, yet, intra- and interphyletic evolutionary relationships remain shrouded in mystery, and even many aspects of gastrotrich biology are still poorly understood. In particular, the large marine clade, Macrodasyida, contains a wide variety of species with unusual body plans and peculiar organ systems that have yet to be explored in detail. Here, I provide an overview of one of these curious organ systems, the epidermal glandular system, with a focus on gland cell structure and diversity. I use data derived from transmission electron microscopy to show that secretory granules are generated by two sets of cellular organelles: the rough endoplasmic reticulum (rER) and the Golgi apparatus. Mature secretory granules that are synthesized from each organelle and destined for exocytosis are initially formed via one of two pathways. In pathway 1, immature granules are formed in the rER and further processed in the Golgi before condensing into mature granules of heterogeneous chemistry in the cytoplasm. In pathway 2, immature granules are formed solely in the rER and condense into mature granules of homogeneous chemistry in the cytoplasm. Further details on the formation of epidermal glands and the biogenesis of their secretory products are provided, as are hypotheses on the potential functions of epidermal glands. The need for future descriptive research on gastrotrich biology is discussed.

***31.4*** HODIN, J.*; BISHOP, C.D.; HEYLAND, A.; Hopkins Marine Station, Stanford University, Department of Biology, Dalhousie University, Department of Biology, University of Guelph; *seastar@stanford.edu*

***Towards a metamorphic and settlement signaling network in echinoids***

Metamorphosis encompasses both a morphogenetic and behavioral life history transition, and is generally irreversible. As such, the temporal and spatial coordination of this complex process needs precise internal and external regulation. In echinoids, the internal morphogenetic processes begin well before the irreversible transformation occurs, as the bilateral larva transforms to a pentameral body plan over days to weeks or longer. At a certain point, the larva reaches the competent stage, where external signals can initiate the irreversible planktonic-to-benthic transformation. We have been elucidating two signaling systems that are involved, respectively, in the morphogenetic and behavioral aspects of echinoid metamorphosis: thyroid hormones (TH) and nitric oxide (NO). Furthermore, we have shown that these two signaling systems interact in a manner which suggests a mechanism for precise temporal regulation of metamorphosis. While these two signaling systems may be more or less conserved across taxa, the external signals that interact with these internal signaling systems show substantial inter-taxon variation. We interpret these results in the context of hypothesized selective landscapes underlying the evolution of the various conserved and diverged elements of metamorphic regulation in echinoids, and offer possibilities for testing these hypotheses in a comparative manner. Towards this end, we will present our preliminary data on a morpholino technique for disrupting gene function during metamorphic stages in echinoids, and outline a molecular approach for uncovering other signaling components that interact with the TH and NO signaling systems.

(authors contributed equally)

***S1.1*** HOLLAND, L.Z.*; SHORT, S.; Univ. of California San Diego, Portsmouth Univ, U.K.; *lzholland@ucsd.edu*

***From Genome to Development in Amphioxus***

Although gnathostome genomes (mammals, fish) were the first deuterostome genomes sequenced, genomes of most major deuterostome groups have now been sequenced. These include an agnathan (lamprey), ascidian and appendicularian tunicates, a cephalochordate (amphioxus) an echinoderm (sea urchin) and hemichordate. Comparative genomics has answered many questions (e.g. the timing of whole genome duplications) but has also raised awareness of how little is known about how genes direct formation of a functional organism. Heritable traits not directly encoded by the genome (epigenetics) have assumed increased importance in this regard. One such epigenetic phenomenon is alternative splicing. Paired box (Pax) transcription factors are involved in development of such endocrine organs as the thyroid and its homolog, the endostyle (in larval lampreys, tunicates and amphioxus) [Pax2/5/8], the thymus [Pax3/7], pharyngeal endoderm [Pax1/9] and adenohypophysis [Pax4/6]. Alternative splicing can affect the DNA binding domains of Pax factors and/or the c-terminal transactivation and repression domains. Some splice forms are evolutionarily conserved, suggesting vital functions, while others are not. Pax splice forms are differentially expressed during development in both amphioxus and vertebrates. To investigate the importance of Pax isoforms in development, we used antisense morpholino-oligonucleotides (MOs) to knock down function of all isoforms of amphioxus Pax2/5/8 and Pax1/9 as well as that of specific isoforms. Our results show that knockdown of all isoforms of these two genes with an MO complementary to the ATG start codon gives the same phenotype as using a splice-blocking MO to convert the major isoform expressed in early development to a minor one. These results suggest that the minor isoforms may function to modulate function of the major ones and underscore the importance of post-transcriptional mechanisms for gene function.

***33.5*** HOLLIDAY, CM*; GARDNER, N; DOUTHITT, M; PAESANI, S; RATLIFF, J; University of Missouri, Marshall University, Biomimetics Inc; *hollidayca@missouri.edu*

***MICROANATOMY OF THE MANDIBULAR SYMPHYSIS IN LIZARDS***

Although the mandibular symphysis is a functionally and evolutionarily important feature of the vertebrate skull, little is known about the soft-tissue morphology of the joint in squamate reptiles. Lizards evolved a diversity of skull shapes and feeding behaviors, thus it is expected that the morphology of the symphysis will correspond with functional patterns. Here we present new histological data illustrating the morphology of the joint in a number of taxa including iguanids, geckos, scincomorphs, lacertoids, and anguimorphs. Symphyses were excised from over 12 species of lizard and serially cut in ultra-thin, plastic sections. Slides were variably stained and viewed with regular and polarized light microscopy. The symphyses of all taxa exhibit dorsal and ventral fibrous portions of the joints that possess an array of parallel and woven collagen fibers. The middle and ventral portions of the joints are complemented by contributions of Meckel's cartilage. Kinetic taxa have more loosely-built symphyses with large domains of parallel-oriented fibers whereas hard biting and akinetic taxa have symphyses primarily composed of dense, woven fibers. Whereas most taxa maintain unfused Meckel's cartilages, iguanids and geckos independently evolved fused Meckel's cartilages however the joint's morphologies suggest different developmental mechanisms. Fused Meckel's cartilages may be associated with the apomorphic lingual behaviors exhibited by iguanids (tongue translation) and geckoes (eye wiping). These morphological data shed new light on the functional, developmental, and evolutionary patterns displayed by the heads of lizards.

***67.8*** HOLT, J.R.*; WILSON, P.S.; BRIGHAM, C.; California State University, Northridge; *holtjocelyn@gmail.com*
***Population Density effects on Pollinator Service of the Endangered Plant Lyon's Pentachaeta (Pentachaeta lyonii)***
There are over 2300 endemic plant species in California. As California's population grows habitat fragmentation will continue to threaten endemics with extirpation or extinction. Lyon's Pentachaeta is a federally endangered sunflower that serves as a food source for generalist pollinators. This endemic plant requires obligate out-crossing and is at risk of extirpation. Understanding if low density patches of Lyon's Pentachaeta experience the Allee effect, the inability to attract mates at low densities, may reduce this risk of extirpation through management plans. In 2008, pollinator observations were conducted on individuals in natural patches. In 2009, potted plants were placed in field to measure the quality of pollinator service varying distances away from patches. This was done to determine how the quality of pollination service depends on the density Lyon's Pentachaeta. In 2008, seed set did not vary with density implying that less dense patches did not experience the Allee effect. I predict in 2009 there will be no significant difference in seed set between individuals in patches versus those varying distances from a patch. If true, this would suggest that low density patches are not at risk of extirpation due to pollinator limitation and that some other factor is causing population declines and eventual disappearance. Other factors contributing to extirpation and population declines could include competition with non-native plants, habitat loss, or decreased seed dispersal. Understanding the pollination ecology of Lyon's Pentachaeta will direct future management and research for this endangered plant of the Coastal Sage Scrub Community.

***96.2*** HOLZMAN, R*; COLLAR, DC; MEHTA, RS; WAINWRIGHT, PC; UC Davis, Harvard; *raholzman@ucdavis.edu*
***Can functional complexity mitigate performance trade-offs? An evolutionary analysis***
The parts of organisms (genes, molecules, and anatomical structures) typically participate in multiple organismal functions. Multiple roles bring about trade-offs because changes to individual traits that benefit one function often impose a cost to a second function. Through this mechanism, functional trade-offs are thought to have strong stabilizing effects on the evolution of organismal performance. Here we put forward and test the hypothesis that in complex systems, performance costs that result from competing demands on one trait are mitigated by independent, compensatory changes in other traits. We use the mechanism of prey capture in fishes to show how complex performance traits allow adaptive evolution to proceed without steep costs to other functions and thereby mitigate the constraining effects of trade-offs. This mechanism permits simultaneous enhancements in feeding performance on prey types that otherwise impose competing functional demands on the fish skull. We further show that the severity of trade-offs between performance traits is affected not only by the number of components that determine performance (i.e. complexity) but also by the evolutionary correlations between components (i.e. integration). Whereas complexity mitigates evolutionary trade-offs, evolutionary correlations between traits limit this effect. Complexity is therefore expected to promote morphological and ecological diversification by mitigating the constraining effects of trade-offs.

***15.1*** HOPKINS, P.M*; DURICA, D.S.; DAS, S.; KHAMBADAKONE, D.; Univ. of Oklahoma, Norman; *phopkins@ou.edu*
***Differential response to eyestalk removal and multiple autotomy in the fiddler crab, Uca pugilator .***
Eyestalk ablation (ESA) and multiple limb removal (multiple autotomy, MA) are techniques used to propel crustaceans into a precocious molt. These two techniques are not, however, equivalent. ESA removes the source of many neurosceretory products and their primary release site whereas MA leaves those sites intact. This study compares the effects of these two operations on the ability of animals to regenerate, on circulating levels of multiple hormones, and on the length of the molt cycle. We have shown that during the period leading up to molt, ESA animals produced more total ecdysteroids than MA animals (Hopkins, 1992) supporting an inhibitory role for eyestalk factors. Moreover, ESA crabs had higher levels of ponasterone A (PA) during the entire period whereas MA crabs had higher levels of 20-hydroxyecdysone (20E) suggesting that eyestalk factors may exert some influence over which ecdysteroid product is produced by the Y-Organs at any given time during the molt cycle. Since ESA removes the source of the molt-inhibiting hormone that putatively inhibits the Y-Organ production of ecdysteroids, one would expect that molting would occur fairly quickly after ablation. This is not the case. Crabs collected during the winter and subjected to ESA (or MA) do not molt for at least forty days after ablation or autotomy. The levels of circulating ecdysteroids cycle during the period leading to molt. Of the animals subjected to ESA or MA fully 50% of them do not go through a complete molt. The circulating ecdysteroids in these animals differs substantially from the animals going through the molt. These non-growing crabs have viable limb buds that emerge from the coxa much later than the molting cohorts. There is also a seasonal effect. Crabs removed from the field during the summer can have a shorter molt cycle in response to ESA and MA than do animals collected during the winter.

***69.2*** HORNER, Angela M*; HANNA, Jandy B; BIKNEVICIUS, Audrone R; Ohio University, West Virginia School of Osteopathic Medicine, Ohio University College of Osteopathic Medicine; *ah312505@ohio.edu*
***Feeling the Squeeze: the Energetic Cost of Tunnel Locomotion***
Many mammals enter tunnels and burrows to escape predators, forage for food or for access to a thermoneutral environment. Although the energetics of digging burrows has been studied in a few fossorial mammals, the locomotion of animals passing through tunnels is less well understood. The physical constraints of entering tunnels present a considerable challenge to semi-fossorial animals that must navigate through them and yet maintain the ability to travel overground efficiently. In this study we investigated the kinematics and energetic cost of locomotion in two semi-fossorial taxa with disparate morphologies and phylogeny—a carnivoran (the domestic ferret, *Mustela putorius furo*) and a rodent (the degu, *Octodon degus*). The animals were trained to run in metabolic chambers on treadmills over a range of speeds for several weeks prior to data collection to ensure behavioral and metabolic stability. The tunnel condition was simulated with a lowered ceiling in the metabolic chambers such that each animal experienced approximately 25% reduction in hip height from the unconstrained condition. Due to the ferrets' tall, arched trunk, the lowered ceiling also resulted in a 35% reduction of profile height, as well as an extension in the functional trunk length of nearly 30%. Oxygen consumption and carbon dioxide production were measured with an open-flow respirometry system. Metabolic rates in each condition were compared within species using a mixed model ANCOVA. Both ferrets and degus demonstrated a higher metabolic rate in tunnels when compared to overground locomotion, and a nearly 20% increase in the net cost of transport. Although ferrets experience a more pronounced change in posture when entering tunnels, some physiological adaptations may counteract the expected increase in metabolic cost relative to the more general bauplan of the degu.

***72.2*** HORROCKS, N.P.C. *; MATSON, K.D.; TIELEMAN, B.I.; University of Groningen, Netherlands; *n.p.c.horrocks@rug.nl*
***Linking measures of immune function with indices of environmental disease risk: antibacterial proteins in eggs as a marker of pathogen pressure***
As part of a project investigating how disease risk in different environments affects immune defence strategies, we studied lark species (*Alaudidae*) living in four dissimilar habitats (Saudi Arabian desert, high altitude Afghanistan, lowland temperate Netherlands, tropical Kenya). We analysed plasma samples to measure indices of immune function (haptoglobin concentration, haemolysis and haemagglutination). We also collected a small number of eggs from lark nests in each environment to measure concentrations of antibacterial proteins (lysozyme, avidin, ovotransferrin) in the albumen. Larks are ground-nesting passerines with open-cup nests and their eggs are potentially exposed to a wide variety of microbes from both the soil, the air and the incubating bird. Antibacterial proteins may be particularly important in protecting eggs from infection in microbe-rich environments or under other conditions favourable to bacterial penetration of the shell and membranes. We hypothesised that concentrations of antibacterial proteins in eggs might provide an index of broader environmental pathogen pressure and might therefore correlate with measures of immune function taken from adult birds. In this presentation I present data testing this hypothesis and discuss the importance of placing measures of immune function within the context of environmental pathogen pressure.

***71.4*** HRISTOV, N.I.*; RISKIN, D.K.; HUBEL, T.Y.; ALLEN, L.C.; BREUER, K.S.; SWARTZ, S.M.; Brown University, Providence, RI; *nickolay_hristov@brown.edu*
***Kinematics of a fast bat: Changes in wing kinematics with flight speed in the migratory bat (Tadarida brasiliensis)***
Bats are unique among mammals in their ability to fly. Although flight in bats originated from a single common ancestor, the primitive flight apparatus has diversified over evolutionary time to match the tremendous radiation of bats. However, to date, there is little knowledge about how bats of different sizes and wing shapes are capable of producing the aerodynamic forces necessary for flight under different flight conditions. Understanding the mechanism of flight in bats requires accurate 3D kinematic descriptions of the wings of bats with diverse flight strategies. In this study we present a detailed description of the wing kinematics of a bat specialized for fast flight, flying at a range of speeds. Brazilian free-tailed bats (*Tadarida brasiliensis*) were trained to fly in a wind tunnel at speeds between 3.5 and 7.5 m/s. To reconstruct 3D motion of anatomical landmarks, markers were placed on the body and wings of bats and their motion was recorded with multiple high-speed digital video cameras. Kinematic parameters calculated from these motions show striking differences in the overall pattern of wing movement in this species compared to other species of bats. Throughout the wingbeat cycle, *T. brasiliensis* maintained a relatively flat wing surface with minimal wing bending. Furthermore, as flight speed increased, there was little change in the pattern of wing motion, instead, bats changed the shape of their wings by modifying wing extension, camber and angle of attack. This study demonstrates that the dynamic shape of the wing in flight is very different from its static morphology and the use of simple models to represent the diversity of flight strategies among bats is insufficient to capture their diversity.

***86.1*** HSIEH, S.T.*; SMITHERS, C.; University of Florida, Gainesville; Temple University, Philadelphia, PA, University of Florida, Gainesville; *sthsieh@post.harvard.edu*
***Adaptive divergence in green anole lizards due to species invasions***
Phenotypic plasticity is cited as a mechanism that can facilitate adaptive evolution, by enabling an immediate response to sudden environmental changes, effectively “buying time” for an organism to genetically adapt to the new conditions. Previous studies have shown that when green (*Anolis carolinensis*) and brown anoles (*Anolis sagrei*) were raised on narrow and broad surfaces, individuals raised on narrow surfaces reached adulthood with shorter limbs than did those raised on broad surfaces (Kolbe and Losos, 2005; Losos et al., 2000). In Florida, brown anole lizards were introduced to the southern tip in the mid-1930s, and have since invaded northward throughout the state, reaching the northernmost border in the mid-1990s. The brown anole invasion in Florida has appeared to decimate the native populations of green anoles while forcing habitat displacement and a vertical habitat shift (Campbell, 2000) on to narrower surfaces. We hypothesized that as a result of increased competitive pressures and subsequent vertical habitat shift associated with the brown anole invasion, post-invasion populations of green anoles would have shorter limbs than pre-invasion populations. To test this hypothesis, we obtained green anoles from museum collections representing populations from Florida, Georgia, and South Carolina. For each individual, we measured fore- and hindlimb lengths, and head length, width, and height. Results show significantly shorter hindlimbs and smaller heads among post-invasion populations, reflecting the habitat shift and possible associated differences in prey type. Work is currently underway to determine if the detected morphological differences are due to plasticity or adaptive evolution.

***5.1*** HU, DL*; MLOT, N; Georgia Tech; *hu@me.gatech.edu*
***Ant raft***
To survive floods, fire ants link their arms together to assemble a raft with their own bodies. Because ants are nearly as dense as water, this cooperative behavior requires that a portion of the ant colony must sacrifice itself by remaining underwater to support the colony's weight. Surprisingly, few ants drown during this process due to a striking metamorphosis of the raft: as we show using time-lapse photography, the raft morphs from a spherical to a pancake shape. This pancake configuration--a monolayer of floating ants supporting their dry counterparts--allows all ants to both breathe and remain united as a colony. Data is presented in the form of the dimensions and the rates of formation of the ant raft. We use the statics of small floating bodies to account for the equilibrium raft size as a function of the initial mass and density of the ants.

***18.5*** HUANG, H.-D.; National Museum of Natural Science; *hdhuang@nmns.edu.tw*
***Mass aggregation for reproduction by a gymnodoridid nudibranch, Gymnodoris ceylonica (Kelaart, 1858), in Lanyu (Orchid Is.), Taiwan***
Widely distributed in Indo-Pacific area, translucent white *Gymnodoris ceylonica* is moderately common and usually found in seagrass or algae zones preying other invertebrates (Debelius and Kuiter, 2007). Observation by divers pointed out this species swim from 30m up to 10m deep for reproduction. Incidentally encountered in mid-July 2009, a mass aggregation for reproduction by *G. ceylonica* was observed at Lanyu (Orchid Is.), southeastern Taiwan. Estimated more than 30 individuals occurred in a 20 by 20m reef flat with sandy bottom at 4-8 m deep. Sizes of *G. ceylonica* individuals ranged from 50 to 80 mm. Over 70% of *G. ceylonica* at the site were ovigerous, judged by the yellow eggs through their translucent body wall. During the observation of approximately 60 minutes, approximately 60% individuals were mating or laying eggs. Mating pairs copulated with everted bifurcate sex organs at the right side of the body for reciprocal fertilization. *Gymnodoris ceylonica* deposited light-yellowish messy egg strings instead of the spiral bands like most other dorid nudibranchs do. At the site, no *G. ceylonica* was foraging; some individuals found weak or dead without eggs inside the body. Few animals ay the site fed on eggs of *G. ceylonica*, yet some eggs were captured by filter feeders on the sea bottom.

***71.5*** HUBEL, T.Y.*; HRISTOV, N.I.; RISKIN, D.K.; SWARTZ, S.M.; BREUER, K.S.; Brown University; *tatjana_hubel@brown.edu*
***Bat flight and hierarchies of variability***
Kinematics as well as morphology differ greatly among the approximately 1200 living species of bats, and it is crucial to understand the effects that the body, wing shape and pattern of wing movement have on wake structure. One key aspect of this subject is to understand the relative magnitude of variation in kinematics and aerodynamics among the wing beats of individuals, among individuals of the same species and among different species. To answer this question, we investigated the aerodynamics and kinematics of multiple individuals of three bat species over a range of flight speeds. Based on the overall patterns of kinematics observed during bat flight to date, we predicted that the wakes of all bat species should develop discrete vortex rings, and generate negative circulation in the wing tip area at the end of the downstroke. We tested this hypothesis in three species of bats: *Cynopterus brachyotis* (Pteropodidae), *Tadarida brasiliensis* (Molossidae), and *Myotis velifer* (Vespertilionidae). These species vary in their ecology regarding foraging, roosting preferences, and migration habits, and have associated differences in morphology, including aspect ratio, wing shape and wing loading. We used PIV to visualize the wake structure and quantify vortex generation over multiple wing beat cycles. Simultaneously, we recorded the wing motions using three high-speed cameras in order to link the kinematics directly to the forces generated on the wing. Our results reveal that wake structure varies among species, and changes over a range of wind speeds. This pattern suggests that bats employ a more flexible strategy that includes variation among species in the details of force production in relation to the specifics of wing form and kinematics, and modulating force production mechanisms with changing velocity.

***102.1*** HUDSON, P.E.*; CORR, S.A.; WILSON, A.M.; Royal Veterinary College; *phudson@rvc.ac.uk*
***Galloping at high speed: insights from cheetahs and racing greyhounds***
High speed locomotion is essential for the survival and success of many species. The cheetah is the fastest living land mammal with a reported maximum speed of to 28.6 $ms^{-1}$. Here we compare cheetahs to racing greyhounds which are similar in size and have been selectively bred for high speed sprints. Greyhounds, however, have a maximum speed of around 19 $ms^{-1}$ during a race. The reason for this difference is unclear and we attempt to shed light on this by comparing the kinematics and kinetics of galloping in cheetahs and greyhounds.

We have collected data from three cheetahs and six greyhounds to date. All animals chased a mechanical lure along a 90 m runway with an array of six to eight Kistler force plates embedded in it. Subjects were videoed from both sides using four AOS high speed cameras (1280 x 600, 1000fps).

Our data to date were recorded at disappointingly submaximal speeds (cheetah 15 $ms^{-1}$, greyhound 13$ms^{-1}$). At these speeds the cheetahs utilised longer stride lengths than greyhounds at a maximum of 5.3m for the cheetah and just 3.5m for the greyhound. In the forelimb, cheetahs had higher stance and swing times than greyhounds however duty factor was similar in the two species. In the hindlimbs, swing time was higher in the cheetahs than the greyhounds and stance times were similar in the two species so cheetahs had a slightly lower duty factor than greyhounds.

It would be interesting to have data for cheetahs at maximum speed. Analysis of wildlife documentary footage is difficult, however, such footage does demonstrate that wild cheetahs use higher stride frequencies than published values for greyhounds which may account for some of the “speed reserve”. In addition the greater range of spinal movement in cheetahs at full speed may enable cheetahs to extend their contact lengths more than greyhounds maintaining a constant duty factor.

***98.6*** HUEY, R.B.*; DEUTSCH, C.A.; TEWKSBURY, J.J; VITT, L.J.; HERTZ, P.E.; ALVAREZ PEREZ, H.J.; GARLAND, T.J., JR.; LISTER, B.C.; GORMAN, G.C.; Univ. of Washington, Seattle, Univ. of California, Los Angeles, Univ. of Oklahoma, Norman, Barnard College, Univ. of Puerto Rico, Rio Piedras, Univ. of California, Riverside, Rensselaer Polytechnic Instit., retired; *hueyrb@u.washington.edu*
***Why tropical forest lizards can't take the heat***
Although the rate of climate warming is relatively low in the tropics, recent studies suggest that tropical ectotherms (especially forest ones) will be especially vulnerable to warming. Field data (body and operative temperatures, reproductive condition) collected in the 1970s and 1980s in Puerto Rico are a rich resource for evaluating the impacts of climate warming on tropical *Anolis* lizards. We present simple simulations suggesting that warming will depress the physiological performance in summer but may enhance reproduction in winter. Warming may also enable open-habitat species to invade the forests and thus increase competition and predation on forest species. Thus tropical forest ectotherms may be vulnerable to the cascading physiological and ecological effects of climate warming.

***S2.4*** HULBERT, AJ; Univ. of Wollongong, Australia; *hulbert@uow.edu.au*

***Metabolism and Longevity: is there a role for membrane fatty acids?***

Over 100 years ago, Max Rubner combined the fact that both metabolic rate and longevity of mammals varies with body size to calculate that "life energy potential" (lifetime energy turnover per kg) was relatively constant. This calculation linked longevity to aerobic metabolism which in turn lead to the "rate-of-living" and ultimately the "oxidative stress" theories of aging. However the link between metabolic rate and longevity is very imperfect. Although unknown in Rubner's time, one aspect of body composition of mammals also varies with body size, namely the fatty acid composition of membranes. Fatty acids vary dramatically in their susceptibility to peroxidation and the products of lipid peroxidation are very powerful reactive molecules that damage other cellular molecules. The "membrane pacemaker" modification of the "oxidative stress" theory of aging proposes that membrane fatty acid composition, via its influence on lipid peroxidation, is an important determinant of lifespan (and a link between metabolism and longevity). The relationship between membrane fatty acid composition and longevity will be discussed for (i) mammals of different body size, (ii) birds of different body size, (iii) mammals and birds that are exceptionally long-living for their size, (iv) strains of mice that vary in longevity, (v) calorie-restriction extension of longevity in rodents, (vi) longevity differences between queen and worker honeybees, and (vii) longevity differences among humans. Most of these comparisons support an important role for membrane fatty acid composition in the determination of longevity. The regulation of membrane composition and especially the influence of fatty acid composition of the diet will be discussed. Consideration of the exceptionally long-living species, Homo sapiens, suggests the fatty acid composition of mitochondrial membranes may be especially important.

***50.3*** HULSEY, CD*; STREELMAN, JT; Univ. of Tennessee, Georgia Institute of Technology; *chulsey@utk.edu*

***Comparative Evolutionary Dynamics in Cichlid Adaptive Radiations: Linking Lower Jaw Genetics, Morphology, and Mechanics***

The lower jaw is a major determinant of feeding diversification in cichlid adaptive radiations. It also provides an ideal phenotype to compare rates and patterns of macroevolution among cichlid radiations. Using a novel phylogeny of four genes (ND2, Dlx2, Mitfb, and S7), we examine the phylogenetic relationships among two of the most evolutionarily disparate cichlid radiations: 1) the Heroines of Central America and 2) the Lake Malawi species flock. To quantify jaw morphology, we measured the in-levers and out-levers of the lower jaw in approximately 40 species in each flock respectively. Then we examined the modularity of the jaw across the phylogeny and compared how integrated the jaw was in the two radiations. Using several external calibration points, we also generated a time-calibrated chronogram for both groups and examined the evolutionary rates for morphology and mechanics. The rates differed in surprising ways between the two clades.

***62.10*** IDJADI, Joshua A.*; HARING, R. Nicholas; PRECHT, William F.; Eastern Connecticut State University, Willimantic CT, The City of San Diego Marine Biology Laboratory, San Diego, CA, Florida Keys National Marine Sanctuary, Key Largo, FL ; *idjadij@easternct.edu*

***Recovery of the sea urchin Diadema antillarum promotes scleractinian coral growth and survivorship on shallow Jamaican reefs.***

The decline and potential recovery of Caribbean reefs has been the subject of intense discussion and is of great interest to reef ecologists and managers. The recent return of *Diadema antillarum* sea urchins at some Caribbean locations and the concomitant changes in coral cover and recruitment provide new perspective on the nature of Caribbean reef community dynamics. This study examined the influence of recovering populations of *Diadema* and the subsequent formation of dense urchin zones on the growth and density of newly settled juvenile scleractinian corals. In these urchin zones, where *Diadema* graze algae, we documented higher growth rates of juvenile corals, and higher densities of small juvenile recruits (likely to be important precursors to reef recovery). Coral survivorship was higher for juvenile corals living in urchin versus algal zones. Roughly 83% of the juvenile corals survived over the two year period of the study, while ~69% survived in the algal zones. Corals in the urchin zones increased in major diameter by an average of 75 ± 7% from 2001 – 2003 versus 24 ± 4% for corals in the algal zones during the same time period. The relatively abrupt decrease in macroalgal cover and the signs of increasing coral cover along the north coast of Jamaica following the return of *Diadema* reported here and by other authors, suggest that these reefs have undergone rapid phase shifts, rather than being constrained to alternate stable states. In the Caribbean, it appears that *Diadema* are effective at enhancing scleractinian coral recruitment and growth, and thus could be used as an important manipulative tool for returning reefs to a coral dominated state, especially on reefs that are severely overfished.

***52.5*** INGLEY, S.J.*; BYBEE, S.M.; BRANHAM, M.A.; WHITING, M.F.; Univ. of Florida, Univ. of California, Irvine, Brigham Young University; *sjingley@gmail.com*

***Life on the Fly: Evolution and Ecology of the Endangered Helicopter Damselflies (Odonata: Pseudostigmatidae)***

Helicopter damselflies (Odonata: Pseudostigmatidae) form a relatively small, yet dynamic group of endangered odonates (including the largest extant odonate, *Megaloprepus caerulatus*, with a wingspan of ~190 mm). This highly specialized group is found in primary-growth rainforest (Central and South America; one East African species) where they oviposit exclusively in phytotelmata and are specialist foragers on orb weaver spiders which are plucked from their web. Pseudostigmatids exhibit unique wing structure within Zygoptera, and within Pseudostigmatidae both broad and narrow wing forms exist. This unique wing structure may account for the unique behaviors present in this group. Oviposition, spider-feeding and wing form evolution are examined for the first time within an evolutionary context using modern phylogenetic methods of tree reconstruction and character optimization. Phylogenetic analyses were performed on a data set composed of 60 morphological characters and ~5.2kb of sequence data (Mitochondrial loci: 12S, 16S, COII, ND1; Nuclear loci: 28S, H3, EF1α). Findings include: monophyletic Pseudostigmatidae; *Coryphagrion grandis* (East African species) as sister to all Neotropical genera; and *Pericnemis* as sister to Pseudostigmatidae. The genera *Mecistogaster* and *Pseudostigma* are monophyletic while *Microstigma* forms a monophyletic group with *Megaloprepus*. Oviposition in phytotelmata evolved multiple times within Zygoptera, with several subsequent losses. Spider-feeding evolved once and is unique to Pseudostigmatidae. There are two separate origins of narrow wings within Pseudostigmatidae.

***90.4*** IRIARTE-DIAZ, J.*; ROSS, C.F.; University of Chicago; *jiriarte@uchicago.edu*

***Kinematic analysis of chewing in primates: comparison of analytical methods on the analysis of jaw motion***

Chewing kinematics in mammals has been traditionally characterized and described by four phases: fast close (FC), slow close (SC), fast open (FO), and slow open (SO). These phases are based on the temporal profile of jaw vertical excursion or gape angle. Jaw motion, however, is essentially three-dimensional, where significant lateral displacements and rotations are necessary to effectively process food. As a consequence, traditional segmentation of the gape cycle based on unidimensional parameters might not completely reflect the complexity and subtleties of chew kinematics. Thus, to evaluate whether traditional chewing phases accurately describe the three-dimensional kinematic, we compared the timing of phases obtained by traditional methods to phases obtained by an alternative method based on the three-dimensional trajectories of jaw motion ("3D-phases"). We propose that a 3D phase can be characterized by the period where the jaw moves predominantly in a plane in space, with a substantial change in plane orientation from one phase to another. We recorded the three-dimensional kinematics of two macaque and three capuchin subjects. Preliminary analysis suggests the existence of four 3D-phases, roughly similar to the phases obtained by traditional methods, although the timing of these phases varied between methods. For example, the timing of the SC-SO transition was usually associated with a 3D-phase transition. In contrast, the differences in timing of both FC-SC and SO-FO transitions with respect to the 3D transitions showed higher variability, suggesting that lateral motions and/or rotations of the mandible might play an important role, probably associated to tongue manipulation and repositioning of food bolus within the oral cavity.

***63.5*** IRSCHICK, Duncan/J; University of Massachusetts at Amherst; *irschick@bio.umass.edu*

***Correlational selection on sexual signal size and performance in lizards***

Although many researchers have studied natural and sexual selection, relatively few have studied correlational selection, particularly in regards to sexual traits and performance. Recent research has shown that many sexual traits in animals show strong relationships with performance traits that are important in the sexual selection process. I studied survival selection on both a classic sexual signal (the anole dewlap) and bite force, a trait that is linked with dewlap size in territorial anole lizards. As a study system, I examined the common and territorial brown anole lizard (*Anolis sagrei*) on the small island of South Bimini Island, Bahamas. I found that there was significant selection on bite force alone, and also on the interaction between bite force and dewlap area. In particular, survival selection favored those adult males (but not females) that had a combination of large dewlaps and high bite forces. By contrast, there was no significant selection on dewlap size alone. In short, only by examining the interrelationship between sexual traits and performance can one fully understand how selection operates on sexual traits.

***87.3*** IWANSKI, E.*; HAGSTROM, K.R.E.; REYES, J.A.; PHAM, M.; KELLEY, K.M.; California State University, Long Beach, Pacific Coast Environmental Conservancy (pceconservancy.org); *kmkelley@csulb.edu*

***Environment Associated Differences in Male Estrogen Levels and Testicular Steroidogenic Gene Expression in a Southern California Flatfish***

In Santa Monica Bay offshore of Los Angeles, CA, males of an indigenous flatfish species (hornyhead turbot) exhibit elevated plasma concentrations of 17-beta estradiol (E2) and estrone (E1) as compared with fish residing in other, nearby locations. Our studies are aimed at determining whether this phenotype may be related to a major WWTP outfall in the bay and/or to other environmental or biological factors. This study tested the hypotheses that increased testicular expression of steroidogenic enzymes involved in estrogen production may be associated with the elevated plasma estrogens in males, and that isolation of these fish from the environment may result in amelioration of the high-estrogen phenotype. Gonadal expression of StAR, P450aromatase and 17β-HSD1 measured by qPCR were all significantly higher in testis of fish from Santa Monica Bay as compared with locations only 25-45 km south, along Orange County. In addition, there was an overall significant positive correlation between E2 and E1 concentration and expression of the genes, which was strongest for StAR. Rearing of fish caught from Santa Monica Bay in aquaria containing clean seawater for 4 and 8 weeks resulted in subsidence of the high estrogen phenotype along with testicular expression of the steroidogenic genes, down to levels seen in turbot and other flatfish males from outside of the region that did not have elevated estrogen levels. These findings suggest that environmental factors may drive increased gonadal steroidogenic gene expression and elevated estrogens in male turbot from Santa Monica Bay. (Supported by NOAA - USC Sea Grant Program)

***70.2*** JACKSON, B.E.; The University of Montana, Missoula; *brandon.jackson@mso.umt.edu*

***Scaling of escape flight performance, power output, and muscle function in perching birds***

Patterns of scaling in animal locomotion offer insight to physical constraints imposed on evolution. Flight, being metabolically costly yet evolutionarily successful, is a particularly useful locomotor behavior through which to examine effects of scaling on locomotor performance, behavior, and ecology. Order Passeriformes (perching birds) includes ~50% of extant avian species, and a diverse array of ecologies, making them a critical component to our understanding of scaling in birds. I used a phylogenetically controlled 3-D kinematic analysis of 32 species of passerines (5 – 900 g) performing maximal escape takeoff and vertical flight. Body mass ($M_b$) specific climb power output scaled as $M_b^{-0.17}$, controlling for typical foraging location (ground vs. elevated). Total mass specific power output estimated from aerodynamic models scaled as $M_b^{-0.10}$, and was limited by a ceiling that scaled approximately as $M_b^{-0.2}$. Ground foraging species performed significantly better than elevated foragers, and resident species performed marginally better than long-distance migrants. Ground foragers also had relatively shorter wings, higher wingbeat frequencies, and greater hind-limb contribution to takeoff. In a complementary study I measured *in vivo* muscle function using sono-strain surgical implants in a single passerine clade, Corvidae (Gray Jay, Black-billed Magpie, American Crow, and Common Raven). Muscle mass ($M_m$) specific mechanical power output scaled as $M_m^{-0.2}$. In both muscle output and whole-body performance, wingbeat frequency appears to impose an ultimate limit. However, the positive allometry of muscle strain ($M_b^{0.11}$) and wing size (length: $M_b^{0.41}$) are potential compensatory mechanisms reducing the effects of body size on whole-body performance *via* wingbeat frequency. Funded by NSF IBN-0417176.

***S3.8*** JACOBS, Molly W.*; PODOLSKY, Robert D.; Woods Hole Oceanographic Institution, Grice Marine Laboratory, College of Charleston; *mjacobs@whoi.edu*

***Developmental Variation, Carryover Effects, and the Importance of Scale and Context***

The life cycles of most metazoan organisms are complex, involving larval stages that are morphologically and ecologically distinct from adult stages. These discrete stages are often subject to very different selection pressures, and yet are inescapably connected through the life cycle of the organism: environmental experiences that affect the fitness of one life history stage may carry over and affect fitness in a subsequent stage. Similarly, inherited variation in morphology, behavior, development rate, or other traits may also carry over from one stage to the next. In recent years a number of researchers have presented convincing evidence of these types of effects, but the adaptive significance of carryover effects is in most cases unclear. Here, we argue that the importance of carryover effects is largely dependent on both the scale of the relevant processes and the environmental context in which they occur. The real importance of developmental variation, whether genetic or introduced by variation in environmental experience, may lie in the flexibility it gives organisms and populations to respond to environmental variation over annual or longer timescales. We will review published examples of carryover effects in this context and also present examples from our own work with gastropods, ascidians, and decapod crustaceans.

***100.5*** JAMNICZKY, H.A.*; BOUGHNER, J.C.; GONZALEZ, P.N.; PARSONS, T.E.; POWELL, C.D.; ROLIAN, C.; SCHMIDT, E.J.; BOOKSTEIN, F.L.; HALLGRIMSSON, B.; Univ. of Calgary, Canada, Univ. Nacional de La Plata, Argentina, Univ. of Vienna, Austria and Univ. of Washington, USA; *hajamnic@ucalgary.ca*

***Mapping the Epigenetic Landscape: Rediscovering Waddington in the Post-Genomic Age***

C.H. Waddington originally defined *epigenetics* as the causal analysis of development. This term has since come to connote the study of a variety of mechanisms and phenomena. We argue that Waddington's original construal of the term was intended to describe the full variety of emergent developmental phenomena above the level of the genome, not only those involving chromatin modification. Such epigenetic mechanisms often result in bias in the direction of generated organismal variation, or in modulation of the amount of such variation. Emergent developmental phenomena generated by epigenetic mechanisms include modularity and canalization, among others, and form a key part of the bridge between genotype and phenotype. These emergent phenomena are of particular interest in the study of the means by which different phenotypes arise. We therefore extend Waddington's epigenetic landscape metaphor, which continues to provide useful explanatory power in the post-genomic age, to explore the generation of selectable variation at the organismal level. The study of epigenetics, as construed here, is a central disciplinary focus of evolutionary developmental biology.

***38.8*** JANZEN, WJ*; RILEY, LG; California State University, Fresno; *whitneyjanzen@yahoo.com*

***The Effects of Acute Cortisol Administration on Appetite Control in the Tilapia***

In response to a stressor, an animal's physiology is altered in an attempt to maintain homeostasis and efficiently utilize its limited metabolic energy. Cortisol, a stress hormone, has widespread actions which mediate the response to stress by coordinating a set of physiological changes allowing an animal to restore homeostasis after a stressor. There are few a reports describing a reduction in appetite in stressed in fish; however, how stress influences the endocrine control of appetite has yet to be elucidated. The objective of this study was to investigate the short-term effects of cortisol on the endocrine regulation of appetite in the tilapia *(Oreochromis mossambicus)*. Fish were given a single intraperitoneal injection of cortisol at 2 µg/g BW (low dose), 10 µg/g BW (high dose), or vehicle only (control). Tissue and blood samples were collected at 24 and 48 h post-injection. Pre-pro mRNA levels of the ghrelin receptor (GRLN-R), as well as mRNA levels of each GRLN-R isoform (GHS-R1a and -1b), and neuropeptide Y (NPY) were measured from brain. Plasma ghrelin levels were also measured. Plasma ghrelin and ghrelin mRNA levels in the brain were significantly suppressed in fish injected with the low dose of cortisol. In addition, mRNA levels of NPY were significantly increased in animals receiving the low dose of cortisol. GHS-R1b mRNA levels were significantly elevated in brain, whereas no change in pre-pro GRLN-R or GHS-R1a mRNA was observed. Our data showed that cortisol inhibited ghrelin mRNA levels providing a possible mechanism for the reduction of food intake reported in fish during stress. However, NPY mRNA levels were significantly elevated following cortisol treatment suggesting that NPY may be playing other roles in regulating overall metabolism in fish. This work was supported by the NSF (IOS-0639771) awarded to LGR.

***46.1*** JAWOR, Jodie M.*; WINTERS, Caitlin P.; University of Southern Mississippi, Hattiesburg; *jodie.jawor@usm.edu*

***Testosterone and melanin face mask coloration in female northern cardinals (Cardinalis cardinalis)***

Melanin-based feather coloration (e.g., black, reddish-brown, or dark brown colors) has been a focus of research interest in sexual selection in terms of the use of melanin ornaments in male dominance relationships. In a variety of species, individuals with either larger or darker melanin-based face-masks, breast stripes, head stripes, etc. are socially dominant. Findings from manipulative studies suggest that testosterone (T) during fall molt may impact male melanin-based coloration, thus providing a potential link between dominance, aggression, and melanin ornament expression. However, not as much focus has been placed on the use of melanin ornaments in females and whether this ornament type may be influenced by T in females. In this research we maintained 20 northern cardinals, *Cardinalis cardinalis* (15 females, 5 males), in captivity through molt and collected plasma samples for T levels every second day until molt was completed. Female face mask expression prior to and after molt was compared to average, minimum, and maximum T levels. We found that average T over the period of molt co-varied with the darkness of the melanin-based face mask; females with darker masks had higher average T during molt. Face mask size and color have been previously shown to co-vary with aggression during conspecific interactions in cardinals and T has recently been shown to increase during aggressive intrasexual interactions between females. Potentially, females with higher T during molt may produce an ornament that reliably displays information on future behavior that is also influenced by T.

***102.2*** JAYARAM, K.*; MONGEAU, J. M.; MCRAE, B.; FULL, R.J.; Univ. of California, Berkeley; *kaushikj@berkeley.edu*

***High-Speed Horizontal to Vertical Transitions in Running Cockroaches Reveals a Principle of Robustness***

We marvel at the gracefulness of large animals as they maneuver over complex terrain with barely a miss-step. Small animals appear to have alternative strategies that rely on the properties of their skeletal system that we should consider no less elegant. To elucidate these strategies, we used high-speed video to record horizontal to vertical transitions in the cockroach *Periplaneta americana*. After eliciting an escape response, animals ran down a trackway at 18 to 43 body lengths/s toward a vertical wall. In 80% of the trials (n=43) animals successfully made the transition. In 60% of the successful transitions, the animal collided with the wall head-first and then reared upward using primarily hind-leg extension. In the other 40% of the successful transitions, animals adopted a high-angle body posture that avoided head-on collisions, but still relied on energy absorption by the head and/or front legs. Successful head-on collision transitions occurred at a faster range of speeds (65-129 cm/s) than non-head-on collisions (54-78 cm/s). Surprisingly, these two strategies showed no significant difference in the average time from wall contact to vertical posture (73±7 SE ms). We found no significant differences in strategies or performance across individuals, lighting conditions, or substrate properties. Our results suggest that when pressed to extreme performance involving severe bandwidth and/or computational limitations from the nervous system, small animals can rely on the mechanical properties of their body and appendages to sustain large impulses and thus simplify task-level control. This principle of bio-mechanical robustness has inspired the design of novel robots that use energy-absorbing exoskeletons to complete challenging maneuvers.

***15.3*** JIAO, Shuang*; LU, Ling; JIANFENG , Zhou; YUN, Li; CUNMING , Duan; University of Michigan, Ocean University of China; *cduan@umich.edu*

***Molecular and functional characterization of the zebrafish clusterin gene: Specific expression in the developing choroids plexus and regulation by Notch signaling***

Clusterin, also known as Apolipoprotein J, is a secreted glycoprotein associated with many pathological states, including cancer, atherosclerosis, diabetes, renal and neurodegenerative diseases. Clusterin has been proposed to act as an extracellular chaperone that inhibits protein aggregation and precipitation caused by physical or chemical stresses. It is poorly understood when, where, and how its gene expression is regulated in vivo. We have cloned and characterized the zebrafish clusterin gene and studied its gene expression and regulation. The structure of zebrafish clusterin gene and protein is similar to its human homologue. There is a strong syntheny relationship between the fish and human homologues. Biochemical assays show that zebrafish clusterin is a secreted protein. In adult zebrafish, clusterin mRNA is detected in multiple tissues. During early development, clusterin mRNA became dateable at 12 hpf and its levels gradually increased as embryos grow. In situ hybridization analysis indicates that clusterin mRNA is highly expressed in the diencephalic and myelencephalic choroid plexus (ChP) in advanced embryos. Among various stresses tested, heat shock, but not hypoxia or osmotic stresses, increases the levels of clusterin mRNA. Specific inhibition the IGF-1 receptor-mediated signaling and overexpression of IGF ligands did not change clusterin mRAN levels in zebrafish embryos. Inhibition of Notch signaling caused a significant increased in the number of clusterin mRNA-expression cells and in clusterin mRNA levels. These results suggest that clusterin is a marker of ChP and its expression is under the regulation of Notch but not IGF signaling

***28.2*** JOHNSEN, S.*; HADDOCK, S.H.D.; Duke University, Monterey Bay Aquarium and Research Institute; *sjohnsen@duke.edu*

***A glowing benthic animal is hard to find: A photographic and spectroscopic survey of bioluminescence on the deep-sea floor***

Bioluminescence is nearly ubiquitous in marine pelagic species, particularly those of the open ocean. However, the extent of bioluminescence in the deep-sea benthos is far less studied, although the relatively large eyes of benthic fish, crustaceans and cephalopods suggests the presence of significant biogenic light. Using the *Johnson-Sea-Link submersible*, we collected numerous species of anthozoans, echinoderms, decapod crustaceans, octopods, teleosts, sponges, and one polychaete from several sites in the northern Bahamas (depth 700 m). Collected animals were tested for light emission via mechanical and chemical stimulation. We photographed the emissions of the bioluminescent species and recorded their spectra. In addition, *in-situ* intensified video and still photos were taken of different benthic habitats. Surprisingly, bioluminescence in benthic animals was far less common than in pelagic animals, with less than 10% of the collected species emitting light. Bioluminescent taxa comprised two species of anemone, the zoanthid *Gerardia* sp., three pennatulaceans, three bamboo corals (Isididae), one chrysogorgiid coral, the carid shrimp *Parapandalus* sp., two swimming holothurians including *Enypniastes exima*, and one un-identified species of ophiuroid. While the emitted light of the ophiuroid and *Parapandalus* was blue (peak wavelengths 470 and 455 nm), that of the remaining species was greener than what is found in related pelagic taxa, with the pennatulaceans being strongly shifted towards longer wavelengths. *In situ* observations suggested that the primary sources of bioluminescence in deep sea benthos are planktonic species that emit light as they strike filter feeders that extend into the water column.

***1.11*** JOHNSON, Sarah/E*; DIEHL, Jennifer/M; TOMANEK, Lars; Cal Poly, SLO; *SeJohnso@calpoly.edu*

***Ecotoxicoproteomics: Protein Expression Profiles of Fish in Response to the Contaminant 4-Nonylphenol***

4-Nonylphenol is a documented endocrine disruptor, but our data is the first to suggest that nonylphenol may be causing tumors in a population of fish in Morro Bay, CA. Nonylphenol is a persistent end product of the biodegradation of alkylphenol ethoxylates, a group of chemicals that are widely used as surfactants in household and commercial products. Small amounts of nonylphenol introduced into the water can accumulate in sediment and organisms, biomagnifying up the food chain. Through chemical analysis we found high levels of 4-nonylphenol in tissues of the arrow goby, *Clevlandia ios,* as well as in sediment and water from the mud flats in Morro Bay. Upon visual inspection since 2006 we have found an average gross gonadal tumor rate of 6.0% in females while our histopathological data indicate gonadal tumors in both males and females, as well as severe lipidosis and glycogen depletion in the liver. We are using proteomics to identify biomarkers of chemical contamination and tumorigenic effects of 4-nonylphenol. Through in-lab exposure to 4-nonylphenol, and two-dimensional gel electrophoresis we tracked the simultaneous changes in expression proteins from the arrow goby liver. Proteins of interest have been identified using MALDI-TOF-TOF mass spectrometry, many of which have been indicated in tumor research. Currently, the EPA is being petitioned to regulate nonylphenol and nonylphenol ethoxylates under the Toxic Substances Control Act. Persistent organic pollutants are not easily detected by traditional water quality methods, though the biological effects are present. The biomarkers we developed can be used for early detection of nonylphenol in the environment, as well as to increase the understanding of cellular effects of anthropogenic organic pollutants.

***104.4*** JOHNSON, N.G.*; BURNETT, L.E.; BURNETT, K.G.; College of Charleston; *ngjohnso@edisto.cofc.edu*

***Characterization of the Bacterial Properties that Impair Respiration in the Atlantic Blue Crab, Callinectes sapidus***

In the blue crab *Callinectes sapidus*, injection with the bacterial pathogen *Vibrio campbellii* causes a decrease in oxygen consumption. Histological and physiological evidence suggests that the physical obstruction of hemolymph flow through the gills, caused by aggregations of bacteria and hemocytes in the gill vasculature, may underlie the decrease in aerobic function associated with bacterial infection. Alternatively, the observed decline in oxygen uptake could be a reflection of hormonal changes known to be induced by bacterial lipopolysaccharide (LPS), a major constituent of the Gram-negative bacterial cell wall. To determine whether generic particles of various sizes and surface charges are sufficient to stimulate immune and metabolic responses in *C. sapidus*, the effects of different inert microspheres on total hemocyte count (THC), hemolymph glucose, and hemolymph lactate were evaluated. Injection of *V. campbellii* caused a dramatic decrease in THC (80% decrease at 0.5 h) that persisted for up to 4 h. Large (4 µm diameter) microspheres caused a mild decrease (ca. 30%) in THC at 0.5 h, whereas small (1 µm) microspheres did not. Surface charge did not have any discernible effects. Hemolymph glucose and lactate levels did not change in response to injected bacteria or microspheres. In future studies, *C. sapidus* will be injected with a variety of other bacteria and purified LPS to further elucidate the microbial elements necessary and/or sufficient to elicit changes in THC, glucose, lactate, and oxygen uptake. In exploring the range of particles capable of inducing changes in these variables, we hope to gain further understanding of the mechanisms responsible for inducing this decrease in aerobic metabolism, and reveal the extent to which this phenomenon may impact naturally infected crabs. (Supported by NSF IBN-0212921)

***60.4*** JOHNSON, S.L.*; BROCKMANN, H. J.; University of Florida; *sheriljohnson@ufl.edu*

***The Role of Good Genes and Genetic Compatibility in Multiply Mating Horseshoe Crabs***

Why do females of so many species mate with several males when the sperm from a single male is often sufficient to fertilize all their eggs? Direct benefits (e.g., nuptial gifts, paternal care) to multiple mating are not expected in externally fertilizing species. These females may gain from mating multiply by insuring fertilization, increasing offspring diversity, improving male quality ('good genes') or increasing genetic compatibility. We evaluate the importance of good genes and genetic compatibility in a natural population of the American horseshoe crab, *Limulus polyphemus*. In this species attached pairs migrate to shore and spawn on high tides; the male fertilizes the female's eggs externally with free-swimming sperm as the eggs are being laid in the sand. Unattached males are attracted to spawning pairs by visual and chemical cues and become satellites of some (polyandrous) females while ignoring others (monandrous). When present, satellites fertilize a high proportion of the female's eggs. But, recent research has shown that polyandry is also very costly in this system. We evaluate the importance of good genes and genetic compatibility by conducting a series of *in vitro* fertilization experiments. Results indicate that attached males of a monandrous and polyandrous females may differ in quality and that partial incompatibilities between males and females may provide a selective advantage to offset the costs of multiple mating. As an ancient and independently evolved arthropod, *Limulus* provides a unique opportunity to extend our understanding of the evolution of multiple mating.

***62.1*** JOHNSON, C.H.; Harvard University; *cjohnson@oeb.harvard.edu*

***Effects of selfing on offspring survival in the marine bryozoan Bugula stolonifera***

Although the reproductive biology of bryozoans is widely studied, investigations examining the occurrence and consequences of selfing in these simultaneous hermaphroditic colonial invertebrates are sparse, and the results are contradictory. Over the past two summers, experiments were conducted examining the effects of selfing in the marine bryozoan *Bugula stolonifera*. Larvae from field-collected colonies were cultured through metamorphosis to reproductively mature colonies either in isolation, or in the presence of other colonies (multi condition). In summer 2008, results demonstrated that colonies reared in isolation produced viable larvae that successfully completed metamorphosis, thus documenting that selfing is possible in this species. Larvae from colonies reared in isolation, however, experienced significantly decreased viability compared to those in the mutli condition. Larvae from the isolated condition had both decreased rates of successful metamorphic initiation and completion. These experiments were extended in summer 2009, whereby metamorphs from colonies reared in the isolated and multi conditions were transferred back to the field. These individuals were routinely monitored and were returned to the laboratory 21 days after onset of reproduction. These experiments revealed additional deleterious effects associated with selfing, as no viable larvae were recovered from colonies deriving from the isolated conditions. In contrast, offspring from the multi condition released 1030 larvae, 98.8% initiated metamorphosis, 96.5% of which completed metamorphosis. Overall, these results demonstrated deleterious effects associated with selfing in *B. stolonifera*. Selfed larvae not only had significantly decreased chances of survival, but those that did survive had a low probability of successfully reproducing.

***82.3*** JOHNSON, JC*; TRUBL, P; BLACKMORE, V; Arizona State University West Campus; *jchadwick@asu.edu*

***Male mate choice in black widows: chemical and physical cues allow males to avoid sexual cannibalism by poor-condition females***

Extensions of Bateman's rule predict male mate choice should evolve as male investment in mating increases. Spiders use chemical cues to avoid predators and locate mates, but it remains unclear whether males courting sexually cannibalistic females use chemical cues to make risk-sensitive mating decisions. Here we test the prediction that cues of female foraging success ("fed cues") encourage male courtship in the black widow spider (*Latrodectus hesperus*). In addition, we test the prediction that previous foraging success reduces pre-copulatory sexually cannibalistic attacks/kills by females. Results show that, in both the absence and presence of females, males courted significantly more in webs containing fed cues. However, when well-fed females were switched to the webs of starved females and vice versa, males preferred courting well-fed females despite the lack of fed cue. Male preferences for well-fed females appear adaptive. Starved females were significantly more likely to attack and kill males before mating, and males were attacked and killed most often by starved females inhabiting webs containing fed cues. We conclude by noting that sexual cannibalism offers a model system wherein chemical communication arms races between predator and prey have broad implications such as the effects on sexual selection described here.

***4.4*** JOHNSON, A.S.*; ELLERS, O; Bowdoin College; *ajohnson@bowdoin.edu*
***Precise measurement of growth using multiple fluorochrome markers, the cubed root of weight and a new growth function***
Fluorochromes have been widely used to mark growing calcitic structures. We present images from a size range (3.9–44.3 mm in diameter) of growing sea urchins that were marked by both immersion and injection using the fluorochromes: tetracycline, calcein, calcein blue and alizarin complexone. These fluorochromes appear as distinct, differently colored lines deposited in skeletal structures with as little as three days separating marks. We show that the marking process, even with multiple fluorochromes, has only a short-term negative impact on growth rate, with no measurable differences in growth rate after three months and no effect on gonad production. To enable us to test for potentially small differences in growth caused by the fluorochromes, we had to develop new methods for quantifying size more precisely. Specifically, we use the cubed root of weight as a measure of size and show that this is more precise then simply measuring a single linear dimension. Analysis of small differences in growth is also made possible by the use of a residuals analysis relative to a fitted function, which describes the rate of growth as a function of linear size. We invented a new function, called the gamma function, which provides a good description of growth rate as a function of size for sea urchins. The early lag phase, which has been noted previously in urchins, had heretofore been described by the Tanaka function, which is more complicated to fit. The fluorochrome images are beautiful and reminiscent of Deutler's (1926) famous sketches of growth lines in urchins.

***36.1*** JONES, S.J.*; WETHEY, D.S.; Univ. of South Carolina; *sierra@biol.sc.edu*
***Mussels, models, and mortality: exploring the respective roles of air and seawater temperatures in the southern range limit contraction of Mytilus edulis***
Poleward range expansions and contractions have been documented for aquatic and terrestrial organisms as a result of the recent climatic warming. Presented here is the first example of a contraction of the equatorward limit of an intertidal organism along the Atlantic coast of the United States. The blue mussel, *Mytilus edulis*, has a historical southern limit at Cape Hatteras, North Carolina. Field experiments coupled with modeling simulations indicate that along the southern portion of its range this species is experiencing catastrophic mortality directly associated with high summer temperatures. In accordance with previously measured upper thermal limits, high levels of mortality as well as expression of the inducible heat shock protein 70 are observed after multiple consecutive daily aerial exposures to temperatures of 32°C or greater, causing shifts of vertical distribution within the intertidal. While exposures to high temperatures during low tide will cause patchy intertidal distributions and change the vertical limit, considering that *M. edulis* may live subtidally, water temperatures in excess of thermal tolerance will have the potential to shift a geographic range. Seasonal air and sea surface temperatures were examined at six locations along the eastern seaboard and determined to have increased by an average of 0.78--1.65°C. South of Lewes, Delaware, summer sea surface temperature have now exceeded the tolerance of this species, and have caused a southern limit contractions of approximately 350 km over the past 50 years.

***43.5*** JORGENSEN, M.E.; Ohio University; *mj207406@ohio.edu*
***Patterns of axial and pelvic muscle architecture and fiber composition in frogs with different locomotor modes***
The composition of fiber types in a muscle, along with its gross architecture corresponds to muscle function. In frog limbs, jumping involves muscles comprised mainly of high force-producing glycolytic muscle fibers that contract rapidly during an escape. On the other hand, muscles comprised mainly of slow oxidative fibers maintain a high endurance capacity and are used for posture and slow repetitive behaviors such as walking, burrowing, or hopping. Axial and pelvic muscles in frogs are poorly understood even though they control vertebral column rigidity, direct sagittal and lateral bending of the vertebral column and pelvis, and function as takeoff-angle regulators to align the anterior half of the frog with the legs and pelvis before and during jump take-off. The goal of this study is to examine variation in vertebral musculoskeletal architecture and muscle fiber-type composition in axial and pelvic muscles of frogs with different locomotor behaviors. I quantified vertebral morphology, muscle architecture (anatomical cross-sectional area, muscle length, tendon length) and fiber-type composition of axial and pelvic muscles in a sample of species and locomotor modes used in frogs (*Ascaphus, Xenopus, Bombina, Anaxyrus, Lithobates*). Patterns of variation in muscle architecture and fiber-type composition are presented and discussed in light of different locomotor behaviors and current hypotheses of the evolution of locomotion in frogs.

***1.1*** JOST, JA*; PODOLSKI, S; WILLARD, K; FREDERICH, M; University of New England; *jjost@une.edu*
***A comparison in cellular stress response between subtidal and intertidal crustacean species***
We investigated the mechanisms involved in cellular stress using AMP-activated protein kinase (AMPK) as an indicator of high temperature stress in invertebrates. AMPK acts as a "fuel gauge" for the cell and is activated in mammals by hypoxia, exercise, osmotic shock and cold stress. While AMPK activity has not been thoroughly investigated in invertebrates, we previously identified AMPK in the subtidal rock crab, *Cancer irroratus*, and measured an increase in AMPK activity due to high temperature stress, which occurred earlier than heat shock protein (HSP70) up-regulation. We conducted similar experiments on the intertidal green crab, *Carcinus maenas*. Crabs were exposed to a fast temperature increase (6°C/hour) and heart tissue was sampled every 2°C between 12 and 35°C. Righting reaction times, heart rate, AMPK activity, HSP70 protein, and lactate accumulation were measured. Above 35°C, there was a loss of righting response, an onset of anaerobiosis and an increased heart rate. At 36°C, there was 100% mortality. HSPs and AMPK activity did not significantly increase. Therefore, the green crab switches from maximum performance to heat coma within a very narrow temperature range. In contrast, previous data show a slow decline in fitness, well before the lethal temperature, in the rock crab. These data can be interpreted in the context of Shelford's law of tolerance: the subtidal rock crab shows an early transition from the optimum range to a range with declining fitness (pejus range), while the subtidal green crab demonstrated almost no pejus range and a sharp transition directly from optimum to pessimum. The differential response of AMPK activation by heat stress indicates habitat specific adaptations of the cellular energy metabolism.

***S2.5*** JUDD, Evan T; DREWRY, Michelle; WRIGHT, Katharine; WESSELS, Frank; HAHN, Daniel A; HATLE, John D*; University of North Florida, University of Florida; *jhatle@unf.edu*

***Nutrient allocation in long-lived ovariectomized grasshoppers: tests of the disposable soma hypothesis***

The conserved trade-off between reduced reproduction and extended longevity is often posited to occur through nutrient allocation (aka. disposable soma hypothesis). There is circumstantial evidence to support this hypothesis, but little direct evidence. Stable isotopes have been used to track ingested nutrients in reproduction, but only two studies have applied this to aging, both using dietary restriction. In grasshoppers, directly curtailing reproduction via ovariectomy increases lifespan by ~30%. Here, diets with distinct stable isotope signatures were used to track the allocation of ingested nutrients in individuals that were either ovariectomized or sham operated. Data on hemolymph proteins hinted that, in ovariectomized females, nutrients are shifted from reproduction to storage after parallel controls lay their 1st clutch. To test this, after the 1st clutch we switched the stable isotope composition of the diet of some individuals. Fat body mass ($P<0.0001$) wase larger in ovariectomized individuals, so morphological results indicate that ovariectomy increases storage. Opposite of the prediction of the disposable soma hypothesis, aqueous extracts of the fat body of ovariectomized females accumulated less 15N ingested during the 2nd clutch ($P = 0.002$) than did the fat body of sham females. Accumulation of 13C was also in the opposite direction of that predicted ($P = 0.053$). Hence, the stable isotope results suggest that allocation of nutrients is not increased in somatic tissues upon ovariectomy, which is inconsistent with the disposable soma hypothesis. Future work will examine allocation between hemolymph storage proteins and vitellogenin.

***21.2*** KAATZ, I.M.*; RICE, A.N.; STEWART, D.J.; LOBEL, P.S.; no current affiliation, Bioacoustics Program, Cornell University, NY, SUNY College of Environmental Science and Forestry, NY, Boston University, MA; *ingridmkaatz1@yahoo.com*

***Why are there silent catfishes: shifts in pectoral fin function and changes in pectoral spine morphology***

The evolutionary selection pressures and constraints responsible for the loss of sound signal communication in fishes are poorly understood. Pectoral spine stridulation is common in catfishes. Spines are part of predator defense or social display in known vocal species. Several catfish clades have secondarily lost the ability to produce sounds. We test the hypothesis that change in functional attributes of the pectoral fin and in particular the spine can lead to loss of sound production. We compared the length of the spine across 38 catfish families (993 species) from the literature and found it statistically significantly longer in vocal families. Spines of families with vocal species also had increased ossification and serration. Microscopy (scanning electron and dissecting) of the surface morphology of the dorsal process where bony vocal ridges are located identified four ridge types at the base of the spine that were absent in silent taxa (124 species, 21 families). We compared locking and swimming behavior, spine strength, dorsal process dimensions and microscopic surface structure for six species of doradoid catfishes. Silent species used fins for hovering not spine locking, while vocal species used spines as weapons in defense and locking. Silent species had atrophied spines and processes while vocal species had well developed spines and processes with "vocal ridges". Thus, there appears to be an integral trade-off in the evolutionary design of pectoral spines. We further evaluate the functional shift hypothesis by identifying other suites of ecological and behavioral traits possibly associated with silent vs. vocal catfishes.

***73.3*** KAISER, Kristine*; ALLOUSH, Menemsha; JONES, Robin M.; MARTINEAU, Katherine; MARCZAK, Susanne; OLIVA, Mark V.; NARINS, Peter M.; Univ. of California, Los Angeles; *kristinekaiser@gmail.com*

***More than one type of tenure: anthropogenic noise affects individual-level and chorus-level tenure in the frog Dendropsophus microcephalus***

For species which communicate acoustically, calls are crucial for a variety of interactions, including mate attraction. As a result, many species have developed mechanisms to overcome noise in their habitat. However, as habitats become increasingly degraded and fragmented, anthropogenic noise becomes unavoidable. How animals overcome novel exogenous noise is not well understood. In many frogs, the main predictor of mating success is number of nights at a chorus. However, we propose that chorus tenure can be thought of as having two components, an individual-level and a chorus-level component. We tested the hypothesis that anthropogenic noise decreases chorus tenure at both individual-levels and chorus-levels in the New World treefrog *Dendropsophus microcephalus*. We marked and monitored frogs naïve to anthropogenic noise at two ponds over 45 nights. We broadcast engine noise to frogs at the experimental pond; at the control pond, no noise was played. Frogs at the experimental pond exhibited a decrease in number of days they were at the pond, and in time participating in chorusing on a given night relative to control pond. Because female frogs tend to come to aggregations of calling males late in the evening, these results have serious implications for reproductive success in frogs. We suggest that anthropogenic noise may play a role in amphibian declines.

***57.1*** KAJIURA, Stephen M*; MCCOMB, D Michelle; Florida Atlantic University; *kajiura@fau.edu*

***Visual and electrosensory integration in hammerhead sharks***

The unique head morphology of hammerhead sharks (Family Sphyrnidae) provides a dorsal ventrally compressed and laterally expanded platform upon which sensory structures are distributed. The spatial distribution of sensors dictates how the sharks perceive their environment. This study examined the consequences of broadly separating the eyes at the distal tips of the cephalofoil. In sphyrnid sharks the eyes are canted slightly forward which provides them with greater binocular overlap (30˚) than their carcharhinid sister taxa (10˚). However, the widely spaced eyes create a larger blind area immediately anterior to the snout in sphyrnids, which would seem to be a detriment for an apex predator. At close ranges (tens of cm) the electrosensory system informs the sharks about the location of prey near the head. Juvenile carcharhinid and sphyrnid sharks orient to prey-simulating electric stimuli from a mean distance of 25cm, and maximally from a distance of 40cm. This electrosensory range completely overlaps the anterior blind area of juvenile scalloped hammerhead sharks, *Sphyrna lewini*, and overlaps nearly the entire anterior blind area of a similar sized, representative carcharhinid species, the blacknose shark, *Carcharhinus acronotus*. By integrating visual and electrosensory information, both species are able to continuously track prey right up to the mouth with no loss of spatial information. Therefore, the sphyrnid head morphology confers several advantages and any potential disadvantages are mitigated by sensory integration.

***93.6*** KAMIO, Michiya; NUSNBAUM, Matthew; AGGIO, Juan; GRIMES, Tiphani; DERBY, Charles*; Georgia State University; *cderby@gsu.edu*

***How to Produce a Chemical Defense: Sea Hares Manufacture Antipredatory Chemicals from Diet-Derived Red Algal Photosynthetic Pigments***

In defense against predators, sea hares use an ink secretion composed of purple ink and white opaline. This colored secretion might protect sea hares through visual or chemical modalities. We used bioassay-guided fractionation to identify components in ink of *Aplysia californica* responsible for its defensive effect against blue crabs *Callinectes sapidus*, bluehead wrasses *Thalassoma bifasciatum*, and the spiny lobsters *Panulirus argus* and *Panulirus interruptus*. We used two behavioral assays: a feeding assay in which secretions were added to food, and a squirting assay in which secretions were released as clouds. For crabs and wrasses, ink was more effective than opaline, and two pigmented molecules in ink – aplysioviolin (APV) and phycoerythrobilin (PEB) – accounted for much of ink's activity. APV and PEB were equally effective at equal doses, but APV is the major deterrent because of its much higher concentration. In contrast, for spiny lobsters, opaline is more effective than ink, and APV and PEB have little effect. Sensory ablations showed that ink secretion's effects were mediated through chemical senses. Sea hares acquire the light-harvesting protein phycoerythrin from red algae, cleave the chromophore PEB from the protein, convert PEB to APV by methylation, and preferentially store APV in ink. Sequestering chemical defenses from food is a strategy of many animals, but converting a food-derived photosynthetic pigment into a chemical defense is novel. Why sea hares convert PEB to APV is currently unknown, since they are equally effective in defense against the predators that we have examined. The results of our and other studies show that sea hares use a diversity of molecules and mechanisms, some but not all diet-dependent, in chemically defending themselves against their many potential predators. Supported by NSF and Naval Surface Warfare Center – Panama City.

***49.2*** KANE, E. A.*; MARSHALL, C. D.; Texas A and M University; *ekane@clemson.edu*

***Behavioral performance of ram and suction feeding odontocetes, and a preliminary evolutionary analysis using functional data***

During their re-invasion, some cetaceans independently and secondarily evolved prey capture modes that are often described as convergent with other more basal aquatic vertebrates. However, cetacean feeding biomechanics have been largely ignored by functional biologists, and systematic analyses of odontocete feeding mode and feeding evolution are lacking. This study investigated the feeding performance of three odontocetes with varying feeding modes (belugas, *Delphinapterus leucas*; Pacific white-sided dolphins, *Lagenorhynchus obliquidens*; and long-finned pilot whales, *Globicephala melas*). In combination with morphology, functional data were mapped onto a composite odontocete phylogeny to reconstruct the likely ancestral feeding mode, and to begin to examine feeding mode evolution. Beluga feeding was composed of discrete ram and suction components, while Pacific white-sided dolphins used ram, with some evidence for suction. Pilot whales relied on a combination of ram and suction that was less discrete than belugas. Subambient pressure was measured in all species, with belugas reaching 126 kPa. Belugas were able to purse the anterior lips to occlude lateral gape and form a small, circular anterior aperture that is convergent with feeding behaviors observed in more basal vertebrates. These data also suggest that ancestral odontocetes relied upon ram feeding to capture prey, but also some suction generation capability, perhaps for prey manipulation or transport. Suction specialization arose independently at least four times, and many-to-one mapping of performance and morphology to function may account for odontocete feeding diversity.

***54.2*** KANO, S*; SATOU, Y; DESCHET, K; MARTIN, P; HAEUSSLER, M; JOLY, JS; CNRS, Gif-sur-Yvette, France, Kyoto University, Kyoto, Japan, INRA. Jouy-en-Josas, France; *kanoic@ciona.info*

***A Dual Origin of the Pituitary Primordium in the Ascidian***

The pituitary is an essential endocrine organ in the vertebrates. While the urochordate possesses no distinct pituitary organ, it has been long proposed that the ascidian neural complex (NC) composes homologous organs to the brain and the pituitary. Recent molecular data suggests that the ciliated funnel (CF), one of the NC components, is the most probable candidate as several placodal genes including *CiPitx* are expressed at the ectodermal stomodaeum and the CF, respectively, in embryonic and the adult stages (Boorman and Shimeld, 2002; Christiaen *et al.*, 2002). To reinforce this hypothesis with insights from the developmental process, we conducted lineage analyses mainly using a photo-convertible fluorescent protein Kaede driven with promoters recapitulating endogenous expressions of *CiPitx* and *CiNut* (the neural tube marker). We validated that a part of the ectodermal stomodeaum invaginates, separates from the major part and gives rise to the distal tip of the CF. Furthermore, we revealed that the proximal domain of the CF, which is adjacent to the distal tip, is derived from the neuroectodermal "dorsal duct". Thus, the ascidian CF has a dual origin and its organogenesis resembles the vertebrate pituitary. We then investigated whether the ectodermal CF expresses genes relevant to an endocrine activity like the vertebrate pituitary. However, we could not confirm it. It is likely that a pituitary primordium is present in the ascidian, but that the endocrine activity of the pituitary is a vertebrate innovation presumably with evolutions of adenohypophyseal transcription factors which terminally differentiate hormone-secreting cells.

***67.11*** KATTI, M*; SCHLEDER, B; California State Univ, Fresno; *mkatti@csufresno.edu*

***Resilience in urban socioecological systems: residential water management as a driver of biodiversity***

Cities are unique ecosystems where human social-economic-cultural activities prominently shape the landscape, influencing the distribution and abundance of other species, and consequent patterns of biodiversity. The long-term sustainability of cities is of increasing concern as they continue to grow, straining infrastructure and pushing against natural resources constraints. A key resource is water, esp. in the more rapidly urbanizing arid regions. Understanding water management is thus critical for a deeper theoretical understanding of urban ecosystems and for effective urban policy. Landscaping and irrigation at any urban residence is a product of local geophysical/ecological conditions, homeowners' cultural preferences, socioeconomic status, neighborhood dynamics, zoning laws, and city/state/federal regulations. Since landscape structure and water availability are key determinants of habitat for other species, urban biodiversity is strongly driven by the outcome of interactions between these variables. Yet the relative importance of ecological variables vs human socioeconomic variables in driving urban biodiversity remains poorly understood. Here we analyze data from the Fresno Bird Count, a citizen science project in California's Central Valley, to show that spatial variation in bird diversity is best explained by a multivariate model including significant negative correlations with % building and grass cover, and positive correlations with interactions between irrigation intensity, median family income, and grass height. We discuss implications of our findings for urban water management policies in general, and for Fresno's planned switch to metering water use in 2013. Ecological theory, conservation, and urban policy all benefit if we recognize cities as coupled socioecological systems.

***99.3*** KAVANAGH, KD*; TABIN, CJ; University of Massachusetts Dartmouth and Harvard Medical School, Harvard Medical School; *kkavanagh@umassd.edu*

***A Developmental Model for the Evolution of Size Proportions in Fingers and Toes***

Phalanges (finger and toe bones) originate from a single condensation that grows and segments sequentially along each digit, repeatedly deploying the same activator-inhibitor gene networks as each element is formed and each joint is initiated. We show that the size of the initially-segmented distal mesenchymal condensation predicts the final size of a given phalanx; as such, the location of the joint initiation along the developing digit is the central developmental "decision" determining the relative size of adjacent phalanges. The key developmental signals involved in this joint positioning are unknown. In this analysis, we use two approaches to understand how variation is produced in this system and assess how developmental variation may influence evolution. First, we experimentally dissect the activator-inhibitor logic of sequential joint formation along the digit, and secondly, we examine the patterns of evolutionary variation within taxa to explore the predictability within the system. We have found that simple developmental rules explain a huge range of variation in phalanges' size proportions in nature.

***2.4*** KEENEY, B.K.*; MEEK, T.H.; MIDDLETON, K.M.; HOLNESS, L.; GERDEMAN, G.L.; RAICHLEN, D.A.; GARLAND, T. Jr.; University of California, Riverside, California State University San Bernardino, Eckerd College, University of Arizona; *bkeen001@ucr.edu*

***Sex-Specific Involvement of the CB1 Receptor in the High Voluntary Wheel Running of Selectively Bred Mice***

The endocannabinoid signaling system is complex, influences multiple regulatory systems, and may also play an important role in voluntary exercise. In particular, the cannabinoid receptor CB1 is known to mediate aspects of voluntary motor function, energy balance, appetite, and analgesia. Previously, we found that a CB1 receptor antagonist (rimonabant or SR141716) differentially and sex-specifically inhibits the wheel running of mice from lines selectively bred for high voluntary wheel running (HR lines)(Behavioural Pharmacology, 2008, 19:812-820). In the present study, we investigated the CB1 agonist WIN 55,212-2 (WIN). Mice were acclimated to cages with attached wheels for ~21 days. Near the end of this period, HR mice were running ~2.5-fold more revolutions/day than C mice. Then, during the time of peak nightly wheel running, each mouse received a low (0.5 mg/kg), medium (1 mg/kg), or high (3 mg/kg) dose of WIN, or a vehicle (20% DMSO, 10% Tween-80 and 70% physiological saline) injection, in randomized order over a period of 12 days. Drug response was quantified as wheel revolutions 10-70 and 70-120 minutes post-injection. We also analyzed average speed (revs/min) and time spent running (min). Nested analysis of covariance for repeated measures indicated that WIN decreased wheel running in all mice; however, the dose-by-linetype interaction was statistically significant for males but not females. These results, in combination with those obtained previously for rimonabant, suggest complex and sex-specific associations between wheel-running behavior and the endocannabinoid system. Supported by NSF IOB-0543429 to T.G.

***37.2*** KEEVER, Carson C*; HART, Mike W; Simon Fraser University; *ckeever@sfu.ca*

***Life history and population genetic structure in live bearing asterinid sea stars***

Comparative studies of population genetic structure in sister species with similar life histories can help to determine the role of life history in shaping levels of gene flow and genetic diversity within and between populations. Sea stars in the family Asterinidae have diverse larval forms and life histories, which have evolved multiple times in parallel. We compared the population genetic structure of a pair of sister species from the family Asterinidae in the genus *Parvulastra* that have similar live bearing hermaphroditic life histories. Using microsatellite markers we investigated levels of genetic connectivity between populations as well as levels of variation within populations. We found that genetic diversity was low in both species relative to other asterinids. However, levels of genetic diversity were higher for *Parvulastra parvivipara* then for its sister species, suggesting that subtle differences in the life history (eg. mating system) or differences associated with geographic locations of the species play an important role in levels of population variation in this pair.

***35.1*** KENAGY, J.; University of Washington; *kenagy@uw.edu*

***Natural History of Mammals in Native American Art***

The artwork of indigenous people depicts animals that inhabit their homelands and waters. The ethnology collection of the University of Washington's Burke Museum of Natural History and Culture contains nearly 2000 contemporary prints representing the Native American art form, and many of the animals portrayed are mammals. The artwork reflects in-depth knowledge of natural history. In addition to their artistic qualities, the images accurately depict mammal anatomy and behavior. Some show mammals obtaining or consuming their preferred foods, for example, a sea otter diving for a sea urchin. Others highlight specialized behavior such as a bull elk bugling or a deer "spronking" (with all four legs off the ground). Some prints depict Native American legends. One, for example, illustrates the origin of chipmunks. Another explains why deer fear wolves and includes a reference to the lack of upper incisors in deer. As curator of a museum's mammal research collection, my experience curating ethnological art for exhibit has been novel. My illustrated talk will provide examples of mammal diversity and insights into natural history that Native American artists have depicted in their work. The Burke Museum is currently showing a series of prints that feature marine mammals of the Pacific Northwest.

***22.6*** KENKEL, C.D.*; ALAMARU, A.; CUNNING, J.R.; KUEHL, K.; MAHMOUD, H.; PALMER, C.V.; PANTILE, R.; SHASHANK, K.; SILVERSTEIN, R.N.; TANG, P.C.; MATZ, M.V.; Univ. of Texas, Austin, Tel Aviv Univ., Israel, Univ. of Miami, Florida International Univ., Miami, Kuwait Univ., Newcastle Univ., UK/James Cook Univ., AUS, Australian Institute of Marine Science, Academia Sinica, Taiwan, Univ. of Miami, Univ. of Louisiana, Lafayette; *carly.kenkel@gmail.com*

***Integrative gene expression analysis of stress response in Porites astreoides***

Gene expression analysis is a recent addition to the field of coral biology. Differential gene expression patterns have been observed for specific processes such as cnidarian-algal symbiosis and a variety of stress responses. In the present study, we integrate analysis of experimentally induced expression patterns resulting from a known stressor with natural variation in gene expression between habitats. We also demonstrate the successful transfer of QPCR primers between species within the same genus. Ten genes, differentially expressed in response to heat/light stress in the Pacific coral, *Porites lobata*, were selected from earlier array data. Primer pairs for these genes were then used to explore expression patterns in the Carribbean species *P. astreoides* in both a laboratory heat/light stress experiment and a separate field-based reciprocal transplant experiment. In the artificial temperature manipulation, significant gene expression changes were observed between control and treated samples for three genes: actin, Hsp16 and complement component C3. Both actin and C3 were down-regulated during heat/light stress by approximately four-fold and seven-fold, respectively. Conversely, Hsp16 was up-regulated by approximately 1000-fold. We integrate these results into a framework for evaluating differential expression of stress response genes in a field-based reciprocal transplant experiment.

***53.3*** KERNEY, Ryan; Dalhousie University, Halifax, NS; *ryankerney@gmail.com*

***Embryology of the red-backed salamander (Plethodon cinereus)***

The red-backed salamander (*Plethodon cinereus*) is a locally common species from Northeastern United States and Eastern Canada. Like other members of its genus, *P. cinereus* is direct developing, and breeds terrestrially. Like other members of its family, *P. cinereus* is lungless. Together these features make the embryology of *P. cinereus* a tractable and compelling topic of research. Detailed information on its development can inform our understanding of both life-history evolution and the developmental basis of adult structure loss. This study describes several embryological features of *P. cinereus*, including an elaboration of the staging series of James Dent (1942), the skeletal changes associated with direct development, and the formation of vestigial lungs in the embryo. Several techniques, including micro-computed tomography, histology, in situ hybridizations and antibody staining, are employed. Together these approaches provide novel data into the evolution and development of plethodontid salamanders.

***18.1*** KERR, K.*; CHRISTY, J.; GUICHARD, F.; COLLIN, R.; LUQUE, J.; JOLY-LOPEZ, Z.; McGill University, Montreal and Smithsonian Tropical Research Institute (STRI), Panama, STRI, Panama, McGill University, Montreal, STRI, Panama and McGill University, Montreal, STRI, Panama and University of Montreal, McGill University, Montreal; *kecia.kerr@mail.mcgill.ca*

***The influence of temperature on courtship timing and incubation period in fiddler crabs (Uca)***

Many tropical marine organisms have marked reproductive cycles that are repeated throughout the year, spanning considerable variation in sea temperature. Several species time the release of planktonic larvae to coincide with nocturnal large amplitude tides thereby promoting larval survival through their avoidance of diurnal predators. In the face of temperature-dependent egg development period, organisms must make adjustments to maintain reproductive timing optimal for reproductive success. We studied the relationship between temperature and courtship timing, and temperature and incubation period, in the fiddler crabs *Uca terpsichores* and *U. deichmanni* in Panama across seasonal upwelling-driven temperature changes. Preliminary results indicate *U. terpsichores* courts earlier when temperature decreases, while for *U. deichmanni*, a relationship between courtship timing and temperature is not evident. Incubation period in the field differed significantly between species and seasons. In contrast, in preliminary lab experiments, incubation period differed significantly between temperature treatments, however there was no significant difference in incubation periods between the species. Ovigerous *U.deichmanni* may behaviourally regulate incubation temperature, and thus incubation period, by moving up and down within their burrows. These differing responses to variable temperature may provide the two species with differing abilities to maintain timing of larval release during variable upwelling conditions and changing climate.

***97.2*** KHANG, S; BENAYAHU, Y; LASKER, HR*; Hawaii Pacific Univ., Tel Aviv Univ, Univ. at Buffalo; *hlasker@buffalo.edu*

***Octocoral reproductive strategies: Trying to see the forest for the trees?***

Published and unpublished data were used to characterize the reproductive biology of 175 octocoral species from 73 genera and 22 families. The data set is dominated by shallow water coral reef species, and the distribution of clades across habitats was not uniform. Plexaurids, xenids, alcyonids are all over represented in tropical communities, while taxa such as pennatulids, primnoids and isiids are most common in deep and/or cold waters. Of the species with sexuality reported, 89% of the species are gonochoric and 9% are simultaneous hermaphrodites. Only eight genera (*Alcyonium, Sarchophyton, Sinularia, Heteroxenia, Xenia, Acabaria, Paramuricea,* and *Primnoa*) exhibit diversity in sexuality across species. However, those were also the most extensively sampled genera and sexuality was independent of genus. Mapping hermaphroditism on recent octocoral phylogenetic hypotheses suggests independent origins of hermaphroditism in multiple lineages. Of the species with mode of reproduction reported, 40% are internal brooders, 11% are external surface brooders, and 49% are broadcast spawners. Mode of reproduction among these species was related to taxonomic group. Brooding and external brooding are not uniformly distributed among the sampled taxa. The distribution of brooders and external brooders across the Octocorallia suggests that these modes evolved multiple times. Although the finding may be confounded by taxonomic and habitat biases sexuality and mode of reproduction are not independent and gonochoric broadcast spawning species are overrepresented in the data set. In tropical seas gonochoric broadcast spawning species dominate the octocoral fauna, which is a striking and still unexplained difference with scleractinians.

***5.6*** KILLPACK, T.*; SINGH, N.; KARASOV, W.H.; Univ. of Wisconsin, Madison, California State Univ., Northridge; *tkillpack@wisc.edu*

***Effect of chronic food restriction on gut morphology and digestive enzymes in nestling House sparrows***

In adult birds, food restriction typically results in reductions in size of assimilation organs, such as intestine and liver, and in total enzymatic capacity, though mass-specific enzyme activities may not be altered. Food restriction due to periodic food shortage can occur during chick development, although their response has been little studied. In young chickens, food restriction had no significant effect on liver and intestine masses or on intestinal mass-specific enzyme activities. We hypothesized that masses and biochemical capacities of assimilation organs are maintained constant in developing nestling birds, despite food restriction, to support demands of growth and development. We present one of the first tests in birds exhibiting the altricial mode of development. House sparrow (*Passer domesticus*) nestlings were raised in the laboratory from day 3 to day 25 post-hatch and fed either age-specific meal sizes (control group) or meal sizes 75% of age-specific amounts (restricted group). On day 25, body and organ masses were measured and intestines were stored for digestive enzyme assays. Chronically restricted nestlings had significantly lower body mass (by 14%). Intestine mass and length were significantly lower in restricted birds (by 17% and 9%, respectively), even when corrected for differences in body mass. Liver mass was also significantly lower (by 18%) in restricted birds. Based on assays of enzyme activity so far, there was little difference between groups in maltase or aminopeptidase-N activity per unit intestine mass. Results so far show that response of the digestive organs of altricial nestlings facing chronic food restriction is not different from findings in restricted adults. Supported by NSF IOS 0615678 to WHK.

***36.5*** KIM, Taewon*; MICHELI, Fiorenza; Stanford University; *ktwon@stanford.edu*

***Global dimming or warming: the effect of light radiation and temperature variability on the invasion of fouling species***

Climate change can alter the community structure as species which have adapted to the changed climate can compete better with other species. It can also influence the recruitment and invasion success of marine introduced species. Climate change involves not only global warming but also global dimming. However, it was not tested which of warming or dimming factors more significantly influence the invasion of marine species. To test this, we manipulated both temperature variability and light radiation by deploying different shading devices (black, white, transparent, and no treatment) for recruitment tiles in the high temperature region where the species invasion rate is high. We compared the species frequency and coverage between shaded and non-shaded treatments. Interestingly, under opaque white plates where light radiation is lower than under transparent plates but the temperature is higher than under black plates, had the highest frequency and coverage of invasive fouling species. The recruitment tiles under black plates got second higher invasion of exotic species. We also employed recruitment tiles in 14 different sites to determine if temperature influences the success of invasive species. The coverage of invasive species over native species increased significantly with increasing temperature. The results suggest that both low radiation and higher temperature facilitates the success of species invasion in the intertidal region.

***S7.11*** KIM, Stacy*; THURBER, Andrew; HAMMERSTROM, Kamille; Moss Landing Marine Labs, Scripps Institution of Oceanography; *skim@mlml.calstate.edu*

***Community Dynamics in a Polar Ecosystem: Benthic Recovery From Organic Enrichment in the Antarctic***

Antarctic nearshore marine ecosystems are oligotrophic; primary productivity is light limited by the ice overhead as well as the long dark period in the annual cycle. Local productivity depends not only on latitude but also on advection from areas to the north. In this food-poor system, sewage from research bases is a rich source of organic material and can also bury existing communities. An experiment to test benthic community recovery from these two disturbances was conducted in McMurdo Sound. The eastern sound generally experiences an annual pulse of production, but the west side becomes ice-free only every decade or so. Organic enrichment reduced both species richness and abundance at all sites, with abundance increasing over 2 years. Burial did not affect richness but slightly reduced abundance in the first year. Scavenger exclusion had no effect on community recovery. As in more temperate ecosystems, community recovery initiated rapidly, however, richness remained low after two years though overall abundance was recovering. Extremely oligotrophic sites were most highly impacted, possibly because of the lack of a local larval source. Nevertheless, on the scale of these experiments (patch size tens of cm2) there is a suite of r-selected infaunal species that is capable of taking advantage of intense organic input such as might come from natural vertebrate sources (e.g. Weddell seal feces). Large and continuous organic input (tens of m2 from the sewage outfall) resulted in the development of an anaerobic microbial mat that effectively excluded multicellular eukaryotic species. Recovery of outfall-impacted communities is facilitated by disturbance to the microbial mat that allows infaunal colonization.

***53.6*** KINGSOLVER, Joel*; DIAMOND, Sarah; SMITH, Matthew; ANGELL, Caitlin; University of North Carolina, Chapel Hill; *jgking@bio.unc.edu*

***Laboratory evolution of instar number in Manduca: consequences for growth, size and developmental plasticity***

The number of larval or nymphal instars varies in many insects in response to environmental conditions. In Manduca sexta, some field populations express substantial plasticity in instar number in response to rearing temperature and diet, but this developmental plasticity has been reduced in some domesticated laboratory populations. We consider the consequences of instar variation for growth trajectories, final size, developmental plasticity, and fitness. Starting with a field sample of M. sexta from North Carolina, we used assortative mating to generate two selection lines based on instar number (5 instar line vs 6+ instar line). After 4-5 generations of assortative mating, there was significant divergence between the lines for mean and range of instar numbers, growth trajectories, development time and final size. Increased instar number consistently resulted in longer development times, greater pupal and adult body masses, and greater egg production; expression of additional instars was also associated with reduced survival to pupation. We discuss the ecological conditions in which selection favoring increased instar number may occur in the field.

***89.5*** KIRCHHEFER, AJ*; GURKA, R; KOPP, G; GUGLIELMO, C; The University of Western Ontario, Ben-Gurion University; *akirchhe@uwo.ca*

***PIV-based study of the near wake of a white-throated sparrow***

Flight has many advantages; however, it suffers due to its relatively high energy cost. One may expect that natural selection will cause birds to have physical characteristics and behaviors which are well suited for flight and reduce this energy cost. Since well before the first flying machines, birds have been studied in hopes of learning first how to create flying machines and subsequently how to improve them. To date, the majority of attention has been given to the far wake, where the vorticity shed from the wing has amalgamated into more or less coherent structures. Knowledge of these coherent structures has facilitated measurement of momentum in the wake, leading to the solution of the "momentum paradox." While this represents a cornerstone in our knowledge of bird flight, our knowledge of the near wake remains limited. Investigation is required to elucidate the role of the body and the role of the different feather types. Particle image velocimetry (PIV) measurements have been performed in the near wake region of taxidermically mounted white throated sparrow models in the Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario. Measurements have been taken at various locations along the wing span to ensure a complete survey of flows characteristic to each feather type. Each white throated sparrow corresponds to a different wing flexion, phase-locked at the mid down stroke. Wake characteristics, including mean velocity profiles and turbulence profiles, are presented over the typical range of speeds and over a typical range of angles of attack. Significant findings include the onset of an asymmetry in turbulence intensity at medium to high speed. The role of this phenomenon in the formation of actual flapping flight is discussed.

***94.2*** KLYMUS, Katy *; HUMFELD, Sarah ; MARSHALL, Vince ; CANNATELLA, David ; GERHARDT, H. Carl; University of Missouri, Columbia; *kektgb@mail.mizzou.edu*

***Behavioral and molecular differentiation within a possible cryptic species complex, the canyon treefrog, Hyla arenicolor***

Cryptic species, morphologically indistinguishable taxa, are commonly identified based on molecular data and/or non-visual mating signals. We tested the hypothesis that the canyon treefrog may comprise a cryptic species complex, as previous work found three highly divergent, mitochondrial clades in the U.S. portion of the range. Expecting to see differences in male advertisement calls among populations, we compared properties of calls from populations sampled throughout the U.S. and Mexican range. We also re-assessed phylogenetic relationships among populations of *Hyla arenicolor* and its sister species *H. wrightorum* using mitochondrial and nuclear sequences. Our acoustic analyses found no biologically significant variation in advertisement calls among the three U.S. clades, whereas Mexican populations show large differences. Our phylogenetic data help explain our behavioral results. Incongruence between the two molecular data sets indicates mitochondrial capture between one U.S. population and *H. wrightorum*. Thus, U.S. populations are not as divergent from one another as once assumed, but Mexican populations are highly divergent. We conclude that canyon treefrog populations in the U.S. may not consist of three highly divergent genetic clades, but further analysis of southern Mexican populations may in fact reveal distinct lineages.

***49.4*** KLEINTEICH, T; University of Hamburg; *thomas.kleinteich@uni-hamburg.de*

***The ontogeny of feeding systems in caecilians (Lissamphibia: Gymnophiona) - sucking, scraping, and biting***

The caecilian feeding system is unique among vertebrates in that two jaw closing mechanisms are integrated: jaw closure is driven by the ancestral jaw closing muscles (mm. levatores mandibulae) plus a secondarily recruited hyobranchial muscle (m. interhyoideus posterior). The caecilian skull is kinetic due to a movable quadrate-squamosal complex. There is a variety of feeding habits (suction feeding, skin feeding, intrauterine feeding, biting) at different stages of caecilian ontogeny, that relate to different reproductive modes. Here I will compare functional parameters of the caecilian feeding system (i.e. lever arm lengths, muscle physiological cross sectional areas, muscle fiber orientations, effective mechanical advantages, estimated bite forces) over ontogeny in three species with different feeding habits. Suction feeding specimens differ notably in their feeding system morphology from specimens that apply skin or intrauterine feeding. In suction feeding caecilians, the ancestral jaw closing musculature has the largest physiological cross sectional area and is supposed to generate the highest forces within the dual jaw closing system. In skin and intrauterine feeding individuals, the additionally recruited m. interhyoideus posterior is the most powerful muscle. Muscle fiber orientation of the ancestral jaw closing muscles relative to the lower jaw is acute-angled in suction feeders and approximately perpendicular in skin and intrauterine feeding caecilians. Differences in muscle fiber orientation reflect different patterns of optimization for velocity (suction feeding) vs. force (skin and intrauterine feeding). The jaw closing system of suction feeding specimens is limited to gape angles less than 35°; skin and intrauterine feeding caecilians feed with wider gape angles.

***59.1*** KNAPP, R.*; MARSH-MATTHEWS, E.C.; VO, L.; Univ. of Oklahoma, Norman; *rknapp@ou.edu*

***Cortisol masculinizes female mosquitofish morphology and behavior***

The ability of sex steroids to influence vertebrate sexual development and differentiation is well known. In many taxa, females can be masculinized by exposure to various androgenic compounds, some of which are human-produced. The effects of environmental androgens and estrogens on sexual development, differentiation and reproduction have been the focus of substantial study in recent years. Much less attention has been paid to effects of endocrine disrupting compounds on the glucocorticoid stress axis. We report here the unexpected finding that exposure of adult female mosquitofish (*Gambusia affinis*) to the stress hormone cortisol induced morphological and behavioral masculinization. Sexually-mature females were housed individually and received one of five cortisol doses or ethanol or water as controls once every three days for approximately two months. Cortisol masculinized the sexually dimorphic anal fin in a dose-dependent manner; control females were not masculinized. Masculinization of this fin is known to be under androgenic control. We also found that some cortisol-treated females attempted copulations with stimulus females with behaviors similar to those exhibited by normal *G. affinis* males. Males also responded differentially to cortisol-treated vs. control females, and some masculinized females attempted copulations with males. We discuss two potential mechanisms by which cortisol treatment masculinizes behavior and morphology in this species. Our results also highlight that the potential of compounds to affect the glucocorticoid axis should be considered when studying mechanisms underlying the effects of endocrine disruptors, both those that have been presumed to work only via androgenic or estrogenic pathways, as well as disruptors which are already known to affect glucocorticoid pathways.

***S3.7*** KOEHL, M.*; HADFIELD, M.; Univ. of California, Berkeley, Univ. of Hawaii; *cnidaria@berkeley.edu*

***Hydrodynamics of larval settlement from a larva's point of view***

Many benthic marine animals release larvae that are dispersed by ocean currents. These larvae swim and respond behaviorally to environmental factors such as light, shear, or chemical cues. However, larvae are so small (~0.01-1mm) that their trajectories are the vector sum of their behaviors and the motion of the water in which they are riding. We focus on settlement (landing and attaching to a surface), the first step in recruitment of larvae into benthic communities, to study how ambient water flow and larval behavior interact to determine where larvae land and where they stick to the substratum. Using coral reefs and fouling communities as study systems, we measure the turbulent, wavy water flow across them in the field and recreate it in wave-flumes where we can measure on the scale experienced by larvae (mm's and ms's) the instantaneous water velocities and the concentrations of odors released by the benthos. We use these data to determine the temporal pattern of velocities, shears, and odor concentrations encountered by settling larvae. On the scale of big organisms (cm's - m's), turbulent water flow across a rough substratum is well characterized by boundary shear velocity, and dispersal of dissolved substances is modeled as a diffusing cloud. However, examination of these processes on the scale encountered by an individual microscopic larva reveals a more complex and variable world. For example, larvae have rapid on-off encounters with chemical cues while swimming through fine filaments of odor swirling in unscented water. After they land they experience rapidly fluctuating hydrodynamic forces with peaks that depend on their location within the fine-scale habitat topography. We use individual-based models of rapid larval responses to spatially and temporally varying water flow to explore how behavior can affect where larvae settle.

***81.5*** KOHL, K.D.*; BRZEK, P.; CAVIEDES-VIDAL, E.; KARASOV, W.H.; University of Wisconsin, Madison, Universidad Nacional de San Luis-CONICET, Argentina; *kkohl78@gmail.com*

***Matching between dietary preferences and digestive capacity in passerine birds***

It has been argued that evolutionary shifts in diet preferences are paired with changes in digestive physiology. For example, the adaptive modulation hypothesis states that enzyme activities should match the relative levels of substrate present in an animal's diet so as not to waste biosynthetic energy or cell membrane space with unneeded enzymes. Indeed, a previous study in birds (Martinez del Rio 1990) found interspecific variation in enzyme activities that matched species' feeding guilds (frugivore, omnivore, nectivore, etc.). To enhance the findings of this study, we measured the activities of pancreatic, intestinal, and hepatic enzymes in six avian species where diet patterns have been extensively studied (estimated % starch and % protein). After using phylogenetic independent contrasts to analyze all data, we found that proteases (aminopeptidase-N, trypsin, chymotrypsin, alanine-aminotransferase) did not correlate with dietary protein. However, carbohydrases (amylase, maltase, sucrase) all correlated positively with % starch. This is especially interesting as short term modulation of carbohydrases by their specific substrates has for the most part not been exhibited in studies on passerine birds. Therefore, it could be that these results support the idea of evolutionary matching between activity of digestive enzymes and the prevalence of their specific substrate in an animal's diet. Natural selection may favor a constitutive level of enzymes that reflect average intake of dietary substrates, especially those mainly supplying energy, such as carbohydrates. Supported by NSF IOS 0615678 to WHK.

***1.9*** KOMAN, James S.*; TOMANEK, Lars; Cal Poly SLO; *jskoman@gmail.com*

***Proteomic analysis of acute salinity stress in the two ascidian species Ciona savignyi and C. intestinalis***

The ascidian species *Ciona savignyi* and *C. intestinalis* have been fully sequenced and thus allow analysis of their proteomic response to environmental stress. We have chosen to analyze their response to hyposaline conditions, which are known to occur during heavy winter rains in the coastal regions in which *Ciona* populations live. Such conditions often lead to population declines and it has been suggested that it may contribute to determining the life history of these species along the West coast of North America. Testing for their proteomic response to salinity may provide insights into the mechanisms that are responsible for setting tolerance limits to hyposaline conditions in these two congeneric species. Characterizing the proteomic response to acute salinity and other stresses also contributes to our understanding of the minimal stress proteome, which we are characterizing for these species. We exposed each species to decreasing salinities, 100%, 85% and 70% full-strength seawater, for 6 hours. After exposure to hyposaline conditions, the specimens were brought back to 100% seawater to recover for 4 hours. Organisms were dissected to remove the tunic, and 2D SDS-PAGE was performed to separate proteins and characterize changes in protein expression. Using a 2D gel image analysis software we identified 5% and 19% of the detected proteins to be differentially expressed in *C. savignyi* and *C. intestinalis*, respectively, in response to acute salinity stress in the treatment in comparison to the control group. Analysis of these proteins with MALDI TOF-TOF mass spectrometry has identified numerous cytoskeletal and general stress response proteins, providing insights into the intense cellular and cytoskeletal restructuring that occurs in response to hyposaline exposure.

***64.5*** KOMISSAROVA, A.*; TRAVIS, J.M.J.; REDPATH, S.M.; Univ. of Aberdeen/Centre for Ecology and Hydrology, UK, Univ. of Aberdeen, UK, Univ. of Aberdeen/Macaulay Institute, UK; *a.komissarova@abdn.ac.uk*

***Dispersal costs and kin selection have a strong effect on the evolution of migratory strategy.***

A better mechanistic understanding of migration and how it interacts with other life-history strategies is important both for predicting how migratory species may react to climate change and for developing robust conservation strategies. Partial migration, where only a proportion of the population migrates to separate over-wintering areas, is prevalent across a range of taxa. Here, we explore how environmental and ecological factors (specifically, dispersal) influence the evolution of partial migration. We describe a spatially explicit individual-based approach within which individuals carry migration propensity 'genes'. By manipulating dispersal strategy we are able to establish how dispersal propensity influences the prevalence of migration within the population. Our results show a strong relationship between dispersal strategy and the evolved level of migration with high rates of dispersal within a population reducing the average proportion of migrants, this effect increasing with increasing dispersal costs. We also demonstrate that kin selection is an important factor and leads to a greater than expected proportion of migrants when population dispersal is low. This work has important implications for models of migration behaviour as it demonstrates that other life history strategies, such as dispersal, can have a large effect on the evolution and maintenance of migration.

***20.4*** KONOW, N.*; AZIZI, M.; ROBERTS, T.J.; Brown University; *nkonow@brown.edu*

***Avian all-terrain: Tendons as power attenuators during rapid energy absorption***

Muscles perform two very different tasks during jumping: they produce mechanical power for takeoff, and absorb it during landing. Tendons can be important in amplifying muscle power during takeoff, but their function in power absorption remains unclear. We studied Eastern wild turkeys landing from different heights to quantify the power-absorbing function of the lateral gastrocnemius muscle-tendon unit. We measured joint angle, muscle fascicle lengths and electrical activity, and used strain gauges on the calcified tendon to calculate muscle-tendon unit force. Landings elicited high muscle forces, approaching fourfold of those measured at intermediate running speed. Flexion of the ankle joint and muscle lengthening were consistently out of phase with joint flexion occurring in the first half of the contact period and muscle lengthening occurring in the second half. During most of ankle flexion, muscle fascicles shortened and did not absorb energy. Fascicle lengthening (30-40% fascicle strain) late in the contact period acted as a significant energy sink, absorbing over 20J/kg muscle. This length-change pattern is consistent with the idea that tendons play an important role in storing energy during the initial period of force development and subsequently releasing energy to do work on the muscle contractile elements during force decay. Estimates of instantaneous tendon power corroborate this interpretation. Peak instantaneous power input to the tendon is significantly greater than the peak instantaneous power input to muscle fibers. Energy-absorbing contractions often lead to muscle damage. Our results suggest that tendons can reduce the risk of muscle damage by acting as power attenuators during activities requiring rapid dissipation of mechanical energy. Supported by NIH grant AR055295.

***54.5*** KOOP, D.*; HOLLAND, L.Z.; Univ. of California, San Diego; *dkoop@ucsd.edu*

***Multiple roles of retinoic acid in the pharyngeal endoderm development of amphioxus***

In the cephalochordate, amphioxus, the pharyngeal endoderm gives rise to Hatschek's pit (homologous to the vertebrate adenohypophysis), endostyle (homologous to the vertebrate thyroid) and gills. However, in vertebrates, pharyngeal structures receive a major contribution from neural crest cells, whereas amphioxus lacks neural crest facilitating the study of the role of the endoderm in pharyngeal patterning. In both amphioxus and vertebrates homologous suites of genes pattern the pharyngeal endoderm. These include *Tbx1/10*, *Eyes* absent, *Six* genes and *Pax* genes. Our previous studies have demonstrated that retinoic acid (RA) signalling, mediated by Hox established the posterior limit of the pharyngeal endoderm. Here we present a second role for RA signalling in the development of the gills. To investigate the role of RA signalling during pharyngeal endoderm morphogenesis, we examined the effects of late RA treatments on the genes that pattern the gill pimordia such as *Six* and *Pax* genes. Our results show that at later stages in development RA does not inhibit gill primordia formation but does plays an important role in regulating gene expression and apoptosis in the forming gill slits. These results suggest that in amphioxus, as in vertebrates, pharyngeal development involves a complex interaction of signalling pathways, often playing multiple roles.

***75.4*** KORCHARI, P.G.*; HIGHAM, T.E.; MCBRAYER, L.D.; Clemson University, Georgia Southern University; *pkorcha@g.clemson.edu*

***Linking characteristics of stance and swing phase muscles with ecology, morphology and locomotor performance in the lizard, Sceloporus woodi***

A question that has intrigued scientists for quite some time is how muscle physiology relates to locomotor performance and ecology. For lizards, the iliofibularis, a swing phase muscle, if often the single muscle studied when addressing related questions. Although this previous work has contributed to our understanding of muscle function in lizards, locomotor performance depends strongly on the contribution from propulsive (stance phase) muscles. Thus, we examined fiber type, fiber diameter, and muscle cross sectional area of both swing (including the iliofibularis) and stance phase hindlimb muscles in the lizard, *Sceloporus woodi*. To assess the influence of ecology, we captured individuals from two types of habitats in the Ocala National Forest in Florida. Prior to examining muscle parameters, we obtained high-speed video (500fps) of each lizard running maximally on a level 1-meter raceway. We also filmed the lizards running vertically on a branch at 300fps. Each lizard was run on each apparatus a minimum of three times and the maximum value across all three trials was retained for analysis. These detailed morphological and performance data will be examined in light of variation in habitat characteristics and the extensive existing literature on lizard locomotion.

***S1.2*** KUBOKAWA, K*; TANDO, T; Ocean. Res. Inst., Univ. of Tokyo; *kubokawa@ori.u-tokyo.ac.jp*

***Evolution of reproductive endocrine system in chordates***

The cephalochordate, amphioxus, is phylogenetically placed at the most primitive position in the chordate clade. Despite many studies on the endocrine system of amphioxus, any definitive evidence has not been reported for the presence of the pituitary-gonadal axis, which is the important endocrine system for the reproduction in vertebrates. Recent genome analyses in amphioxus, *Branchiostoma floridae*, showed that amphioxus has no pituitary hormones except thyrostimulin (Holland *et al*., Genome Res 2008). It is a glycoprotein hormone which forms a heterodimer with α and β subunits, and presents in various organs in vertebrates. The analyses of a phylogenetic tree and a synteny suggested that the amphioxus thyrostimulin is the ancient type of glycoprotein hormones in chordates. Furthermore, the sex steroidogenic enzymes, members of CYP enzymes, were found in the genome sequences. The conversion pathway of sex steroids from cholesterol to estrogen and androgen, and the major sex steroids was also identified in gonads of amphioxus, *B. belcheri in vitro* and *in vivo*. We cloned the genes coding for amphioxus thyrostimulin and sex steroidogenic enzymes, and confirmed their expression in amphioxus by *in situ* hybridization technique. On the basis of these findings, we discuss the evolution of hormones and their function in the pituitary-gonadal axis in chordates.

***92.5*** KUHN, C. E.*; TREMBLAY, Y.; REAM, R. R.; GELATT, T. S.; National Marine Mammal Laboratory, NOAA, Centre de Recherche Halieutique MÃ©diterranÃ©enne et Tropicale; *Carey.Kuhn@noaa.gov*

***Coupling GPS tracking with dive behavior to examine the relationship between foraging strategy and fine-scale movements***

The foraging behavior of diving marine species is often categorized into three fundamental groups: epipelagic (mid-water feeding), mesopelagic (deep-water feeding), and benthic (feeding on the bottom). Since these foraging strategies are shaped in part by the distribution and behavior of prey, we tested the hypothesis that searching behavior and space use will differ depending on the foraging strategy employed. Northern fur seals (*Callorhinus ursinus*) were used as a model, as individual fur seals can display both epipelagic and benthic foraging strategies in distinct bouts over the course of a single foraging trip. Dive bouts were characterized into foraging strategies based on numerous dive parameters (e.g. depth and bottom time). For each strategy we compared movement patterns (e.g. transit rate and path straightness) and space use (the size and intensity of area-restricted search zones [ARSZ]). Foraging strategies were significantly different for all dive and movement parameters measured but did not differ in overall space use. For example, benthic bouts were composed of deeper dives (78.1±1.6 vs. 22.2±0.5m) with more time in the bottom phase (62.7±1.6 vs. 48.4±0.9sec). During epipelagic bouts females traveled at a slower rate (4.6±0.1 vs. 5.1± 0.2ms-1) and followed a more sinuous path (straightness index: 0.88±0.01 vs. 0.95±0.01). On average only 1.4±0.1 ARSZ were identified per trip and the characteristics of epipelagic and benthic ARSZ were not significantly different. This study suggests the pooling of these fundamentally different foraging behaviors may result in the masking of small changes that may be critical for species management.

***17.3*** KULKARNI, Saurabh*; ELINSON, Richard; SINGAMSETTY, Shrikanth; BUCHHOLZ, Daniel; University of Cincinnati, Duquesne University; *kulkarsb@email.uc.edu*

***REGULATION OF DEVELOPMENT BY CORTICOTROPIN RELEASING HORMONE IN DIRECT DEVELOPING FROG ELEUTHERODACTYLUS COQUI***

Direct developing frogs lack a free-living larval period and hatch from the egg as a juvenile. Even under such extreme rearrangement of ancestral biphasic developmental pattern, development in direct developers is still dependent on thyroid hormone (TH). As vital as TH is to metamorphosis, its hypothalamic regulation plays vital role in deciding the timing of metamorphosis. In particular, corticotropin releasing hormone (CRH) regulates TH production in tadpoles, but in adults, both thyrotropin releasing hormone (TRH) and CRH regulate TH. Because direct developing frogs lack a tadpole stage, it was not clear whether hypothalamic regulation of TH would be tadpole-like or adult-like in embryos. To test this, we compared morphological responses of *Eleutherodactylus coqui* embryos to CRH and TH treatments. We injected them with 1)60% PBS, 2)CRH, 3)TRH or 4)astressin (CRH receptor antagonist) from Townsend-Stewart (TS) stage 8 and 10 to TS 15. We measured days taken to reach TS 15 and monitored morphological changes, including adult like skin pattern, snout shape, relative hindlimb length and tail resorption. CRH but not TRH significantly accelerated rate of development, whereas astressin-treated animals showed developmental arrest. To confirm the effects of CRH, we examined expression levels of TH receptor (TRbeta) in response to CRH and PBS injections. We found that TRbeta was up-regulated due to CRH but not PBS injections. Our gene expression data confirms results from morphological data that TH production is regulated only by CRH in a tadpole-like manner. We then treated animals with three different doses of TH; 1)ethanol only, 2)2nM, 3)10nM and 4)50nM. We found that 50nM TH significantly increased the rate of development and tail resorption comparable to the results obtained from CRH injections. Thus, our results provide substantial evidence that TH is regulated by CRH in embryos of direct developers. We conclude that despite of evolution of radically different developmental model, the underlying hypothalamic regulation of TH and thus development is well conserved in direct developers.

***S6.7*** KUNZ, Thomas H.*; REICHARD, Jonathan D; PRAJAPATI, Surech I; AUSTAD, Steven N; KELLER, Charles; Boston University, University of Texas Health Center, University of Texas Health Center; *kunz@bu.edu*

***A Unique Adaptation of Bats in the Family Molossidae for Long-distance Foraging and Migration***

Heat generated as a byproduct of energetically costly flight must be dissipated to avoid hyperthermia. Brazilian free-tailed bats, *Tadarida brasiliensis*, dissipate large amounts of heat from the head and body. However, wings and the tail membrane remain significantly cooler than air temperature during flight, reducing their ability to dissipate heat. Thermal infrared (TIR) imaging of free-ranging *T. brasiliensis* revealed thermal windows on the flanks and proximal portions of the wing that are uniquely vascularized and hairless, but are absent from syntopic cave myotis, *Myotis velifer*. The anatomy of these regions was analyzed with light and TIR imaging, microscopic x-ray computed tomography (microCT), and light microscopy to characterize form and function. Two branches from the ulnar artery in Brazilian free-tailed bats are uniquely developed, creating a specialized thermal radiator. We postulate that these radiators facilitate thermoregulation and water balance through localized heat loss. Transcutaneous water loss through the hairless wing membranes is reduced while blood is shunted away from flight membranes to fuel flight muscle activity. Countercurrent exchange may also play an important role in thermoregulation at lower air temperatures such as those encountered at high altitude. Comparative analysis of 133 fluid-preserved Chiropteran species from 15 families suggests that similar anatomy is present only in the Molossidae, many of which are known to undertake extended foraging flights and migration in warmer geographic regions. We suggest that this thermal radiator is a unique adaptation for long-distance foraging and migration in the family Molossidae.

***43.6*** KUO, CY*; IRSCHICK, DJ; Univ. of Massachusetts Amherst; *chiyun@bio.umass.edu*

***Loading effects on jumping and running in green anole lizards (Anolis carolinensis)***

Animals in nature commonly encounter the problem of large loads that they must carry, such as when they are pregnant, have consumed a large meal, etc. By studying how animals cope with large loads, one can also examine how the musculoskeletal system drives locomotion, particularly in terms of how much mechanical power muscles can produce. There has been extensive research to quantify such effects on terrestrial horizontal locomotion. However, the effects of increased loads for two modes of locomotion that require large amounts of power, namely vertical running and jumping, have been less well-studied. Green anoles are a good study system for this line of inquiry because of their arboreal lifestyle, and their propensity to run uphill and jump from branch to branch. In addition, males have large heads relative to females, which can be regarded as a load that might impose a constraint on vertical running and jumping. Female anoles, on the other hand, have to carry eggs, which also represents a load. In this study, we tested three hypotheses concerning the influence of weight loading on performances and kinematics of two modes of locomotion . First, are larger anoles affected to a greater or lesser extent by proportional loads (expressed as a similar percentage of body weight) compared to small anoles? Second, does loading on more distal body parts have more of an influence on locomotor performance compared to loading on the center of the body?. Third, are male lizards affected to a greater extent by loading on the body compared to female lizards, who must normally cope with large loads in nature due to pregnancy. Our work sheds light on both the dynamics of jumping and running, and specifically, how animals cope with extra loads both behaviorally and mechanically.

***S1.10*** KURAKU, S; University of Konstanz; *shigehiro.kuraku@uni-konstanz.de*

***'Post-2R' cyclostomes: a molecular phylogenetic view of the vertebrate ancestor***

Whole genome sequencing and elaborate comparative analyses for early chordates and jawed vertebrates (gnathostomes) have revealed highly conserved gene repertoires between these distant lineages and their expansion in the vertebrate lineage through the so-called two-round (2R) genome duplications. Undoubtedly, this has contributed to a basis of comparative analyses in functional aspects of the invertebrate-vertebrate transition, e.g. in Evo-Devo. This line of progress has also been awaited for cyclostomes (hagfishes and lampreys). However, amount of available sequence resources for cyclostomes and effort to characterize them remains insufficient. Importantly, there are quite a few difficult factors unique to this challenge in their phylogenetic position, basic genomic properties, and patterns in gene family evolution. To fill the invertebrate-gnathostome gap, insights into cyclostome genomics will be discussed by introducing original data supporting the recently proposed 'post-2R cyclostomes' hypothesis and evidence of lineage-specific gene losses and duplications in some regulatory genes.

***90.6*** LA CROIX, S.*; ZELDITCH, M.L.; SHIVIK, J.A.; LUNDRIGAN, B.L.; HOLEKAMP, K.E.; Michigan State Univ., East Lansing, Univ. of Michigan, Ann Arbor, USDA Wildlife Services National Wildlife Research Center & Utah State University, Logan; *lacroixs@msu.edu*

***Skull development, functional integration and feeding performance in a top North American carnivore, Canis latrans***

The coordination of form and function is of particular interest during ontogeny, when developing animals must resolve the conflicting demands of growth and survival. Infant mammals do not directly compete with adults for food but must be competent to do so after weaning. During post-natal development, skull size and shape undergo tremendous changes across steep growth trajectories and must remain functional throughout that transition. Using an ontogenetic series of known-age coyote skulls, we address questions of form and of function concurrently. We find that, at birth, the shape of the coyote cranium is much less mature than the mandible. Both cranium and mandible exhibit significant changes in their ontogenetic allometries between pre- and postweaning life history stages as well as between postweaning and juvenile stages. Both cranium and mandible continue to grow and change shape past 20 wks of age, long after weaning at 6 wks of age. Cranial and mandibular shape are significantly correlated during the preweaning, postweaning and juvenile life history stages, a covariance that cannot be explained solely by age- or size-related allometry. Feeding performance improves beyond morphological maturation, with bite-force of adults exceeding that of subadults. Our results show that skull size and shape continue development after weaning, with feeding performance improving even after skull size and shape mature. That ongoing improvement in feeding function suggests an integration of the cranium and mandible beyond their individual size and shape allometries.

***78.3*** LAFONTANT, P.J.*; GRIVAS, J.A.; GOLDEN, B.L.; LESCH, M.A; FROUNTFELTER, T.; DePauw University; *pascallafontant@depauw.edu*

***Models of Cardiac Repair and Regeneration in Teleost Fish***

The limited ability of mammalian adult cardiac myocytes to proliferate often results in scaring and permanent loss of cardiac function after injury. By contrast, in models including newt and axolotl, the destruction or resection of ventricular tissue is mitigated by partial to complete replacement of the lost tissue and the restoration of functional contractile myocardium; regeneration occurs with little to no scarring. More recently, robust regeneration has been demonstrated in the teleost zebrafish (Danio rerio). We developed a cardiac ventricular injury model in Goldfish and Giant danio to test whether the ability to repair and regenerate is widely distributed among teleosts. Following partial cauterization of their ventricles, we observed three distinct and temporally overlapping processes occurring. The first phase is an intense inflammatory response, characterized by increased presence of myeloperoxidase-positive cells. The inflammatory cells were also observed by electron microscopy. A second phase involves tissue remodeling with differential accumulation of collagen in the two species and the presence of PCNA-positive cells. The third phase involves the resorption of necrotic tissue and of accumulated collagen, and is accompanied by apparent regeneration of the injured ventricle by 45 days. Our data suggests that the ability to regenerate heart tissue may extend beyond the teleost zebrafish, and that the Goldfish and Giant danio can be used as models of heart repair and regeneration.

***60.5*** LAILVAUX, SP*; ZAJITSCHEK, F; BROOKS, R; University of New Orleans, La Station d'Ecologie Experimentale du CNRS Â  Moulis, University of New South Wales; *slailvaux@gmail.com*

***Sex, death and aging: life history trade-offs between reproductive investment and whole-organism performance in Teleogryllus commodus crickets***

Age-related declines in survival and reproductive performance have been reported in a range of vertebrate and invertebrate animal species. Recent evidence suggests that aging rates in reproductive investment can differ between males and females as a result of sexually dimorphic reproductive strategies, resulting in sex-specific life-histories. We tested for life-history trade-offs between reproductive investment and two kinds of whole-organism performance (biting and jumping) in male and female *Teleogryllus commodus* crickets. By examining the relationships between each performance trait and sexual advertisement (in males) and fecundity (in females), as well as the effects of aging on these relationships, we are able to place whole-organism performance squarely within a life-history framework that takes into account sex-specific priorities in reproductive investment.

***S9.11*** LAMBERT, J D; Univ. of Rochester; *dlamber2@mail.rochester.edu*

***Cracking the code of the spiralian quartets: RNA segregation in Ilyanassa***

In spiralian embryos, the animal-vegetal axis is divided into tiers of cells with similar developmental potentials. These tiers are quartets of micromeres that are born from the macromeres in the same cleavage cycle, or sets of four equivalent progeny of the members of a quartet. Different tiers have very different cleavage patterns and cell fates, but how these differences arise is unknown. In the *Ilyanassa* embryo, many RNAs are specifically localized to centrosomes and segregated during these cleavage cycles, and RNAs are segregated in a tier-specific way. Recent results from our lab (presented elsewhere) demonstrate the functional significance of segregated RNAs for the cells that inherit them. We have been examining the mechanisms that specifically localize and segregate RNAs to particular tiers. For two RNAs that are specifically localized to the first quartet, we mapped similar stem loop regions that are capable of recapitulating the localization patterns of the transcript, and found that deletion of these prevents RNA localization. Addition of a stem loop to a normally unlocalized RNA is sufficient to localize it. The same elements that mediate centrosomal localization are also segregated into the first quartet. We have also found that there is a distinct window in late cytokinesis and early interphase when localization to the centrosome can occur, and if an RNA is introduced after this window it will not localize to the interphase centrosomes or be segregated to the 1st quartet micromeres. These results suggest a model where RNAs destined for segregation to a particular tier are localized to the mother cell centrosome at least in part by specific secondary structural elements, and the diversity of RNA localization patterns observed is generated by combinations of different elements in particular transcripts.

***75.5*** LAMMERS, A.R.*; ZURCHER, U.; Cleveland State Univ., Ohio; *a.Lammers13@csuohio.edu*

***Dynamic stability during quadrupedal arboreal locomotion in the Siberian chipmunk (Tamias sibiricus)***

Locomotion on narrow tree branches, twigs, and foliage presents many challenges to maintaining stability during locomotion. We hypothesize that the *movement* of an arboreal animal plays an important role in maintaining its stability. Because the substrate reaction force applies a non-zero torque, the angular momentum of the animal is not conserved (constant). Specifically, we expect that angular momentum is regulated during each gait cycle of the animal. Three Siberian chipmunks (*Tamias sibiricus*) were trained to run across a 2 cm diameter cylindrical trackway about 1.8 m long. The animals were filmed at 120 Hz from two angles, and we used a motion analysis program to digitize body segments from each viewpoint. Digitized coordinates were converted into a 3-D coordinate set. Using body mass distribution obtained from a dead specimen, we calculated both the angular and linear momentum of each segment and the whole-body values. We found partial cancellation of segmental contributions resulting in distinct patterns for the whole-body angular momentum. Our results suggest that *dynamic* stability plays an important role in quadrupedal arboreal locomotion.

***53.5*** LANDBERG, Tobias; University of Connecticut; *tobias.landberg@uconn.edu*

***Oxygen-induced plasticity and evolution of larval tail morphology in stream and pond-breeding salamanders (genus Ambystoma)***

Adaptive variation in larval ecotypes has evolved in five salamander families, but the environmental contributions to evolutionary differences are barely explored. Large gills and tail fins contribute to gas exchange in low-oxygen pond-dwelling larvae. Reduced gills and tail area in stream dwelling larvae decrease drag and should mitigate against drifting in high flow (and high oxygen) streams. I investigated the evolution of larval morphology in two salamander species with ancestral pond-dwelling larval habits (Ambystoma maculatum & A. texanum) and one derived stream species (A. barbouri). As predicted, the derived stream species has a shorter tail relative to snout vent length and smaller tail area relative to tail length than its pond-breeding sister species, A. texanum. In all three species, tail fin area decreased in high oxygen relative to low oxygen. Oxygen-induced tail area plasticity contributes to evolutionary differences between stream and pond species because wild oxygen levels differ. When raised similarly, the difference between pond and stream sister species decreased. However, fixed differences in egg size–snout/vent length and relative tail length account for the majority of sister species' differences. Since the ancestral response to oxygen was apparently in the direction of tail shape evolution in the derived stream larvae, primitively pond-breeding salamanders similar to A. texanum invading streams 1-2 million years ago would have experienced relatively high oxygen levels and an induced plastic response that reduced tail area. This underscores that environmentally-induced variation not only contributes to current adaptive phenotypes, but can serve as a primary source of initial variation for adaptation.

***S11.10*** LANGERHANS, R.B.; University of Oklahoma; *langerhans@ou.edu*

***Multifarious selective agents and diverse trait functions: Poeciliids shed light on the evolution of fish morphology***

The evolution of body and fin size and shape in fishes is undeniably complex. Body/fin form can experience both direct and indirect selection from numerous selective agents in the wild. For instance, morphology can exhibit a direct link to fitness via sexual selection when members of the opposite sex exhibit morphology-biased mating preferences. Further, fish morphology typically experiences indirect natural (and sexual) selection from various selective agents via its influence on numerous performance variables (e.g., locomotion, feeding, oxygen extraction). Put simply, a multitude of factors affects the evolution of fish morphology, as body/fin traits must function reasonably well at an array of diverse tasks. Such a scenario may drive morphological differentiation and speciation, but also can cause the evolution of fish morphology to be highly unpredictable. Here I examine a conceptual framework for studying the evolution of morphological diversity and its predictability using livebearing fishes (Family Poeciliidae) as a model system. Focusing on links between morphology and mating behaviors, and between morphology and locomotor performance, I conceptually elucidate the ways that selection can act on fish morphology, highlight connections presumably most important in the wild, pinpoint areas most in need of future work, and review and synthesize existing data to investigate the relative importance of various selective agents and forms of selection in shaping fish morphology in both predictable and unpredictable manners.

***90.10*** LAPPIN, A.K.*; WILCOX, S.C.; California State Polytechnic Univ., Pomona; *aklappin@csupomona.edu*

***Scaling of bite-force performance in horned frogs, Ceratophrys***

Of the nearly 6,000 extant frog species, most have weak jaws that play a minor role in prey capture. A notable exception is *Ceratophrys*, a genus of South American frogs that use a vice-like grip of their jaws to restrain and immobilize prey. These frogs are renowned for an aggressive temperament and the ability to consume large vertebrate prey, such as rodents and other frogs, nearly their own size. We measured bite-force performance during post-metamorphic ontogeny to test the hypothesis that bite force scales isometrically with body and head size. A model of isometric scaling predicts that bite force should scale with a coefficient of 2.0 relative to linear dimensions and a coefficient of 0.66 (i.e., 2/3) relative to volumetric measures (e.g., body mass). This is based on bite force being a resultant of the forces generated by several muscles, forces that in turn are determined by the cross-sectional areas of those muscles. In *Ceratophrys*, bite-force performance scales with strong positive allometry with respect to body length (2.5), body mass (0.8), and external linear head dimensions (3.0-3.8). These results are in general accordance with previous studies of various amniote taxa, including lizards, turtles, and crocodylians. The pattern of positive allometry of bite force on morphology in *Ceratophrys* is observed even though linear head dimensions scale with negative allometry on body length (0.6-0.8) and body mass (0.21-0.26), thus indicating that head size relative to body size decreases as the frogs grow. We discuss possible explanations for this counterintuitive ontogenetic relationship between morphology and performance.

***S1.11*** LARHAMMAR, D; Uppsala Univ., Uppsala, Sweden; *Dan.Larhammar@neuro.uu.se*

***Early vertebrate chromosome duplications and the evolution of the neuropeptide Y receptor gene regions***

The early stages of vertebrate evolution involved major genomic events, namely two tetraploidizations before the gnathostome radiation. The time points for divergence of hagfishes and lampreys relative to the two tetraploidizations are still unclear. We have investigated several gene families that expanded in early vertebrate evolution, particularly the neuropeptide Y (NPY) family of peptides and the corresponding receptors (NPYR). The NPY peptide genes are located close to the homebox (Hox) gene clusters that quadrupled as a result of the tetraploidizations. The observation that lampreys have three NPY-family genes and probably more than two Hox clusters indicates that they have undergone two tetraploidizations, either the same ones as the gnathostomes or perhaps one shared and one independent. We are presently analyzing additional Hox/NPY-linked gene families that may shed light on lamprey divergence: voltage-gated sodium channels (SCN), insulin-like growth factor binding proteins (IGFBP), and activin receptors. The NPYR family is located in a different quartet of related chromosomes and has a more complex evolutionary history due to a local triplication before the tetraploidizations. We have shown that the ancestral gnathostome had seven NPYR genes, a situation still prevailing in sharks and amphibians. Other lineages have lost one or more NPYR genes. In lampreys only two NPYRs have so far been identified. Amphioxus does possess an NPY-like peptide but its receptor has not yet been confirmed. Tunicates seem to have lost the NPY system. More detailed studies of chromosomal locations in conjunction with sequence-based phylogenies are expected to elucidate the genomic events in early chordate evolution. (Supported by the Swedish Research Council and Carl Trygger's Foundation.)

***24.1*** LATTANZIO, Matthew S.*; MILES, Donald B.; Ohio University; *ml195406@ohio.edu*
***Modeling shifts in resource use by lizards due to anthropogenic disturbance: An isotopic approach***
Historically, many ecosystems depended on fire to maintain habitat diversity and ecosystem integrity. Implementation of a fire suppression policy in the early 1900's reduced the frequency of wildfires and changed forest composition and structure throughout the US. Recently, management policies have been revised to use prescribed burns for restoring forest ecosystem integrity, despite a number of criticisms on their effectiveness. Disturbance can have many effects on animal populations, most notably an alteration of the physical environment. Such alterations can trap species if they are unable to adapt to shifting resource bases. Prescribed fires most notably result in numerical and functional reductions in available vegetation that can have marked bottom-up trophic effects. Modeling these effects on animal populations requires determining physical and biogeochemical (i.e., elemental isotopes) parameters in the system. Here, I demonstrate the applicability of applying models of resource use and diet specialization to predicting the effects of disturbance on lizard populations. Lizards are effective model organisms for these studies since reptiles have been shown to respond primarily to vegetation (and thus resource) changes rather than the disturbance itself (e.g., burning). By comparing lizard populations among regions varying in disturbance frequency, one may determine how these habitat changes can affect their resource use and trophic linkages. Predictions may be made based on comparisons of isotopic measures of dietary specialization and isotopic niche width among regions. With this information, one can determine the direct (changes within each trophic level) and indirect (changes among trophic levels) impacts of prescribed burning (and other) management practices. This is vital information for land managers and conservationists that plan to continue using prescribed burning.

***17.2*** LAUFER, H.*; CHEN, M.; BACLASKI, B.; STEWART, J.; BOBBITT, J.; JACOBS, M.; ZUO, Y.; JOHNSON, M.; ZHU, Z.; Uconn, Woods Hole Oceanographic, UMass, UConn; *laufer@uconn.edu*
***Effects of Alkylphenols on Lobster Molting and Metamorphosis***
Alkylphenols, including bisphenol A, are extensively used in plastics, detergents, antioxidants and other industrial consumer products. They are released into the aquatic environment as a result of production, use and disposal. They are of concern to scientists and the public because of their toxicity and estrogenic endocrine disrupting activities in vertebrates and invertebrates. We have found a wide distribution as well as effects on lobster molting and larval development. Between 15-50% of lobsters in Long Island Sound were contaminated with at least l compound. Some have as many as 6 (up to1-2 µg/gm). The compounds are 2-t-butyl-4-(dimethylbenzyl)phenol (Comp. 1), 2,6-bis(t-butyl)-4-(dimethylbenzyl) phenol (Comp. 2), 2,4-bis-(dimethylbenzyl) phenol (Comp. 3), and 2,4-bis (t-butyl)-4-(dimethylbenzyl)-6-t-butylphenol (Comp.4), 4-cumylphenol and bisphenol A (BPA). Effects on molting in vitro using $C^{14}$ tyrosine and $C^{14}$ Comp. 3, revealed incorporation to be dependent on the enzyme phenoloxidase; unlabeled Comp. 3 competed more actively than tyrosine. Alkylphenols compete with tyrosine derivatives at molting which normally crosslink proteins, and function in shell hardening, making lobster shells weaker and more susceptible to invasion by microorganisms. Effects on larvae of less than 5 or 10ng/per day of Comp. 3 or BPA administered in food resulted in increased larval mortality (770 larvae, 71% controls vs. 22-29% experimentals). Treated survivors were intermediate juveniles at metamorphosis in significant numbers. In conclusion, alkylphenols are toxic endocrine disruptors interfering in metamorphosis. Alkylphenols have two mechanisms of action, interfering in shell hardening and larval metamorphosis, adversely affecting lobster health.

***94.5*** LAVROV, D.V.*; BURLAKOVA, O.O.; ITSKOVICH, V.B.; WEINBERG, E.V.; BELIKOV, S.I.; Iowa State Unviersity, Limnological Institute, Irkutsk, Russia; *dlavrov@iastate.edu*
***Baikalian sponges as a model for the study of endemic speciation***
Speciation – the emergence of discrete entities (species) in the course of continuous biological evolution – is a fundamental process underlying most of the Earth’s perceivable biodiversity. This process can be particularly striking in lakes and on islands, where large endemic biotas often evolve in relatively short periods of time. Although much progress has been made on understanding speciation from genetic, paleontological, microevolutionary, and ecological perspectives, the number of systems where it has been studied remains surprisingly small, and studies that approach a single system from multiple perspectives are rare. Here we introduce Lake Baikal sponges as a convenient system to study the process of speciation using phylogenetic, microevolutionary and paleontological approaches. Situated in Southeast Siberia, Lake Baikal is the oldest, deepest, and most voluminous lake in the world that contains 20% of the world's total unfrozen fresh water. Baikal’s age, size, and isolation has produced one of the world's richest and most unusual freshwater faunas (2500 described species; more than half of them endemic), and has earned the lake the name of the 'Galapagos of Russia'. Baikal sponges (family Lubomirskiidae) dominate the benthic community of the lake, play an essential role in its ecology, and represent the most spectacular example of endemic radiation in freshwater sponges in the world. We show that both molecular markers and fossil record can be informative for understanding the process of speciation in this group.

***S5.3*** LAWRENCE, J.M.; Univ. of South Florida; *lawr@cas.usf.edu*
***Costs of arm loss and regeneration in stellate echinoderms***
The cost of regeneration is greater in asteroids than in crinoids and ophiuroids because of greater development of the body wall and presence of gonads and pyloric caeca. In addition, arm loss occurs at locations along the entire length of arm in extant crinoids and ophiuroids but usually only at the disc in asteroids. The cost of regeneration of organic matter in an arm can be estimated from analysis of intact arms. This does not include the cost of anabolism of organic compounds or energy required for deposition of calcium carbonate. A major consequence of arm loss that affects regeneration is loss of feeding structures and decrease in food consumption. Cost of regeneration has the potential to affect growth of small individuals and reproduction of adults because nutrients in food consumed can be diverted to regeneration. Whether this occurs depends on the quantity and quality of food consumed. The effect of nutrition on regeneration is difficult to demonstrate in the field because of the variability in quantity and quality of food available and the amount consumed. These can be controlled in laboratory studies to evaluate the role of nutrition on cost of regeneration. In addition, growth factors can be added to formulated feeds to evaluate their effect on regeneration. Asteroids appear to be a good model to study the role of nutrition on the cost of regeneration because it is possible to control the quantity and quality of food consumed. Considering life-history strategies, ruderal and competitive species have a greater capacity for production and regeneration than stress-tolerant species.

***98.7*** LEE, A.H.*; PADIAN, K.; TAYLOR, M.T.; WEDEL, M.J.; IRMIS, R.B.; WERNING, S.; Ohio University, Univ. of California, Berkeley, University College London, Western University of Health Science, University of Utah; *alee712@gmail.com*

***The Universal Temperature Dependence Model fails to predict body temperatures of mammals and dinosaurs***

A recently published equation seemingly solved the question of dinosaur body temperature by demonstrating a pattern of increasing body temperature with size for several dinosaur species. These data suggested that extinct non-avian dinosaurs were poikilothermic and that only the largest ones could use their mass to attain homeothermy. However, that conclusion is unwarranted because the data points were incorrectly assumed to be statistically independent and a validation study of the temperature equation using extant animals was not performed. Here, we show that when phylogeny is taken into account, no significant trend exists between temperature and mass in dinosaurs. More important, we demonstrate that the temperature equation is highly inaccurate in extant mammals. In 110 of the 178 species that we analyzed, predicted and observed temperatures deviated by at least 20%. Inaccurate predictions for mammals also revealed a significant negative correlation between body temperature with size contrary to observations showing a positive trend between temperature and size. These failures stem from an assumed universal "3/4-law" in metabolic scaling, which must be rejected.

***58.4*** LEE, Sabrina/SM*; TOM, Novak; PIAZZA, Stephen/J; The Pennsylvania State University; *sabrina_lee_4@sfu.ca*

***Plantarflexor moment arm correlates with walking speed in mobility-limited older adults***

Classical research in comparative functional morphology suggests that the skeletal structure and muscle architecture of many animals are well adapted to their locomotor behaviors. The influence of variation of musculoskeletal structure on locomotor function is not as well established for human movements, especially in older adults. Decreases in plantarflexor strength and power have been found to correspond to reduced gait speed in older adults, but all the determinants of reduced strength and power are not well characterized. In the present study, we used ultrasound imaging to quantify musculoskeletal architectural parameters of the lateral gastrocnemius (fascicle length, pennation angle, muscle belly thickness, and plantarflexion moment arm) in healthy elderly men for whom gait speed was also measured. Moment arm was found to be a strong predictor of preferred gait velocity during a 6-minute walk in the slowest elderly subjects after subjects were separated post-hoc into n=10 slow (1.06 to 1.38 m/s) and fast (1.44 to 1.64 m/s) groups. For the slow group, there was a significant relationship between preferred gait velocity and moment arm ($R2 = 0.669$, $p = 0.004$) but for the fast group, there were no significant relationships between preferred gait velocity and any musculoskeletal architectural parameters. Nor were any significant relationships found between maximal gait speed over a 4 m course and any musculoskeletal parameter, even when subjects were separated by speed. These results suggest that moment arm is determinative of gait speed among mobility-limited older adults, perhaps because of the constraints of age-related sarcopenia upon muscle adaptation.

***103.5*** LEE, D.V.; University of Nevada Las Vegas; *dvlee@mac.com*

***Effects of CoM Position on Forelimb and Hindlimb Mechanics during Incline and Decline Trotting***

Quadrupedal running on inclines and declines presents the mechanical challenge of balancing pitch moments about the center of mass (CoM) while maintaining a steady velocity in the direction of travel. The mechanical strategies by which dogs accommodate these demands were explored by loading manipulations of 10% body mass positioned over the CoM, forelimbs, or hindlimbs. Whole body and individual limb ground reaction forces, as well as spatial and temporal step parameters, were measured during downhill and uphill trotting on a 15 degree grade. Ratios of forelimb impulse to total (forelimb + hindlimb) impulse were computed for normal and shear forces. Normal impulse ratios were more different from level values during uphill than downhill trotting - indicating that the limbs act more as levers on the incline. The forelimb supplied a greater fraction of braking impulse during downhill trotting and the hindlimb supplied a greater fraction of propulsive impulse during uphill trotting than would be predicted from normal impulse distributions. This reflects the braking-propulsive affinities of fore- and hindlimbs during level trotting. In both uphill and downhill trotting, adding mass near the ‘uphill’ limb resulted in fore-hind normal impulse distributions more similar to those of level trotting and more equal fore-hind shear impulse distributions. This result suggests a functional trade-off in quadruped design: a CoM closer to the hindlimbs distributes downhill braking more equally, while a CoM closer to the forelimbs distributes uphill propulsion more equally. Because muscles exert less force when actively shortening than lengthening, it would be advantageous for the muscles of both limbs to share the propulsive burden during uphill trotting - a prediction consistent with the anterior CoM positions of most terrestrial quadrupeds.

***80.4*** LENTINK, D*; KRUYT, J.W.; QUICAZAN, E.M.Q.R. ; GUSSEKLOO, S.W.S.; ALTSHULER, D.L.; VAN LEEUWEN, J.L.; Experimental Zoology Group, Wageningen University, 6709PG Wageningen, The Netherlands., Department of Biology, University of California, Riverside, CA 92521, USA, Department of Biology, University of California, Riverside, CA 92521, USA; *david.lentink@wur.nl*

***Comparative aerodynamic performance of hummingbird wings from Colombia***

Hovering is a key behavior of hummingbirds that allows them to time-effectively extract nectar from flowers and catch arthropod prey, which is critical to their high-energy lifestyle. The aerodynamic and inertial power demands are high during hovering but how these demands compare among different species is, however, not fully understood. Here we compare the aerodynamic quasi-steady performance of wings from 12 species of hummingbirds from Colombia to determine how wing morphology mediates hovering performance. We attained lift and drag over a range of angle of attack for Reynolds numbers below 10,000. Whereas other spinner experiments recorded negative drag at low angles of attack, our spinner measured drag accurately across the full range of wing angles. The accurate drag and lift measurements combined allow us to compare not only aerodynamic lift, but also glide ratio and more relevant, the power factor. The power factor captures the efficacy of hummingbird wings to lift a unit weight with a minimum of aerodynamic power. We contrast these aerodynamic results with estimates of inertial power and show that there is a tradeoff between aerodynamic and inertial power that is critical to our understanding of hummingbird flight.

***63.6*** LETTIERI, Liliana*; STREELMAN, J. Todd; Georgia Institute of Technology; *liliana@gatech.edu*

***Evolution of bribery in a diffuse cleaning mutualism***

Most examples of tolerance traits come from plant-herbivore and host-parasite systems. The mutualism between Caribbean cleaner gobies and their many client fish species appears to provide the first vertebrate animal example of using a set of traits that reduced the costs of interactions with risky individuals. Novel blue stripes in some species "bribe" predators to become clients that receive parasite-cleaning services in turn providing a reliable alternative food source for the gobies. Our results highlight evolutionary changes from predator resistance traits (camouflaged colors within aposematic patterns) to tolerance traits (conspicuous advertising stripes and chemically mediated attack reduction). These shifts were most likely driven by the sensory and learning biases of a large suite of piscivorous reef fish species. In field trials, stereotypical client posing behaviour and antagonistic attack occurrences varied inversely among control, yellow, and blue striped models, with blues receiving more posing and fewer attacks. In addition, wild caught cleaners deterred predation in feeding trials, surviving more often and for longer when enclosed with small predatory fishes. Notably, cleaner status was a significant predictor of survival, and blue cleaners were spit out more often than other goby species. Blue cleaners are also more likely to service piscivorous clients than yellow and green basal species. We propose *Elacatinus* gobies have evolved in a repeated adaptive fashion to promote interactions with risky clients, while pre-existing adaptations deter attacks and reduce costs. The key innovation of "bribery" has mediated this shift from conflict to cooperation via tolerance. Similar trajectories of evolution from resistance to tolerance may occur in other diffuse mutualisms.

***48.1*** LEVINTON, Jeffrey *; MACKIE, Joshua; KOZAK, Kenneth; RODGERS, Brooke; Stony Brook Univ., Moss Landing Marine Lab., Bell Museum of Natural History; *levinton@life.bio.sunysb.edu*

***Dynamics of speciation, larval dispersal, and biogeographic overlap in a pantropical group of crustacea, the fiddler crabs***

Geographic overlap of closely related species is of crucial interest because its character and degree have important ecological and evolutionary consequences. Using morphological, molecular and GIS-based geographic range data we investigated the phylogeny and biogeography of fiddler crabs (genus *Uca*). We used a GIS system ARCMAP to quantify the geographic distributions of fiddler crabs in the western Pacific and Indian Ocean, eastern Pacific, and western Atlantic into 50x50 km units and compared these ranges with the phylogenetic relationships of fiddler crabs as determined from subgenus membership, and a tree based on morphological characters. We consider three main biogeographic regions: western Atlantic, eastern Pacific, and Indo-Pacific. Geographic range overlap of coexisting species differed substantially among regions, with the most overlap in the eastern Pacific and the Gulf of Mexico. Overlap in the Indo-Pacific cannot be readily distinguished from a random distribution. Among regions there are consistent and differing monotonic patterns between geographic range and overlap with other species. We found no differences among subgenera, suggesting that phylogenetic position has no influence on biogeographic overlap patterns. Even though there are strong geographic associations the most closely related sister species arising recently, we found no relationship of geographic clade overlap and evolutionary history (node depth); this suggests that, with passing time, dispersal erases the evolutionary footprints. The strong overlap in the eastern Pacific and Gulf of Mexico probably results from basin confinement, which allows planktonic larval dispersal to result in extensive overlap. Basin confinement may be unimportant in the Indo-Pacific.

***S2.6*** LEWIS, K.; MELE, J.; KIM, S.-A.; BUFFENSTEIN, R.*; Barshop Inst. for Longevity and Aging Studies, Dept. Physiology, Dept. Celllular and Structural Biology, Univ. Texas Health Science Center, San Antonio

***Xenobiotic metabolism, lifespan and aging***

Mammals that are long-lived for their body size provide powerful tools with which to elucidate molecular mechanisms that may abrogate aging and facilitate prolonged longevity. It is well documented that cells from long-lived species are more resistant to cellular stressors than those of short-lived species. This may be due to enhanced cellular protection and better maintenance of somatic integrity, although the mechanisms facilitating this enhanced resilience are poorly understood. Nuclear factor erythroid 2-related factor 2 [Nrf2] is a versatile regulator of cellular adaptation to stress that transactivates antioxidant response element [ARE]-driven genes under both basal and stress conditions. Nrf2 thus regulates the expression of antioxidants, detoxicants, molecular chaperones, p53, as well as both proteasome and lysosome activity. As such, Nrf2 mediates a complex and coordinated defense against damage accrual and potentially lethal injury, and may be a key factor in longevity. We hypothesized that long-lived species constitutively have higher levels of Nrf2 and and up-regulated Nrf2 transcription activity with augmented detoxicant activity, and that this is due to enhanced Nrf2 stability, and nuclear localization. We tested this in a comparative study in rodents with disparate longevity, including at the extremes laboratory mice (maximum longevity 3.5 years) and naked mole-rats (maximum longevity 30 years). Nrf2 was present in all tissues (liver, kidney, brain, small intestine, large intestine) examined to date. Under non-stressed homeostatic conditions Nrf2 levels vary among the various tissues with the small intestine, and the liver exhibiting the highest levels. Western blot analyses, using antibodies raised against mouse Nrf2, and liver tissues reveal that protein homogenates from NMR livers contain ~-5-fold higher levels of Nrf2 protein than those of mice with an intermediate living rodent (the white footed deer mouse (maximum longevity 8 years) showing an intermediate value. DNA binding activity of Nrf2 to the ARE-oligonucleotide is >20-fold greater in liver nuclear extracts of naked mole-rats than in those from mice and not surprisingly constitutive levels of NAD(P)H:quinone oxidoreductase 1 [NQO1] and glutathione S-Transferase [GST] activity are also significantly higher in the longest-lived rodent species. Furthermore, Nrf2 induction in response to both cellular stressors to fibroblasts and xenobiotics is increased in the longer-lived species. These findings suggest that compared to shorter-lived species naked mole-rats, not only have higher constitutive levels of Nrf2 and ARE-proteins, but also that these proteins are both constitutively more active and more responsive to induction. This greater chemoprotective efficacy may play a critical role in species longevity.

***76.2*** LEYRER, J*; ROBIN, F; DEKINGA, A; BRUGGE, M; SCHRIMPF, A; BOCHER, P; PIERSMA, T; University of Groningen, University of La Rochelle, Royal Netherlands Institution for Sea Rearch, Den Burg, Royal Netherlands Institution for Sea Rearch, Den Burg; *jutta.leyrer@nioz.nl*

***When skipping a high quality stopover site makes sense***

Many bird species migrate in a series of long-distance flights alternating with stopover periods where energy stores are accumulated. Stopover site use and optimal departure fuel loads have been the focus of many theoretical and empirical studies, suggesting that time-minimizing migrants should skip stopover sites with low or unpredictable food supplies. Departure fuel loads should enable birds to reach their destination. Carrying more fuel than necessary might be dangerous (higher predation risk) and is both time and energetically costly (storage or/and transport). Yet, overloading is a widespread phenomenon and is regarded as 'safety net' when conditions en route or upon arrival are unpredictable. The Afro-Siberian Red Knots *Calidris c. canutus* migrate from West Africa to central Siberia in two long-distance flights via the key staging site, the Schleswig-Holstein Wadden Sea, Germany. An annually varying number also stops at the central French Atlantic coast. We studied food resources for several years and show that the French stopover sites provide more predictable and better conditions to fuel than the main springboard for the last leg to the breeding grounds, the Wadden Sea. Despite the good food, in most years most Red Knots skip France. Body mass upon departure from Africa and arrival in the Wadden Sea indicate that some wind assistance is needed to reach the destination. But stochastic wind conditions prevent the birds from selecting a departure date coinciding with helping winds. We wonder why Knots do not overload in Africa in order to become more independent from wind assistance as well as to avoid an extra stopover in France.

***32.9*** LEYSEN, H.*; ROOS, G.; VAN WASSENBERGH, S.; ADRIAENS, D.; Ghent University, Belgium, University of Antwerp, Belgium; *heleen.leysen@ugent.be*

***Syngnathid feeding apparatus morphology: long vs short snouts***

The family Syngnathidae (Gasterosteiformes) encompasses pipefishes and seahorses, which are characterized by an elongated snout with small terminal jaws. They are extremely fast suction feeders, with a feeding strike consisting of a rapid neurocranial elevation accompanied by an equally rapid retraction of the hyoid. Within the family, there is a large diversity in snout morphology, with variation in both snout length and diameter. A long and narrow snout is thought to increase the flow rate of the incoming water and allows prey to be captured from a greater distance. However, it also limits prey size, increases the moment of inertia during snout rotation and probably results in higher friction because of viscous forces becoming more important. So, is there an advantage of having a long snout? Are long snouted syngnathids really faster compared to short snouted ones? Kinematical analyses show that the snout of long snouted pipefishes travels a longer distance and so more elusive prey can be caught, but velocity and acceleration was lower in the long snouted syngnathids compared to the shorter snouted ones. The aim of this study is to investigate whether these observed kinematical differences can be explained by morphological variation in lever systems involved in suction feeding. A detailed morphological description of the cranium of a long and short snouted seahorse and of a long and short snouted pipefish is given, based on cleared and stained specimens, dissections, histological serial sections, CT scans and graphical 3D reconstructions. Special attention is paid to the anatomy of the ligament/tendon attachments and articulations between the moveable units (lower jaw, hyoid, suspensorium, neurocranium).

***11.1*** LI, C.; UMBANHOWAR, P.B.; GOLDMAN, D.I.*; Georgia Tech, Northwestern University; *chen.li@gatech.edu*

***The effects of limb kinematics on the motion of a legged robot on sand***

Effective locomotion of organisms and physical models of organisms (robots) can require subtle changes of limb kinematics to achieve high performance on different substrates. To develop predictive models for legged devices and to provide hypotheses for biological locomotors, we systematically study the performance (forward speed) of a small legged robot, SandBot, on granular media as a function of stance and swing gait parameters. At fixed limb frequency and volume fraction, speed is sensitive to variations in the gait parameters that control angular onset, angular duration, and temporal duty factor of the stance phase of the limb cycle. High performance occurs only in a small region of gait parameter space. A modified version of an existing kinematic model [Li et. al, PNAS, 2009] predicts the speed, and reveals that performance is maximized when gait parameters minimize limb acceleration and interference to increase interaction with the solid phase of the media. For example, gait parameters that generate fast bouncing motion on hard ground generate much slower motion on sand. Instead, high performance on sand is achieved when the start of the stance phase is advanced to better utilize the asymmetric resistance force produced by rotational penetration of limbs into sand. A similar phase shift is observed in the zebra-tailed lizard, *Callisaurus draconoides*, when the substrate is changed from hard ground to sand, suggesting that the physics of granular media may constrain animals to employ similar strategies for achieving effective locomotion.

***57.6*** LIAO, James C.; The Whitney Laboratory for Marine Biosciences, U. Florida; *jliao@whitney.ufl.edu*

***Organization and function of lateral line afferent neurons in larval zebrafish***

Afferent neurons of the zebrafish posterior lateral line relay hydrodynamic signals sensed along the body to the hindbrain. We labeled individual neurons to reveal their connections to single and multiple neuromasts along the body. Electroporation of Alexa 647 in HUC-Kaede fish, a transgenic line expressing a photo-convertible protein under control of a pan-neuronal promotor, indicates that single and multiple-neuromast afferent neurons correspond to later and early-born cells, respectively. We normalized ganglion area across individuals and plotted position of afferent neurons to show that early-born cells are located centrally in the ganglion, with newly developing cells added to the periphery. Whole-cell recordings of afferent neurons show an inverse relationship between soma area and input resistance, where input resistance is a proxy for excitability. Taken together, a picture is emerging that large, early-born cells are less excitable and may therefore fire only to strong hydrodynamic stimuli across the whole body, while small, later-born cells that are more excitable sense local flows. We hypothesize that large, coarse coding afferents innervating multiple hair cells are critical for initiating powerful escape responses while small, fine coding afferents are responsible for modulating routine motor behaviors such as swimming. Aspiration of ganglia led to the inability of animals to avoid a constant flow source in the absence of light compared to control animals, indicating that the posterior lateral line is required for rheotaxis.

***30.4*** LIEBL, Andrea L.*; SCHMIDT, Evelyn J.; MARTIN, Lynn B.; University of South Florida; *aliebl@mail.usf.edu*

***Physiological Correlations of Neophobic behavior: Is Regulation of the Hypothalamic-Pituitary-Adrenal Axis Correlated to Responses to Novelty?***

One of the best predictors of success for an introduced species is response to novelty. Animals can be attracted to (neophilia), fearful of (neophobia), or indifferent to novelty, but those that minimize neophobia or enhance neophilia are most likely to exploit unfamiliar resources in new areas. Novelty has previously been associated with glucocorticoids (GCs), hormones released in response to stressors. In laboratory rodents, elevated GCs typically reduce interest in novelty. In the present study, we investigated relationships between GC regulation and response to novelty in house sparrows (*Passer domesticus*), a notoriously successful invader. We then experimentally manipulated GCs to assess their direct influence on response to novelty. We found that GC elevation in response to restraint was strongly positively correlated to dexamethasone-induced negative feedback, indicating that individuals releasing the most GCs also reduced it most rapidly. In terms of effects on novelty, individuals that released more GCs in response to restraint were also slowest to interact with a novel object when tested later in captivity and individuals with the most rapid negative feedback approached and consumed novel food most quickly. Direct manipulation of GCs indicated that these relationships were likely indirect, as treatment with metyrapone (to block GC surges in response to stressors) and corticosterone did not affect response to novel food or objects. In sum, GC regulation and response may be a physiological indicator of neophobia, and future study of regulation and neophobia in free-living birds will rectify captivity confounds and address possible correlations with invasion.

***41.1*** LIGHTON, JRB; Sable Systems International; *lighton@sablesys.com*
***Background baselining: A new approach to metabolic measurement***
Because traditional respirometry measures metabolic rates as a function of the difference between incurrent and excurrent gas concentrations (usually air entering and leaving a sealed chamber or a mask), the accuracy with which small changes in gas concentrations are measured can limit the overall accuracy of the technique. Usually flow-through respirometry requires frequent measurement of incurrent gas concentrations in order to accurately characterize the effect of the organism under study on (incurrent - excurrent) gas concentrations. The repeated measurement of incurrent gas concentrations is usually referred to as "baselining." Baselining, though necessary, interrupts measurements and disrupts the continuity of metabolic recordings. As a result, researchers have had to trade off between temporal continuity and accuracy. Differential gas analyzers, although an improvement on single-channel analyzers, do not eliminate the baselining requirement. I have developed a technique (patent pending; free license to academic researchers) that allows baselining to occur in the background. Signal processing of the resultant raw data reassembles a complete, unbroken metabolic recording. I present some details of the technique, and data from three case studies: A 24-hour metabolic recording of a mouse with running wheel, gas concentrations in a scientific meeting room, and data from a 28,000 liter room calorimeter for humans showing a 24-hour response-corrected metabolic record ($VO_2$, $VCO_2$, EE and RQ) including episodes of activity and sleep, and demonstrating excellent temporal resolution.

***19.4*** LILLYWHITE, H.B.*; LIU, Y-L; TU, M-C; University of Florida, Gainesville, National Taiwan Normal University; *hblill@ufl.edu*
***Do Sea Snakes Anticipate Tropical Storms?***
*Laticauda* spp. sea snakes inhabit coastal zones characterized by high energy due to tidal surge and wave action. The impact on sea snakes of the dynamic energy regimes associated with coastal environments can be especially intense during tropical storms, yet almost nothing is known concerning how sea snakes cope with rough seas. We are investigating the ecology of sea snakes at Lanyu Island, Taiwan, where we have sampled several coastal sites repetitively during 5 previous years. Three species of *Laticauda* are relatively abundant: *L. colubrina, laticaudata,* and *semifasciata.* The mean number of all sea snakes counted during prescribed 1h sampling periods at one focal site was 35 during 2005–2008. Recently, we were present on Lanyu during typhoon Morakot, which impacted the island directly from August 7–9, 2009. Winds gusted to near 150 km/h, and extremely rough seas pounded the shoreline and washed heavy rocks inland beyond the beach. We sampled the presence of sea snakes during the evenings of August 5 and 6 before the impact of the typhoon, and we continued observations following passage of the typhoon, Aug 12–17. We counted 7 snakes at one site on Aug 5, and we saw but a single snake during counts at 3 sites on Aug 6. Snakes returned quickly following passage of the typhoon (mean n=21 during Aug 12–17), and the numbers were similar to those we observed well before the storm (n=21, 24 on July 10, 20). A single dead snake was found at one of the sites. Observations suggest the possibility that sea snakes anticipate the approach of a tropical storm and probably find refuge in cavernous spaces beneath coastal rocks where they can surface to breathe air while being protected from wave action. It remains to be determined whether storm–related mortality significantly impacts the population.

***89.1*** LIN, H.*; PAETSCH, C.R.; SLATE, D.J.; DORFMANN, A.L.; TRIMMER, B.A.; Tufts University; *huai-ti.lin@tufts.edu*
***Ontogenetic scaling of overall body properties in Manduca caterpillars and its implications on the use of a hydrostatic skeleton***
Unlike most other soft-bodied animals, caterpillars such as *Manduca sexta* have an internal respiratory system consisting of air-filled tubes called trachea. Because air can be compressed or even expelled during locomotion they do not have a constant volume, incompressible coelom as found in annelids. This invalidates one of the fundamental assumptions used to model closed-vessel hydrostatic skeletons. Instead, we have found that caterpillars use the substrate as their external skeleton during normal locomotion with a relatively small amount of stiffening from turgor pressure. A more conventional hydrostatic skeleton (and its associated metabolic inefficiency) may be reserved for casting or other ballistic behaviors requiring a higher pressure. In this study, we modeled the caterpillar body as a thin-wall inflatable cylinder with fiber reinforcement. Under normal condition, the longitudinal load is taken by the muscles while the circumferential stress is held by the cuticle. Using known mechanical properties of *Manduca* muscles and cuticle, a simplified finite element model was constructed where flexural stiffness was computed numerically. By changing the cylinder dimensions and incorporating air cavities, we could calculate the work associated with establishing given pressures and stiffness. To provide input for the model, we directly measured the body density and body pressure of *Manduca* across different developmental stages and sizes. By comparing the model predictions to caterpillar behaviors we can determine some of the biomechanical and developmental constraints in a low pressure, climbing, soft bodied, terrestrial animal.

***94.4*** LINDGREN, AR*; PANKEY, MS; OAKLEY, TH; University of California, Santa Barbara; *lindgren@lifesci.ucsb.edu*
***The Cephalopod Cornea: Testing for Convergent Evolution using a Supermatrix Phylogeny***
One leading edge question in evolutionary biology is how similar structures can evolve multiple times. Cephalopods possess camera-type eyes similar to humans that are comprised of an iris, lens, retina, and in some lineages a cornea, which is derived from the eyelid, and appears to have evolved independently at least twice, once in octopods and once in squids. Furthermore, several squid lineages possess a cornea, but it is unclear whether this structure is homologous across squids due to conflicting hypotheses on evolutionary relationships. To clarify relationships among cephalopods and test for phylogenetic homology of corneas, we comprised and analyzed a dataset of all available molecular data for approximately 450 taxonomic units. Preliminary results suggest independent origins of a one-part and two-part cornea in the squid and octopod lineages, respectively. Within the octopod lineage, the two-part cornea appears twice, once in the Octopoda and once the cirrate octopod genus *Cirrothauma*, and differences in corneal morphology between shallow, benthic octopods and deep, benthic octopods require further examination. Within the squid lineage, the presence of a cornea is the ancestral state, with a single loss in the clade consisting of the orders Spirulida, Bathyteuthoidea, and Oegopsida, which possess an eyelid only. To examine the molecular basis for corneal evolution, gene expression data is currently being obtained using 454 pyrosequencing for key taxa in all cephalopod lineages. Results from this study elucidate the molecular changes associated with transitions from eyelids to one and two-part corneas by testing hypotheses of gene parology, duplication, ancestry and character homology.

***S5.1*** LINDSAY, S.M.; University of Maine, Orono; *slindsay@maine.edu*

***Ecology of injury and regeneration in marine benthic invertebrates: from individuals to ecosystems***

Many marine invertebrates are able to regenerate lost tissue following injury, but regeneration can come at a cost to individuals in terms of reproduction, behavior and physiological condition, and can have effects that reach beyond the individual to impact populations, communities and ecosystems. For example, removal and subsequent regeneration of clam siphons, polychaete segments, and brittlestar arms can represent significant energetic input to higher trophic levels. In marine soft-sediment habitats, injury changes infaunal bioturbation rates and thus secondarily influences sediment-mediated competition, adult-larval interactions and recruitment success. The importance of injury and regeneration as factors affecting the ecology of marine invertebrate communities depends on the frequency of injury, as well as individual capacity for and speed of regeneration. A key question to answer is "How frequently are marine benthic invertebrates injured?". I will review sources and frequency of injury in a variety of marine invertebrates from different benthic habitats, discuss challenges and approaches for accurately determining injury rates in the field, consider evidence for species-specific and geographic variation in injury rates, and present examples of indirect effects of injury on marine invertebrates to illustrate the ways that injury can modify larger scale ecological patterns and processes.

***83.1*** LIPINSKI, Doug*; MOHSENI, Kamran; Univ. of Colorado, Boulder; *mohseni@colorado.edu*

***Propulsive and feeding mechanisms of the hydromedusae Aequorea victoria and Sarsia tubulosa***

We examine the flow structures created by the swimming jellyfish *Aequorea victoria* and *Sarsia tubulosa*. These jellyfish use two different types of propulsion, rowing and jetting respectively, which produce very different flow structures and swimming characteristics. *Aequorea victoria* extends it tentacles and feeds while swimming and the flow structures produced during rowing propulsion tend to enhance feeding and produce vortices which linger in the tentacle region. Conversely, *Sarsia tubulosa* retracts its tentacles and swims to escape predators and reposition itself in the water column. The structures produced during jetting propulsion are not conducive to efficient feeding. We also examine new structures which are observed within the bell of the jellyfish *Sarsia tubulosa*.

***26.3*** LOCKWOOD, Brent L.*; SANDERS, Jon G.; SOMERO, George N.; Hopkins Marine Station of Stanford University; *blockwoo@stanford.edu*

***Transcriptomic responses to heat-stress reveal the molecular basis for the success of invasive mussels***

Invasive species are increasingly important factors in marine ecosystems worldwide. Although many studies have examined the ecological effects of invasives, little is known about physiological mechanisms that might contribute to invasive success, for example, by allowing an invasive species to out-compete and replace a similar, native species. The mussel *Mytilus galloprovincialis*, a native of the Mediterranean Sea, is a successful invader on the central and southern coasts of California, where it has largely displaced the native congener, *Mytilus trossulus*. Previously, it has been shown that thermal responses of several physiological traits may underlie the capacity of *M. galloprovincialis* to out-compete *M. trossulus* in warm habitats. To elucidate possible differences in stress-induced gene expression between these congeners, we developed an oligonucleotide microarray and used it to study gene expression patterns under conditions of acute thermal stress. The two species exhibited key differences in their transcriptomes during heat-ramp exposures, particularly among genes encoding proteins involved in cellular damage and damage repair. *M. trossulus* showed higher induction of genes involved in apoptotic (cell death) and proteolytic pathways. Conversely, *M. galloprovincialis* showed higher induction of genes involved in protein folding, energy metabolism, anti-oxidant activity, and cell cycle control. These different responses to acute heat stress may help to explain—and predict—the invasive success of *M. galloprovincialis* in a warming world.

***64.6*** LOHMANN, K. J.*; PUTMAN, N. F.; LOHMANN, C. M. F.; Univ. North Carolina at Chapel Hill; *KLohmann@email.unc.edu*

***Geomagnetic Imprinting: The Key to Long-Distance Natal Homing in Sea Turtles and Salmon?***

Several marine animals, including salmon and sea turtles, disperse across vast expanses of ocean before returning as adults to their natal areas to reproduce. How animals accomplish such feats of natal homing has remained enigmatic. Salmon are known to use chemical cues to identify their home rivers at the end of spawning migrations, but such cues do not extend far enough into the ocean to guide migratory movements that begin in open-sea locations hundreds or thousands of kilometers away. Similarly, how sea turtles reach their nesting areas from distant sites is unknown. Both salmon and sea turtles detect the magnetic field of the Earth, and sea turtles are known to derive positional information from two magnetic elements (inclination angle and intensity) that vary predictably across the globe and endow different geographic areas with unique magnetic signatures. We propose that salmon and sea turtles imprint on the magnetic field of their natal areas and later use this information to direct natal homing. This hypothesis provides the first plausible explanation for how marine animals are able to navigate to natal areas from distant oceanic locations; it also appears to be compatible with present and recent rates of field change (secular variation). One implication, however, is that unusually rapid changes in the Earth's field, as occasionally occur during geomagnetic polarity reversals, may affect ecological processes by disrupting natal homing, resulting in widespread colonization events and changes in population structure.

***S11.8*** LONG, J.H.*; ROOT, R.G.; PORTER, M.E.; LIEW, C.W.; Vassar College, Lafayette College; *jolong@vassar.edu*
***Go Reconfigure: How Fish Shift Shape Dynamically and Evolutionarily to Modulate Swim-mediated Behaviors***
Propulsion and maneuverability are driven by dynamic reconfigurations of body shape that are controlled, in part, by the mechanics of the musculoskeletal system and the evolutionary history of the lineage. To measure dynamic reconfigurations of the whole body during an undulatory swimming sequence, we have developed a method to compute shape reconfiguration errors and propulsive unsteadiness. An extreme example of transient body shape reconfiguration is turning. Using sharks, we examine turning reconfiguration and maneuvering performance as correlates of the shape of the static body, the biomechanical properties of the vertebral column, and shape of the vertebral column. To examine the evolutionary relationship between mechanical properties, body shape, propulsion, and behavior, we present a physics-based computer simulation of fish-like robots. These fish-like robots are self-propelled and autonomous, sensing light gradients and altering heading in response. We evolve these robots using a fitness function that rewards navigation and foraging success, both of which positively correlate with the spring stiffness of the tail. The spring stiffness is a mechanical property that varies inversely with the fineness ratio (lateral width: axial length) of the body. In sum, reconfigurations of body shape in physiological and evolutionary time could be mediated by mechanical properties and selection. This work was supported by NSF DBI-0442269 and IOS-0922605.

***82.5*** LONGPRE, KRISTY M.*; KATZ, L. S.; Rutgers University, New Brunswick; *kristylongpre@gmail.com*
***Males can not lie: Females use honest cues to assess fitness.***
In a promiscuous species like *Capra hircus*, in which maternal investment is greater than paternal investment, a female may mate selectively with a more fit male, resulting in improved reproductive fitness. Previous research from our laboratory indicates that estrous females prefer males with higher serum testosterone (T) concentrations over males with lower concentrations, suggesting that females are using a T-dependent cue to assess potential mates. Further, our data provide evidence that both courtship display and chemical signals play an important role in the female's preference for a particular male. When estrous females were provided a choice between rags saturated with odors from bucks (gonad-intact males) versus stags (castrated males), they spent more time near the buck-scented rags. Estrous females also preferred bucks who courted them at a high frequency (120 courts/10m) compared to those who courted them at a low frequency (40 courts/10min). In two preliminary studies examining chemical signaling and serum T concentrations, we found that males display an increase in self-scent marking (self-enurination) early in the breeding season when T concentrations are high. This behavior decreased as the breeding season progressed and T concentrations normally decreased. In the second preliminary study we found that high-courting bucks have higher serum T concentrations compared to low-courting bucks, and bucks that courted at a medium frequency had serum T concentrations that fell between the high- and low-courting males. Taken together, these results suggest that both courting frequency and chemical cues provided by bucks may be honest indicators of T concentrations and thus buck quality. Additional studies are underway to further examine the relationship between courtship frequency, chemical cues and serum T concentrations.

***37.7*** LOPEZ-MEJIA, M.*; MEJIA-ORTIZ, L. M.; Evolutionary Biology & Population Genetics Lab. Universidad de Quintana Roo, Biospeleology & Carcinology Lab., Universidad de Quintana Roo; *marlopez@uqroo.mx*
***Morphological phylogeny of crayfish from Yucatán Peninsula, México***
In order to establish the phylogenetical relationships of crayfishes species from Yucatán Peninsula, México, a morphological analysis was made. Crayfish in this peninsula are represented by subgenus *Austrocambarus*, and particularly *Procambarus (A.) llamasi*. The subtlety morphological variation inside the subgenus made this species to be supposed as the only one spread along the peninsula for many long time, with the exception of one record of *P. (A.) pilosimanus*. That changed with the recent description of *P. (A.) maya*. The new population finding, result of an exhaustive morphological analysis and field work, suggest the existant of other species still undescribed. This study involves populations of the three species of Yucatán Peninsula, *Procambarus llamasi, Procambarus maya*, and *Procambarus pilosimanus*, as well as *Procambarus acanthophorus* (external group) and ten more populations still unidentified. The measurment, comparison and register of a number of somathic characters, even those of ornamentation from all populations, enable the obtaining of a character list and their stages and the best parsimonian phylogenetic tree. We found that *Procambarus llamasi* is a very representated species in Yucatán Peninsula, however the analysis support our hypothesis of new species populations.

***58.2*** LOUDON, C.; University of California, Irvine; *cloudon@uci.edu*
***Walking with grappling hooks: bed bug locomotion***
Most insects have specialized organs on their feet that allow them to reversibly adhere to smooth surfaces, such as shown by flies walking on vertical glass window panes. Cave-dwelling insects are an exception, usually showing a loss of these specialized "sticky" organs. Bed bugs are thought to have evolved from cave-dwelling bat bugs, and similarly lack such tarsal organs. However, bed bug feet do have tarsal claws that presumably facilitate locomotion on rough or fibrous surfaces. In order to evaluate the ability of bed bugs to generate traction on different surfaces, bed bugs were videotaped at 125 frames/s as they ran across wood, glass, fibrous tape, painted surfaces, polypropylene, and high density polyethylene. On wood and fibrous tape, bed bugs showed an alternating tripod gait, with hardly any slipping of their feet on the surfaces. On the plastic surfaces, even in a horizontal orientation, bed bug feet slipped with almost every step, and there was little evidence for a tripod gait. Bed bugs walking on painted or glass surfaces showed an intermediate level of slipping, and a less synchronized tripod gait. Stride frequencies and duty factors also changed with surface type. With bed bug numbers skyrocketing in North America, and few effective chemical control methods, understanding the biomechanics of bed bug locomotion is important to inform the development of physically-based control methods.

***S10.6*** LUCKENBACH, Mark W.; Virginia Institute of Marine Science, College of William and Mary; *luck@vims.edu*
***Fisheries collapses, restoration challenges, spread of non-natives and the emergence large-scale aquaculture: anthropogenic-driven changes to ecosystem-engineering oyster species***
Oysters in the genus *Crassostrea* are quintessential ecosystem engineers, often providing the predominant hard substrate habitat in temperate, soft-sediment, estuarine environments. The role of these reef habitats in providing attachment surfaces for epifauna and nesting, foraging and refuge sites for motile species is well established, as are their roles in benthic-pelagic coupling and control of some water column processes. Dramatic declines in native oyster reefs have occurred globally, primarily resulting from overfishing, habitat destruction, coastal pollution and disease. Numerous efforts are ongoing to restore these biogenic habitats, but these efforts face significant challenges, including resolving conflicts between capture fishery and ecological restoration goals. In general, these efforts have failed to address the multiple stressors that threaten existing oyster reefs and declines continue. Meanwhile, oysters introduced outside their native range for the purpose of fisheries enhancement or aquaculture have become invasive in many areas, threatening native oyster populations and local biodiversity. The emergence of large-scale oyster aquaculture as an alternative to a wild capture fishery has resulted in what are essentially agro-ecosystems in which the growth form and, presumably, ecosystem functions of oysters are altered in many coastal systems. In reviewing and summarizing these trends, I argue that determining the broader ecological consequences of anthropogenic changes to oyster populations requires understanding which ecosystem engineering functions are, and which are not, provided by these human-altered populations.

***29.6*** LUTTRELL, S.; BENGTSSON, B.C.; SWALLA, B.J.*; University of Washington; *bjswalla@u.washington.edu*
***Central Nervous System Development and Regeneration in Hemichordates***
Hemichordates share several characteristics with chordates, a Hox-specified A-P axis, pharyngeal gill slits, a dorsal central nervous system (CNS) and an embryonic postanal tail in some species. Ptychoderids are the more complex of the motile hemichordates and their planktonic larvae share many similarities with echinoderm larvae. We describe here developmental, morphological and molecular characteristics that distinguish ptychoderid hemichordates, such as *Ptychodera flava* from harrimanid hemichordates, such as *Saccoglossus kowalevskii*. We show dramatic differences in the development of the larvae and CNS. An additional interesting property of the ptychoderid hemichordates is their amazing capacity to regenerate. We have been comparing the development of the central nervous system in ptychoderid hemichordates during metamorphosis and regeneration. Surprisingly, development of the CNS appears to be similar and is dependent on the dorsal vessel, suggesting that there may be some signaling properties in the dorsal vessel. We suggest that ptychoderid hemichordate worms are more likely to represent the hemichordate ancestor than saccoglossid worms. These results have important implications for the evolution of chordates and central nervous system evolution.

***87.11*** LUZANIA, R.R.*; UPTON, K.R.; EARLEY, R.L.; RILEY, L.G.; California State University, Fresno, University of Alabama; *rluz123@csufresno.edu*
***The effects of fasting and re-feeding on the neuroendocrine control of appetite in tilapia, Oreochromis mossambicus***
Appetite is coordinated primarily in the hypothalamus which integrates orexigenic and anorexigenic signals from the brain and peripheral signals (i.e. metabolic and hormonal). Ghrelin – a novel gut peptide – stimulates appetite in both mammals and fish: its orexigenic actions are mediated by stimulating neuropeptide Y (NPY)-containing neurons in the hypothalamus. Lack of adequate food resources is a constant environmental challenge faced by fish. In spite of this knowledge, our understanding of the hormonal control of appetite during fasting and re-feeding in fish is limited. The current study investigated the effect of fasting and re-feeding on the neuroendocrine control of appetite in the tilapia (*Oreochromis mossambicus*). Tilapia were subjected to three treatments: fasting for 30 days; fasting for 21 days and re-fed for 9 days; and fed for 30 days (control). Fasting resulted in a significant reduction in growth. Re-feeding reversed the negative effects of fasting on growth. Brain ghrelin mRNA levels were significantly reduced by fasting. Re-feeding for 9 days elevated brain ghrelin mRNA levels, but these levels were not significantly different from either control or fasted fish. Fasting for 30 days did not alter brain mRNA levels of NPY or the ghrelin receptor (GHS-R1a). These data suggest that tilapia are well adapted to a 30 day fast, since NPY mRNA levels (possibly NPY activity) were unaltered by a 30 day fast. Further, our data suggest that brain derived ghrelin may be functioning as a metabolic signal and not as an orexigen. This work was supported by the NSF (IOS-0639771) awarded to LGR.

***61.3*** LYONS, S.M.*; MORRIS, M.R.; Ohio University; *sl411302@ohio.edu*
***Headstands: a sexually selected signal in the swordtail fish Xiphophorus nezahualcoyotl***
Behaviors associated with aggression in male–male competition may also be used in courtship. Headstands are performed by male *Xiphophorus nezahualcoyotl* during male–male interactions and by both males and females during courtship. This behavior consists of a descending vertical tilt of the head until the body is at a 45° to 90° angle with the substrate. We examined the function of headstands in male–male contests by investigating differences in their use by winners and losers, and correlations between headstands and other behaviors. We also investigated their function in mate choice by determining if females preferred videos of males performing headstands over videos of the same males not performing headstands. There was no correlation between performing the first headstand and biting first, or the total number of headstands and bites used. However, winners performed more headstands than losers in the second half of contests. We suggest that the headstand is an aggressive display providing information about Resource Holding Potential (RHP) in male contests. In addition, females had a significant preference for males performing headstands as compared to males that did not. I discuss the dual role of this behavior in sexual selection in relation to the information it may contain.

***58.3*** MACAYEAL, Leigh C.; RISKIN, Daniel K.; SWARTZ, Sharon M.; BREUER, Kenneth S.*; Brown University (Currently: Cornell University), Brown University; *kbreuer@brown.edu*
***Vertical climbing performance and reserve power in loaded and unloaded Lesser Dog-faced Fruit Bats (Cynopterus brachyotis)***
All flying animals must sometimes fly while carrying loads. Load-carrying is especially relevant for bats, which experience nightly and seasonal fluctuations in body mass of 40% or more. In this study, we examined how the climbing flight performance of fruit bats (*Cynopterus brachyotis*) was affected by added loads. The body weights of animals were experimentally increased by as much as 21% by means of intra-peritoneal injections of saline solution, then flights were recorded as animals flew upwards in a small enclosure. Conventional analytical treatments of hovering flight were extended to include slowly climbing vertical and near-vertical flight. Using these analytic methods, we have estimated the power expended under unloaded and loaded conditions, and the relative power used for both weight support and climbing. We found that even our most heavily-loaded bats were capable of upward flight, but that as the magnitude of the load increased and the power requirement for weight support increased, flight performance (climbing velocity and angle, in particular) diminished. The total power expenditure increased with added load, and this was achieved primarily by increases in wingbeat frequency and stroke plane angle. Some intriguing aspects of the new theory regarding the scaling of hovering flight will also be discussed in the presentation.

***16.2*** MAGIE, Craig R.*; DALY, Marymegan; MARTINDALE, Mark Q.; California State University, Fresno, Ohio State University, University of Hawai'i; *cmagie@csufresno.edu*
***Cell Adhesion and the Cell Biology of Gastrulation in the cnidarian, Nematostella vectensis***
Gastrulation is a central event in metazoan development and the first morphogenetic process in the embryo, resulting in the formation of a multilayered embryo from a monolayered blastula. Adhesive mechanisms, both cell-cell and cell-extracellular matrix, are intimately involved in this process. Modulation of adhesive complexes could therefore be seen as a central component in the molecular control of morphogenesis, the translation of information encoded within the genome into organismal form. Understanding how morphogenesisis controlled in early-branching metazoans will help clarify the evolution of morphogenetic mechanisms. To this end we have examined the cell biology underlying gastrulation in the cnidarian, *Nematostella vectensis*, a valuable context in which to study morphogenesis in an early-branching taxon. Gastrulation in *Nematostella* occurs through invagination. The cells adjacent to the blastopore adopt extreme bottle-like morphologies as they constrict their apical surfaces, but retain projections that extend to the archenteron as they zip up against the basal surface of the ectodermal cells. In silico screening of the *Nematostella* genome has revealed a number of cell junction components that may be involved in this process, as well as other genes potentially involved in cellular behaviors required for gastrulation. Discovery of the molecular nature of morphogenesis in early-branching groups such as cnidarians, coupled with comparisons across the metazoa, promises to reveal the ways evolution has generated the myriad forms seen in the animal kingdom.

***S4.4*** MACH, K.J.*; STAAF, A.V.; TEPLER, S.K.; BOHNHOFF, J.C.; DENNY, M.W.; Hopkins Marine Station of Stanford University; *mach@stanford.edu*
***Killing them softly: failure by fatigue in the wave-swept macroalga Mazzaella***
Repeated force application typifies the lives of many plants and seaweeds. Winds repeatedly blow through the branches of trees; waves regularly crash over nearshore seaweeds, with algal thalli commonly breaking or tattering as a result. To date, however, much biomechanical investigation of plant and macroalgal tissues has focused on single applications of force, bending branches until they crack and pulling algal blades until they rupture. In the case of wave-swept seaweeds, such pull-to-break tests have found individual waves often not forceful enough to account for observed rates of algal breakage. I have investigated an alternative explanation for breakage of algal blades: failure may occur by fatigue, with damage accumulating over the course of smaller, repeated loadings. In laboratory tests on the red macroalga *Mazzaella*, I have quantified the process of fatigue, from initial formation of small cracks through eventual specimen fracture. Susceptibility to fatigue failure varied with species and life history stage. Most of the loading cycles to failure for any given specimen were associated with crack initiation, with cracks forming after 80-90% of the cycles required for failure had passed. Furthermore, a tradeoff between reproduction and crack formation, as well as a cost of endophyte infection, was discovered; cracks frequently formed in association with reproductive structures and endophytes. Extrapolation of fatigue behavior measured in the laboratory suggests an important role for fatigue failure in breakage observed in the field. Large, female gametophyte fronds are predicted most liable to fail by fatigue in the field, whereas at the other extreme, small, male gametophytes are unlikely to fracture from fatigue. An ongoing field study is assessing these predictions.

***S5.4*** MAGINNIS, Tara L; The University of Texas at Austin; *taramaginnis@austin.rr.com*
***Regeneration: a framework for future research***
Many organisms have the ability to shed an appendage (autotomy) to escape a predator or fouled molting event. Despite its immediate advantage on survivorship, autotomy can have important consequences for locomotion, foraging, survivorship, and/or reproduction. Thus, regeneration is a way that animals alleviate some of the costs associated with losing an appendage. Like autotomy, however, appendage regeneration can have important consequences for a variety of aspects of fitness; in a wide range of amphibians, reptiles, fish, and arthropods, the allocation of resources to regenerate a lost appendage negatively affects somatic or reproductive growth. Previous research into the costs associated with autotomy and regeneration has provided a strong framework to explore how tradeoffs associated with regeneration may have influenced its evolution, and has all been done from a specific set of comparisons: individuals autotomising and regenerating an appendage compared to individuals that have never lost an appendage. I suggest a shift in the way we approach our studies in order to specifically address why regenerative capacities themselves evolve or persist. Future work in this direction promises new insights into how the tradeoffs associated with autotomy and regeneration may be shaping its evolution, as well as how regeneration may be influencing animal form and function.

***14.3*** MAIA, A.*; WILGA, C.D.; Univ. of Rhode Island; *amaia@mail.uri.edu*

***Dorsal Fin Function in Spiny Dogfish and Bamboo Sharks during Steady Swimming***

White-spotted bamboo sharks, *Chiloscyllium plagiosum*, inhabit complex reef habitats and are highly maneuverable. Spiny dogfish, *Squalus acanthias*, occupy a variety of coastal and continental platform habitats and use the water column for feeding, schooling and migration. Dorsal fin shape, area and location on the body differ between the two species. In order to determine whether these characteristics have an affect on fin function, steady swimming was replicated in a flow tank at 0.5 and 0.75BL.s$^{-1}$ in four individuals of each species. Dorsal and lateral views were recorded using high speed video and four tail beats per individual were analyzed for kinematics. The goals were to determine if the dorsal fins are moving independently of the body during steady swimming and if first and second dorsal fins have different kinematic patterns. Spiny dogfish first dorsal fin moves independently of the body with a higher amplitude at lower speeds, indicating a stabilizing function to counter increased instability. The first dorsal fin has a three dimensional conformation at maximum displacement. The second dorsal fin appears to be moving passively with the caudal portion of the body, although it can not be ruled out that the dorsal fin may augment thrust. Bamboo shark dorsal fins move in synchrony with the trunk, showing relatively higher amplitude of movement compared to dogfish at both speeds. First and second dorsal fins show a similar kinematic pattern with comparable displacements when corrected for axial displacement and appear independent of speed. The function of the dorsal fins during steady swimming differs in spiny dogfish and bamboo sharks. The first dorsal fin in spiny dogfish likely contributes to stability while the second dorsal fin, as well as both dorsal fins in bamboo sharks, appears to contribute to added thrust. Electromyography and fluid dynamics will verify these results.

***88.4*** MAIE, Takashi*; SCHOENFUSS, Heiko L; BLOB, Richard W; Clemson Univ., St. Cloud State Univ.; *tmaie@clemson.edu*

***ALLOMETRY OF ADHESIVE CAPACITY IN WATERFALL-CLIMBING GOBIID FISHES***

Many species of goby fishes from oceanic islands are able to adhere to surfaces using a ventral disc formed from fused pelvic fins. This disc is used by juveniles of many amphidromous species as they scale waterfalls during migrations to upstream adult habitats upon completion of oceanic development. However, adults may still use these discs to resist flows from flash floods, or to scale waterfalls if they are displaced. The discs adhere by generating sub-ambient pressures that produce suction; their adhesive performance is expected to affect climbing ability and, thereby, potentially impact longitudinal instream distributions of species. The size of pelvic discs in climbing gobies has been shown to scale isometrically. Because attachment force in suction is proportional to the area of the disc, the forces gobies have to resist from body mass might be expected to outpace the adhesive capacity of the disc as fish grow because mass should grow faster than disc area. Thus, adult individuals might have decreased climbing capacity relative to juveniles. However, we have used pressure transducers to measure adhesive pressure and force across wide size ranges of goby species from Hawai'i, Dominica, and Japan, and found that even adult fish can produce adhesion sufficient to support twice their body mass. Moreover, the suction pressures generated are higher than expected if adhesion were strictly a passive function of disc area. These findings could explain why laboratory selection experiments on climbing performance do not produce clear patterns of selection for larger disc sizes, because (1) all discs may be over designed for the demands they typically face, and (2) adhesion of goby suction discs may be regulated by variation in pelvic muscle contraction, complicating expectations for disc size. NSF IOS-0817794, 0817911.

***38.4*** MALISCH, J.L.*; CRINO, O.L; BREUNER, C.W.; University of Montana; *jessica.malisch@mso.umt.edu*

***Corticosterone, corticosteroid-binding globulin, and free corticosterone, 24-72 hours following an acute stressor in a wild population of white-crowned sparrows***

The acute stress response is typically assumed to be a short-term (minutes to hours) rise in circulating glucocorticoid levels. However, acute stress in laboratory populations of mice and Japanese quail has been shown to alter hormone profiles 24 hours after the termination of the stressor. These changes include increased baseline corticosterone (CORT: the primary glucocorticoid in birds and mice), increased free CORT and decreased corticosteroid-binding globulin (CBG) levels. These more long-term changes in hormone levels indicate that the repercussions of an acute stress response may last for days as opposed to minutes or hours. Here we investigate this phenomenon in a population of free-living white-crown sparrows (WCSP) from Tioga Pass, CA. WCSP were captured in seed-baited Potter traps between 8:00-13:00 hours in May and June of 2009. Baseline blood samples were obtained within three minutes of the observer approaching the trap; each bird was held in a cloth bag for 15 minutes and released. Birds were recaptured 24, 48 or 72 hours later and a second blood sample was obtained at this time. We predicted that baseline total CORT and baseline free CORT would be elevated and CBG levels would be reduced for at least 24 hours following acute stress, as has been found for laboratory animals. In mice CORT and CBG return to pre-stress levels within 72 hours. Therefore, we predicted total CORT, free CORT, and CBG at 72 hours to not differ from the initial blood sample. Interestingly, we saw no change in total CORT 24, 48, and 72 hours following the initial blood sample. Analysis of CBG and calculation of free CORT are still under investigation.

***31.2*** MALISKA, M.E.*; SWALLA, B.J.; Friday Harbor Laboratories and University of Washington; *mem24@u.washington.edu*

***Settlement cues and their effect on gene flow in sibling species of rocky intertidal gastropods, Littorina plena and Littorina scutulata***

Periwinkle snails *Littorina plena* and *Littorina scutulata* (Caenogastropoda: Littorinidae) are an excellent sibling species pair to examine if larval dispersal and larval settlement affect gene flow in marine organisms with planktonic dispersal. No ecological differentiation has been shown in these planktotrophic species and studies have shown *L. plena* to have less gene flow than *L. scutulata*. We have taken a combined approach to examine what differences there may be in the dispersal of egg capsules that hatch out swimming larvae and what cues may promote settlement and metamorphosis in these swimming larvae. We cultured larvae in concentrations of 50-200/L in still flasks. We fed the larvae daily concentrations of *Isochrysis galbana* and *Nanochloropsis* sp. at $10^5$ cells/ml. Pilot experiments found *Littorina plena* and *Littorina scutulata* to develop into pediveligers as early as 21 days post-fertilization. We also found both species to settle more often when exposed to rocks found in the high intertidal or a high intertidal alga, *Fucus* sp., versus a control. Both species were also found only to metamorphose in the presence of rocks or *Fucus* sp. Larval durations ranged between 35-58 days in *L. plena* (n=9) and 35-42 days in *L. scutulata* (n=3).

***2.3*** MANSHAD, Ahmad/S.*; SALAZAR, Evan/E.; GÜTH, Robert; UNGUEZ, Graciela/A.; New Mexico State University; *amanshad@gmail.com*

***Electrical activity-dependent regulation of muscle gene expression in the electric organ after chronic stimulation in live Sternopygus macrurus***

Skeletal muscle responds to changes in electrical activity by modifying its phenotypic properties. An extreme case of activity-dependent muscle plasticity occurs in electric fish whereby some differentiated skeletal muscle fibers convert into the non-contractile, current-producing cells (electrocytes) of the electric organ (EO). In the gymnotiform *S. macrurus*, mature EO down-regulates some, but not all muscle-specific genes, and neural activity is required to maintain this phenotype of electrocytes as removal of neural input results in the re-expression of sarcomeric proteins (Unguez & Zakon, 1998). The activity-dependent molecular mechanisms regulating the expression of select muscle-specific genes in the EO are not known. To test the *hypothesis* that the pattern of neural activity regulates muscle genes in EO, we will investigate the correlation between different activation patterns and expression levels of genes in molecular pathways that control the muscle program. To date, we have developed a system to chronically stimulate EO in live fish at frequencies of 10-300 Hz. After removal of endogenous neural input by spinal transection, electrodes were implanted subcutaneously in EO (N=3 fish) and stimulation sustained for at least 3 days. Preliminary data suggest no tissue damage beyond electrode placement (N=1). These results are novel in that we have created the first device for chronic stimulation of myogenic tissues in live fish. We will begin characterizing changes in molecular pathways known to regulate muscle phenotype (Kim et al., 2004; 2008) after chronic stimulation for up to 2 weeks with EO and muscle-like stimulation patterns.

***32.10*** MARA, Kyle R.*; MOTTA, Philip J.; University of South Florida; *kmara@mail.usf.edu*

***Feeding Morphology and Bite Force Generation in Hammerhead Sharks (Sphyrnidae)***

Hammerhead sharks offer a unique opportunity to study form and function through phylogeny. Because sphyrnid sharks posses cranial morphologies with extreme variation, they can be used to address questions about the evolution of cranial design and investigate the effects of changes in head morphology on feeding structures and bite force. Five individuals each of *Eusphyra blochii*, *Sphyrna mokarran*, *S. lewini*, *S. tudes*, *S. tiburo*, *Carcharhinus acronotus*, and *Rhizoprionodon terraenovae* were chosen to represent a continuum of head shape through phylogeny. The mass of the four principle jaw adductors as well as the mechanical advantage of the jaws was used to estimate the theoretical maximum bite force. Additionally, the volume of the upper and lower jaws and hyoid arch were determined through reconstructed CT scans. Preliminary data suggest that *R. terraenovae* and *C. acronotus* have the largest anterior and posterior mechanical advantages (0.3, 0.33 and 1.18) with *S. tiburo* having the lowest (0.22 and 0.84). The largest bite force values occurred in *S. mokarran* (4.6 KN). However, size removed analysis revealed that bite forces were similar among species. No consistent trends were observed in the masses of the jaw closing musculature and the relative volume of the upper and lower jaws do not differ among sphyrnid sharks. The volumes of the remaining feeding elements are variable with no major trends. While there are significant changes in external head morphology in sphyrnid sharks, there are no correlated changes in the feeding apparatus. This and previous work demonstrates that changes in cranial morphology are primarily confined to cartilaginous and sensory structures towards the periphery of the head with the centralized core of feeding structures remaining unchanged.

***37.5*** MARKO, P.B.*; HOFFMAN, J.M.; EMME, S.A.; MCGOVERN, T.M; KEEVER, C.; COX, L.N.; Clemson University, Limestone College, Simon Fraser University; *pmarko@clemson.edu*

***The "Expansion-Contraction" Model of Pleistocene Biogeography: Rocky Shores Suffer a Sea Change?***

Among the many factors affecting the abundance and distribution of species, climate change has received the most attention. Historical data from eastern North America and western Europe provide an empirical basis for an "Expansion-Contraction" (EC) model of Pleistocene biogeography. Under the EC model, most northern hemisphere species survived in low-latitude glacial refugia, only re-populating higher latitudes through range expansions after the last glacial maximum (LGM). In addition to forming an important paradigm of modern biogeography, the EC model also provides a useful framework for understanding community-wide responses to climate change. To address the question of whether marine communities responded similarly to those on land, we conducted a survey of mitochondrial and nuclear DNA diversity from 14 rocky-shore northeastern Pacific species. Although mtDNA analyses from some species were consistent with large population expansions occurring near the LGM (the pattern expected if species recently recolonized the region), most species had histories consistent with long-term stability in population size, and thus regional persistence. Multilocus analyses for five species were consistent with mtDNA. Our results indicate that the LGM did not extirpate the majority of species in this community; instead, regional persistence during the LGM appears a common history. The demographic stability of only a subset of this community in the face of glacial-interglacial changes is consistent with the known ecological and physiological features of individual species and has important implications for understanding the impacts of climate change on patterns of rocky shore diversity.

***31.6*** MARKS, J.A.*; BIERMANN, C.H.; Univ. of Oslo, Norway, Portland State Univ.; *Jessica.Marks@bio.uib.no*

***Reproductive character displacement in egg-jelly carbohydrates reinforces mating barriers in two broadcast-spawning marine invertebrates***

In marine broadcast-spawning organisms, geographic divergence in gamete compatibility may reflect the first step toward speciation, yet little is known about patterns of pre-zygotic isolation among populations or mechanisms involved in the formation of reproductive barriers. We determined fertilization success within and between *Strongylocentrotus droebachiensis* and *S. pallidus*, two closely related species of sea urchins that overlap in geographic distribution and spawning season. We studied populations of both species from the NE Atlantic (Norway, Svalbard) and the NE Pacific (WA). In sea urchins, carbohydrates in the egg-jelly coat trigger the sperm acrosome reaction, a necessary step in the fertilization cascade that is a species-specific mediator of fertilization in these species. Eggs can also discriminate among sperm using the sperm protein bindin and its egg receptor. To elucidate the mechanism behind gametic incompatibility, sperm were also pre-treated with egg jelly. We found greater incompatibility in heterospecific crosses in sympatry than in allopatry, a pattern of reproductive character displacement that is consistent with reinforcement. Pre-treatment with egg jelly mitigated this effect, implicating divergence in egg-jelly carbohydrates but not sperm bindin. In contrast, intra-specific barriers among allopatric populations reflect divergence in bindin; for most populations, conspecific crosses had lower fertilization in allopatry that could not be remedied by pre-treatment with egg jelly. We demonstrate reproductive character displacement in a broadcast-spawning marine invertebrate and suggest barriers to fertilization can arise through different mechanisms operating between individuals, populations and species.

***S6.10*** MARRA, P.P.; Smithsonian Institution; *marrap@si.edu*
***Seasonal interactions and carry-over effects: understanding the biology of migratory organisms within the context of the annual cycle***
Migratory birds spend different parts of the annual cycle in geographically disparate places. The conditions and selective pressures at winter locations are likely to affect individual performance during the breeding season, and vice versa. This simple fact has important implications for the ecology, evolution, and conservation of migratory birds. Such inter-seasonal effects are poorly understood within most avian migration systems, in large part because it has been difficult to determine the connections between specific summer and winter populations. Stable isotopes have contributed enormously to our ability to link events in the annual cycle and research in my lab has begun to uncover the ecological and evolutionary significance of these connections. For example, because migratory organisms spend different parts of the annual cycle in geographically (and ecologically) separated locations, the dynamics of summer populations are likely to be strongly influenced by events on the wintering grounds and vice versa. Simple mathematical models illustrate the effects of density-dependence on population dynamics. Events on wintering grounds are also likely affect both arrival time and body condition of individual birds on the breeding grounds, and these parameters are likely to have important consequences for breeding behaviour, natal dispersal and annual survival. In this talk, I will describe through many of these specific examples how understanding seasonal interactions, carry-over effects and migratory connectivity is essential to our basic understanding of migratory bird biology. Finally, I will emphasize how it is essential to study biological phenomena in the context of the entire annual cycle.

***S7.5*** MARSH, Adam*; KENDALL, Lindsay; GUIDA, Stephanie; University of Delaware; *amarsh@udel.edu*
***Environmental Imprinting (Epigenetics) and Adaptation in Antarctic Marine Invertebrates.***
DNA methylation is an important epigenetic information system. Many environmental factors such as temperature and nutrition have been shown to impact patterns of genome methylation in animals with a net effect of altering gene expression rates. Genomic distributions of 5-methylcytosine residues are replicated during cell division and thus germ-line epigenetic modifications can be transferred across subsequent generations. We are assessing the potential for DNA methylation to be involved in adaptations to polar conditions of low temperature and limited food in two macroinvertebrates: the sea urchin *Sterechinus neumayeri* and the polycheate *Capitella perarmata*. In addition, we have broadly surveyed a range of temperate invertebrate phyla for the prevalence of DNA methylation. We have found that both polycheates and sea urchins have substantial methyl-cytosine compositions, and that patterns of genome methylation are responsive to experimental temperature manipulations. Shifts in methylation around specific loci could play a large role in altering metabolic activities as has been found in model animal systems, particularly in terms of glucose metabolism as determined by the IGF-2 locus. DNA methylation may serve as a cellular memory system by which strict environmental constraints in polar habitats are imprinted upon a genome to balance gene expression activities. Thus, an epigenetic mechanism of gene expression regulation could be an important determinant of phenotype fitness in polar organisms.

***78.1*** MARTIN, G.G.; JAMES, D.M.*; SCHULZ, J.; Occidental College, Los Angeles; *gmartin@oxy.edu*
***The Proboscis of Predatory Conus: Sensory Structures and Tissue Regeneration***
Over the last 50 million years members of the Genus *Conus* have evolved into over 600 species of predatory marine snails, many of which are highly specialized. Although there has been considerable interest in the pharmaceutical applications of *Conus* venom, there are relatively few studies on the morphology and comparative biology of the sensory structures within these marine gastropods. Three basic groups of cone snails have been proposed; vermivores, piscivores and molluscivores. All members of these three groups show a remarkable ability to locate and dispatch prey with powerful venom delivered by a radular harpoon found within the proboscis. With limited eyesight, reduced motility, and a nocturnal lifestyle, it is still unknown how they identify and locate their prey with such accuracy. Using SEM and TEM we have found ciliated structures (“sensory papillae”) near the distal tip of the proboscis from representatives of all three groups. Variations between these groups occur with the length, quantity, and position of the sensory papillae. Confocal and fluorescence microscopy shows extensive innervation within the proboscis leading up to the sensory papillae, suggesting that these structures do play a sensory role. Additional studies revealed that these sensory structures can regenerate after the tip of the proboscis has been ablated, which occurs in the wild as well as in lab settings. Feeding behaviors do not commence after ablation until the papillae have reformed. Further studies are needed to determine the type(s) of sensory information being detected by the papillae and if that is consistent among the three groups of cone snails.

***72.6*** MARTIN, LB*; LIEBL, AL; ALAM, JL; BUTLER, LK; IMBOMA, T; KUHLMAN, JR; ROMERO, LM; SORCI, G; STEWART, I; WESTNEAT, D; LEE, KA; Univ of South Florida, Tampa, National Museum of Kenya, Nairobi, Tufts University, Medford, Univ of Bourgogne, University of Kentucky, Lexington, Univ of California, Davis; *lmartin@cas.usf.edu*
***House sparrow immune functions are influenced by introduction history***
Many life history and behavioral traits of individuals promote the success of population introductions or range expansions, but whether physiological traits too are important has been less studied. Alterations in immune functions in particular may facilitate colonizations because most hosts carry smaller parasite burdens outside their native range and because sacrifice of costly immune functions would promote an invasive life history strategy. In the present study, we asked whether sacrifices of some of the most expensive yet broadly and rapidly protective immune options organisms have available may have influenced house sparrow (*Passer domesticus*) introductions. Specifically, we compared the release of haptoglobin (Hp), nitric oxide (NO: a broad spectrum anti-microbial molecule), and mass loss (the typical outcome of the anorexia that occurs during sickness in most vertebrates) after simulated infection among two native (Eurasian) and five introduced populations of sparrows: (three in the USA, one in Panama and one in Kenya). We found that Hp and NO were quite variable whereas mass loss was minimal among populations. Nevertheless, introduced populations had on average more Hp (but not NO) in circulation, consistent with our expectation. As the main roles of Hp include scavenging of free heme after inflammatory responses and attenuation of inflammatory mediators, introduced populations generally may attempt to damp or offset the collateral damage of inflammatory responses more than native ones. We are presently investigating whether climate, weather, or genetic relatedness or heterozygosity explains residual immune variation.

***S9.7*** MARTINDALE, Mark Q.*; LEE, Patricia; HENRY, Jonathan Q.; Kewalo Marine Lab, Univ. Hawaii; *mqmartin@hawaii.edu*
***The development of the mesentoblast in the gastropod Crepidula fornicata***
One of the hallmarks of the spiralian cleavage program is the ability to identify and compare the development of homologous cells in embryos from disparate taxonomic groups. One cell of particular importance in all spiralian embryos is the mesentoblast, termed 4d. This cell is said to be the sole progenitor of endomesoderm and this cell and or its precursor, the 3D macromere has “organizing” activity patterning the dorso-ventral axis. We have used microinjection and laser ablation to study in detail the early cleavage program and endodermal and mesodermal fates of 4d sublineages in the gastropod, Crepidula fornicata. These results can be compared to those in other spiralian taxa. Furthermore, we have carried out a molecular analysis of mesendoderm formation in Crepidula. Injections of synthetic mRNA encoding GFP-tagged beta-catenin into fertilized eggs reveal that this protein is selectively stabilized in the 4d mesentoblast lineage, consistent with a role in the development of endomesoderm. Experiments using truncated messages, reveal that the C-terminal end, which includes some of the armadillo repeats is necessary for the subsequent degradation of this protein within that lineage.

***S4.6*** MARTONE, Patrick T.; University of British Columbia; *pmartone@interchange.ubc.ca*
***Bending corallines: biomechanical adaptations of segmented calcified seaweeds***
Flexibility is a critical characteristic of plants growing in unsteady flow. For example, leaves flutter in the wind and seaweeds ‘go with the flow’ to reduce drag. Given this paradigm of flexibility, I explore calcified coralline algae (Rhodophyta, Corallinaceae) which thrive in and dominate wave-exposed coastlines around the world. Many corallines produce flexible upright fronds by separating calcified segments with joints, called genicula. Such segmentation has evolved convergently in several lineages of hydrodynamically-stressed calcifying seaweeds and is thought to represent a common evolutionary trade-off decreasing herbivory susceptibility while increasing flexibility. In this study, I explore the consequences of segmentation on seaweed flexibility and the biomechanical adaptations of articulated coralline algae to facilitate bending. Using a numerical model, I evaluate the effects of genicular morphology and material properties on frond flexibility and demonstrate that several genicular features appear to be adaptations to hydrodynamic stress. In addition, I describe the adaptive significance of genicular material properties and cellular structure and explore the developmental and chemical underpinnings that likely contribute to their emergent mechanical properties. By exploring the biomechanics of genicula at a variety of scales, these studies erect an extensive framework for investigating the convergent evolution of joints in other segmented taxa.

***87.1*** MARUSKA, KP*; LEVAVI-SIVAN, B; FERNALD, RD; Stanford Univ, Hebrew Univ; *maruska@stanford.edu*
***Rapid Activation of the Reproductive Axis During Social Ascent***
Reproduction is arguably the most important event in an animal’s life, and social interactions can have profound effects on fertility via the brain-pituitary-gonad (BPG) axis. In an African cichlid fish, *Astatotilapia burtoni*, reproductive capacity is controlled by the social environment where males reversibly switch between dominant and subordinate status. Dominant males defend territories and court females, have large GnRH1 neurons, high androgen levels, and large testes, while subordinate males do not show dominance behaviors and have a suppressed BPG axis. Prior work showed a suite of differences between stable dominant and subordinate phenotypes, but little is known about the timeline of changes during social transition, and nothing is known about changes at the level of the gonadotropins. Here we induced suppressed males to rise in status, and then measured the resultant changes in behavior and physiology at various times after ascension. Subordinate males increased dominance behaviors within minutes, but decreased territorial and increased reproductive behaviors over subsequent days as they established a territory. There was a rapid increase in pituitary mRNA and circulating plasma levels of the gonadotropins luteinizing hormone (LH) and follicle stimulating hormone (FSH). FSH receptor levels in the testis were also rapidly elevated, while increased LH receptor levels were not detected until 3 days after ascension. Changes in testis cell composition were detected at 3 days, but testicular size was not greater until 5 days. Subordinate males also retain sperm and can successfully spawn within hours of social opportunity. Our results suggest that BPG axis activity is decoupled from both behavior and the ability to reproduce as an adaptation for rapid transition to dominance in a dynamic social environment.

***29.5*** MASHANOV, V.S.*; ZUEVA, O.R.; HEINZELLER, T.; GARCIA-ARRARAS, J.E.; University of Puerto Rico, LMU, Munich; *mashanovvlad@googlemail.com*
***Echinoderm nervous system as an emerging model to study neural regeneration***
The phylum Echinodermata is of particular interest to a regeneration researcher for at least two main reasons. First, the phylum belongs to the monophyletic group Deuterostomia, which also includes our own phylum, the Chordata. Second, echinoderms are well known for their capacity to regenerate almost any part of their body following injury. However, the echinoderm nervous system has been largely ignored so far as a subject of serious research. The main reason behind that is the set of peculiar features, which has been attributed to the nervous system, such as the pentaradial symmetry, subdivision into anatomically separated ectoneural and hyponeural subsystems, possible mesodermal origin of the latter. However, our recent research in organization, development, and regeneration of the main nerve cords in sea cucumbers has refuted many of the misconceptions about the echinoderm nervous system and showed that there is much more in common between the nervous system in echinoderms and chordates than was thought previously. Among the most intriguing findings is the organization and emerging functional role of echinoderm glia. Employing a combination of electron microscopy and immunocytochemical techniques, we have demonstrated that the echinoderm glial cells share morphological and antigenic properties with chordate radial glia and, most intriguingly, play a key role in both the post-traumatic neurogenesis and normal cell turnover, as do glial cells in vertebrate CNS regenerators. Further studies of the nervous system regeneration in echinoderms, with special reference to the glial reaction, will most probably provide a new understanding of what makes the CNS regeneration successful in echinoderms and lower chordates and why it does not readily occur in higher vertebrates, including human.

***S9.4*** MASLAKOVA, S.A.; Oregon Institute of Marine Biology, U. of Oregon; *svetlana@uoregon.edu*
***The invention of the pilidium larva in an otherwise perfectly good spiralian phylum Nemertea.***
The nemertean pilidium is one of the most unusual larval forms among the spiralians. It is restricted to the monophyletic clade Pilidiophora. All other nemerteans have juvenile-like planuliform larvae, some of which possess a vestigial prototroch, which relates them to the classical spiralian trochophore. The invention of the pilidium larva is associated with several major developmental innovations, starting with the formation of an extensive gel-filled blastocoel which supports the delicate larval frame. Meanwhile, the trochoblast cell lineage must escape cleavage-arrest, forming a growing, elaborated ciliary band instead of a prototroch. It appears that the hoplonemerteans and at least some palaeonemerteans also evaded the typical spiralian fate of the trochoblast lineage, possibly setting the scene for the origin of the pilidium larva. The most remarkable innovation of the pilidium is the development of the juvenile worm inside the larva from a series of isolated rudiments, called imaginal discs. The paired cephalic, cerebral organ and trunk discs originate as invaginations of larval epidermis and subsequently grow and fuse to form the juvenile. I review recent data on development of palaeo- and hoplonemerteans and speculate about the possible homology between pilidial imaginal discs and invaginated rudiments observed in planuliform larvae. Comparative analysis of cell lineage and rudiment-specific genetic markers will help to test this hypothesis. I describe preliminary results from a global search of pilidial developmental transcriptomes for differentially expressed genes that will identify such markers.

***92.4*** MATEO, J.M.; Univ. of Chicago; *jmateo@uchicago.edu*
***Hormonal responses to calls warning of predators and development of survival behaviors***
Shortly after emerging from natal burrows at one month of age, juvenile Belding's ground squirrels (*Spermophilus beldingi*) learn to respond to whistle and trill alarm calls, which warn of aerial and terrestrial predators, respectively. In a variety of vertebrates, exposure to a predator, its cues, or calls warning of it can lead to physiological reactions such as metabolic adjustments, cardiovascular changes, or glucocorticoid release, suggesting that predator contexts are arousing. Increased arousal after hearing an alarm call, coupled with watching the responses it elicited in others, may facilitate juveniles' acquisition of an association between calls and behavioral responses. Such rapid learning would be adaptive for vulnerable prey animals. I examined experimentally whether young juveniles exhibit differential acute cortisol responses to alarm and non-alarm calls, which would facilitate differential attention to the calls, and perhaps promote rapid learning of the appropriate responses. Cortisol responses to playbacks of whistles, trills, squeals (a conspecific control vocalization) and silent controls were compared within individuals across call types. Results are discussed in terms of physiological and ecological correlates of attention and learning, as well as the general role of glucocorticoids in the development of survival behaviors.

***72.1*** MATSON, K.D.*; HORROCKS, N.P.C; VERSTEEGH, M.A.; TIELEMAN, B.I.; University of Groningen; *k.d.matson@rug.nl*
***Repeatability and the predictive capacity of acute phase protein concentrations in pigeons***
The indices of immune function used by ecological immunologists are often assumed to reflect fundamental attributes of individuals. Such an assumption is important if the measures are interpreted in an evolutionary context since variation among individuals is a driver of natural selection. The immune system, however, is dynamic. For many immune indices, the extent to which individuals vary over short and long timescales is unknown. We examined the repeatability of haptoglobin, an acute phase protein, in pigeons using 13 plasma samples collected over a 14 month period. In this case, repeatability, which is defined as the portion of total variation that is attributable to among individual differences, signals the degree to which haptoglobin concentration is a distinctive trait of individuals. Haptoglobin is a particularly interesting parameter for studying repeatability. Using a simple functional assay, plasma concentrations can be easily quantified in a variety of avian species as often encountered in comparative ecological approaches. Yet concentrations within individuals are expected to vary widely as a result of the molecule's role in inflammation, infection and trauma. Despite some short-term fluctuations, we found plasma haptoglobin concentrations to be significantly repeatable over different timescales. To further develop our understanding of among individual differences in these "baseline" haptoglobin concentrations, we explored the capacity of these values to predict the amplitude of a sickness response. Specifically, we tested correlations between "baseline" haptoglobin concentrations and the physiological effects of an experimental lipopolysaccharide challenge that followed the baseline period.

***11.2*** MAZOUCHOVA, Nicole*; GRAVISH, Nick; SAVU, Andrei; GOLDMAN, Daniel; Georgia Institute of Technology, Atlanta; *nmazouch@gatech.edu*
***No slip locomotion of hatchling Loggerhead Sea turtles on granular media***
Sea turtle locomotion occurs predominantly in aquatic environments. However, upon hatching, juvenile turtles (hatchlings) must cross an expanse of unconsolidated particles (beach) to reach the sea. They achieve speeds up to 3 BL/sec on sand, a granular medium that exhibits both solid and fluid-like dynamics. To discover how sea turtles locomote effectively on sand with aquatically adapted limbs, we studied the kinematics of 31 hatchling Loggerhead sea turtles (*Caretta caretta*) in the field (Jekyll Island, GA, USA) and thrust generation of model limbs in the lab. We challenged sea turtles to traverse a sand filled trackway of controlled packing and incline angle $\theta$, tracking body and limb position using high speed infrared video. We characterized locomotion at $\theta=0°$ while flowing air up through the sand to reduce the granular yield stress. For all tested angles and sand preparations the turtles employed a diagonal gait, similar to terrestrial organisms moving on solid ground. Average forward speed $v$ increased linearly with limb frequency $f$ with slope, $dv/df$, significantly greater than zero ($p<0.0001$) for all treatments. Compared to the slope at $\theta=0°$ with no air flow, $dv/df$ was 2/3 smaller ($p=0.049$) at $\theta=20°$, while at $\theta=0°$ with air flow $dv/df$ shows no statistical difference ($p>0.05$). We explain the results by balancing frictional and gravitational forces against flipper thrust. Whereas the frictional and gravitational forces are roughly constant, our lab experiments reveal that flipper thrust increases with relative displacement of the limb through the sand (slip). Limb slip without body motion occurs until thrust equals the resisting forces; $dv/df$ is then determined by the effective stride length (stride length in the body frame minus total limb slip).

***22.1*** MAZZILLO, Maria*; KEMPF, Stephen C.; Auburn University; *mmazzillo@gmail.com*

***Mucilage Secretion in Different Symbiodinium Strains***

*Symbiodinium* are brown, unicellular dinoflagellates that reside intracellularly in a variety of invertebrate hosts, including many cnidarians. In this mutualism, the endosymbiotic algae are enclosed in a symbiosome membrane (both host and symbiont-derived) and donate photosynthetically fixed carbon to their host in exchange for nutrients. *Symbiodinium* is a diverse genus of 8 clades with multiple strains in each clade. The specificity of the association between symbiont and host varies with some highly specific relationships and others of a more general nature. The symbiont secretes mucilage that lies at the interface between host and symbiont (as part of the symbiont contribution to the symbiosome membrane). Cultured *Symbiodinium* from a variety of clades were labeled with an antibody to symbiont mucilage (PC3; developed to a clade B alga cultured from *Aiptasia pallida*). The labeling was visualized with a fluorescent marker and examined with a confocal microscope. Previous work found PC3 antigen in cultured *Symbiodinium* from clades A and B but not in clades C and D. New mucilage markers are being developed to further characterize mucilage differences between clades. Biochemical analyses of the mucilage are also being performed to examine the protein and carbohydrate composition. Using $^{13}C$ tagged Na-bicarbonate to label cultured algae in the dark and light and measuring the amount of $^{13}C$ in the mucilage shows incorporation of 6.8%, indicating photosynthetically fixed carbon is a significant part of the mucilage in the strain of alga tested. These data suggest that the mucilage may play a role in both specificity (via host-symbiont interaction) and in translocation of carbon to the host.

***31.9*** MCALISTER, J/S*; MORAN, A/L; Clemson University; *jmcalis@clemson.edu*

***Assaying echinoid eggs for evolutionary associations among egg size, egg composition, and egg energy***

Marine invertebrates with feeding larvae use maternally-derived biochemical constituents (carbohydrate, protein, and lipid) in the egg to fuel larval metabolism and to construct the feeding larva. How then are evolutionary changes in egg size associated with egg biochemical composition and the amount of energy available for larval development? We are investigating these associations using the eggs and larvae of echinoid 'geminate' species pairs from tropical America, in which species from the low-productivity waters of the Caribbean have larger eggs (by volume) than their sister taxa in the highly productive Pacific. We analyzed egg biochemical constituents of echinoids in the genera *Diadema* and *Echinometra*, and found that eggs of the Caribbean species contained more protein and lipid, but carbohydrate did not differ between oceans. Egg compositions differed between oceans in that eggs of Caribbean species were characterized by a higher lipid-to-protein ratio. Total energy (mJ) in the egg (based on summing energy equivalents of constituents) was greater for all Caribbean species, but when controlled for egg volume, total egg energy density (mJ/nl) was significantly *lower* in the Caribbean *Echinometra* sp.. Thus, the large eggs of Caribbean *Echinometra* sp. are not simply 'scaled up' small eggs, but contain less energy per unit volume than eggs of the Pacific species. One possible adaptive advantage to producing large, energy-poor eggs is that females can maintain high fecundity while producing eggs that are better targets for fertilization by sperm. We are currently examining larval growth rates, arm lengths, and energy utilization in these taxa to determine the fate of egg constituents and the downstream effects of egg energy density for larval physiology and growth.

***S7.4*** MCCLINTOCK, J.B.*; AMSLER, C.D.; BAKER, B.J.; Univ. of Alabama at Birmingham, Univ. of South Florida; *mcclinto@uab.edu*

***An overview of the Chemical Ecology of Marine Macroalgae and Benthic Invertebrates along the Antarctic Peninsula***

Thirteen years ago in a review that appeared in the American Zoologist, we presented the first survey of the chemical and ecological bioactivity of Antarctic shallow-water marine invertebrates. In essence, we reported that despite theoretical predictions to the contrary the incidence of chemical defenses among sessile and sluggish Antarctic marine invertebrates was widespread. Since that time we and others have significantly expanded upon the knowledge base of Antarctic marine chemical ecology, both from the perspective of examining new distinct geographic regions, including macroalgae which dominate shallow-water communities along the Antarctic Peninsula, as well as broadening the evaluation of the functional and ecological significance of secondary metabolites. Importantly, many of these studies have been framed within established theoretical constructs, particularly the Optimal Defense Theory (ODT). In the present symposium, we provide an overview of the chemical ecology of macroalgae and benthic marine invertebrates that comprise communities along the Antarctic Peninsula, a region of Antarctica that is in many respects both physically and biologically distinct from the rest of the continent.

***44.5*** MCCUE, Marshall/D*; SIVAN, Orit; MCWILLIAMS, Scott/R; PINSHOW, Berry; Blaustein Institutes for Desert Research, Ben Gurion University, Univ Rhode Island; *mmccue@bgu.ac.il*

***Tracking the oxidative kinetics of carbohydrates, amino acids, and fatty acids in the house sparrow using exhaled 13CO2***

Clinicians have measured the $^{13}CO_2$ in exhaled breath samples following administration of a metabolic tracer (breath testing) for decades, but comparative physiologists have only recently begun using breath testing to study the oxidation of exogenous sugars in nectivores. We examined several predictions regarding the oxidative kinetics of various carbohydrates, amino acids, and fatty acids in a dietary generalist, the house sparrow, *Passer domesticus*. After administering postprandial birds with 20 mg of one of seven $^{13}C$-labled tracers, we measured rates of $^{13}CO_2$ production every 15 min. over 2 hours. We found that sparrows oxidized exogenous amino acids far more rapidly than carbohydrates or fatty acids, and that different tracers belonging to the same class of physiological fuels had unique oxidative kinetics. Glycine had a mean maximum rate of oxidation (2021 nmol $min^{-1}$) that was significantly higher than that of leucine (351 nmol $min^{-1}$), supporting our prediction that nonessential amino acids are oxidized more rapidly than essential amino acids. Exogenous glucose and fructose were oxidized to a similar extent (5.9% of dose), but the time required to reach maximum rates of oxidation was longer for fructose. The maximum rates of oxidation were significantly higher when exogenous glucose was administered as an aqueous solution (122 nmol $min^{-1}$), rather than as an oil suspension (93 nmol $min^{-1}$), supporting our prediction that exogenous lipids negatively influence rates of exogenous glucose oxidation. Dietary fatty acids were oxidized at the lowest rates (2 – 6 nmol $min^{-1}$), and differed significantly in the quantity of which each was used, with 0.73%, 0.63%, and 0.21% of palmitic, oleic, and stearic acid tracers being oxidized, respectively.

***80.6*** MCCULLOUGH, E.L.; University of Montana; *mccullough.e@gmail.com*

***Horn possession does not appear to limit natural flight performance in the giant rhinoceros beetle Allomyrina dichotoma***

Sexually selected characters are assumed to be costly to produce and maintain, and individuals are expected to reduce the magnitude of these costs whenever possible through morphological and/or behavioral modifications. In the giant rhinoceros beetle *Allomyrina dichotoma*, males have a long, branched head horn that they use in male-male competitions over access to resources where hornless females feed and mate. Males with longer horns are more likely to win these comtests and thereby gain fertilization opportunities. However, the cost of bearing horns has not been elucidated. Males sometimes fly long distances to feeding sites, and flight performance is likely to be critically challenged in males with long, heavy horns. As a first step in identifying possible flight costs in this species, I tested whether the presence of a horn and/or differences in horn size affected natural flight behavior. I used radio telemetry and scan samples to measure how far large-horned males, short-horned males, and hornless females traveled each night, and a radar gun to measure normal flight speeds. I predicted that long-horned males would fly shorter distances and at slower speeds than short-horned males or females due to the increased mass and aerodynamic drag imposed by the elaborate horns. Surprisingly, I found no relationship between flight speed and size or between flight distances and size, which suggests that, at least in this species, horns do not appear to limit flight performance in the field. Future research will focus on determining the specific energetic and aerodynamic costs of flight in this species, whether these costs differ among long-horned males, short-horned males, and hornless females, and if individuals can ameliorate these costs through morphological and/or behavioral modifications.

***44.2*** MCDONALD, B.I.*; GOEBEL, M.E.; CROCKER, D.E.; COSTA, D.P.; Univ. of California, Santa Cruz, Antarctic Ecology Research Division, NOAA, Sonoma State University; *mcdonald@biology.ucsc.edu*

***Maternal investment in the Antarctic fur seal: Impacts of maternal traits, pup traits, and provisioning strategy***

Life history theory predicts that reproductive effort should increase with age in long lived animals. More recent studies indicate state variables such as individual quality and physiological state play an equally, if not more important role, in reproductive decisions. Reproductive effort was investigated in Antarctic fur seals (*Arctocephalus gazella*) at Cape Shirreff, Livingston Island. Prenatal effort was determined by catching and weighing 49 known-aged females and their pups. Milk intake was measured in the same pups during the perinatal period and at one and two months of age using the doubly labeled water technique. Total reproductive effort during the perinatal period was measured in 10 females. Reproductive effort did not increase with age, but mass and condition were important in determining maternal investment. Heavier females gave birth to larger pups and invested more during the perinatal period and at two months of age. Females in better condition gave birth to heavier pups and only invested more during the perinatal period. Pup mass and sex were important in determining maternal investment. Male pups were heavier at birth and at one month of age larger pups ingested more milk. Maternal investment during a nursing bout increased significantly with increasing foraging trip/visit cycle duration. However, when investment was controlled for trip/visit cycle duration, the overall rate of parental investment was similar across trip durations. The data suggest strong impacts of maternal traits, pup traits and provisioning strategy on investment that vary across the period of reproductive effort, emphasizing the importance of considering state variables in life history studies.

***S3.5*** MCDONALD, K. A.*; GRUNBAUM, D.; Smithsonian Tropical Research Institute, University of Washington, School of Oceanography; *mcdonaldk2@si.edu*

***Swimming embryos point to planktonic performance standards for early-developmental motility***

Cilia perform critical swimming, feeding, and sensory functions in planktonic invertebrate larvae. Development and phylogeny constrain larval form, but evidence for the independent evolution of complex ciliary structures (for instance, opposed bands) suggests that functional analysis of swimming and swimming/feeding structures may reveal more about performance requirements than developmental constraints. Ecological performance standards could also apply to the earliest free-living stages. Though earliest motile stages are simple swimming 'blobs,' species already differ in parameters of size, shape, ciliary length, and patterning/extent of ciliation. These morphological differences could contribute to significant differences in performance, and thus transport and mortality. Consistently high performance achieved despite differences in these characteristics could indicate that swimming is under strong selection from earliest development. We developed a hydrodynamic model of embryonic swimming, parameterizing swimmers as ciliated ellipsoids. Model predictions were tested against experimental results for swimming in thirteen broadcast-spawning species. In ten species, predicted actual and neutral-weight swimming speeds conformed well to measured results, indicating that embryo size and density are sufficient to predict swimming performance without detailed knowledge of ciliation. Experimental results showed a strong decrease in density with size across species, but little trend in swimming speed with size, suggesting that diverse species trade off density against speed at first swimming. Together, modeling and experimental work indicate that swimming performance 'standards' apply from the time of first motility.

***S8.2*** MCFADDEN, CS*; BRISSON, V; FRANCE, SC; Harvey Mudd College, Claremont, CA, University of California, Berkeley, University of Louisiana, Lafayette; *mcfadden@hmc.edu*

***Molecular Phylogenetic Insights into Octocoral Evolution***

The Anthozoan sub-class Octocorallia comprises approximately 3000 described species of soft corals, sea fans, and sea pens. Although the monophyly of Octocorallia is well supported by both molecular and morphological evidence, ordinal and sub-ordinal relationships within the clade remain very uncertain. Previous single-locus molecular phylogenetic analyses have failed to support any of the traditional morphology-based classification schemes, yet have offered no well-supported alternative hypotheses of octocoral diversification. As part of the Cnidarian Tree of Life project, we sequenced complete large (28S) and small (18S) subunit nuclear ribosomal genes, plus partial mitochondrial large subunit ribosomal (16S), cytochrome oxidase I (COI) and mut-S homolog (msh1) genes for approximately 110 taxa representing 38 of 47 octocoral families. Here we present the results of the combined phylogenetic analysis of ~8 kB of sequence data, and discuss implications for the evolution of morphological diversity (in particular, skeletal morphology and colony architecture) within Octocorallia. In addition, we highlight some taxonomic advances we have made at the inter- and intrageneric levels by using molecular phylogenetic analyses to discover new, phylogenetically informative morphological characters for taxonomy.

***32.7*** MCGEE, MD*; WAINWRIGHT, PC; Univ. of California, Davis; *mcgee@ucdavis.edu*

***Contingency and determinism in the trophic apparatus of threespine stickleback: implications for adaptive evolution***

Adaptive evolution is often thought to proceed in a deterministic fashion, with chance and contingency playing only a minor role as the population ascends to a new phenotypic optimum. However, if selection acts on an index trait that combines several phenotypic traits into one functional trait, then ascension to a new adaptive peak may produce similar index trait values even if they are derived from different phenotypic combinations. To test this, I cleared and stained specimens of threespine stickleback from British Columbia and Alaska belonging to both the "limnetic" and "benthic" ecotypes. For each fish, I measured the components of the suction index model, which predicts the maximum suction pressure generated during a feeding event. Limnetics from Alaska and British Columbia had a low suction index consistent with their preferred diet of evasive zooplankton, and benthics from the two locales had a high suction index consistent with feeding on epi- and infaunal invertebrates. Limnetic-benthic differences within British Columbia populations related mostly to epaxial muscle cross-sectional area, with benthics having significantly higher CSA than limnetics. Suction index in Alaskan fish differed primarily due to size of the buccal cavity, with benthics having a significantly shorter buccal length and a smaller gape than limnetics. Despite the fact that each ecotype had similar values of suction index when compared to other populations of that same ecotype, the underlying phenotypes of each population were highly divergent. This result suggests that for complex traits, evolution to a new adaptive optimum can proceed in a deterministic fashion with an underlying diversity of outcomes due to chance and contingency.

***1.8*** MCGINN, N.A.*; CHERR, G.N.; University of California, Davis; *namcginn@ucdavis.edu*

***Diversity and complexity of multidrug resistance phenotypes of marine invertebrate oocytes***

While multidrug resistance (MDR) was originally described in cancer cells resistant to multiple chemotherapeutic agents, we now know that MDR is utilized by a wide variety of cell types to remove targeted compounds from cells via ATP-dependent, plasma membrane transporters. This fundamentally protective role of MDR is vital to cells in a diverse range of organisms including bacteria, plants, invertebrates, and mammals. MDR activity has been documented in the early life history stages of broadcast-spawning marine invertebrates where MDR is believed to provide a basic defense against xenobiotics well before other mechanisms of detoxification develop. Using a standard assay, we measured the intracellular accumulation of a fluorescent MDR substrate and found that sea urchin eggs had greater MDR activity than oocytes of the echiuran worm *Urechis caupo*. However, using scanning laser confocal microscopy, we observed that *Urechis* oocytes exhibited intracellular sequestration of the fluorescent dye within cytoplasmic vesicles identified as lysosomes. This particular MDR phenotype is well established in drug resistant cancer cell lines, but has not previously been observed in normal animal cells. Rather then relying solely on membrane transporters for the efflux of potentially hazardous substances, as is the case in sea urchin eggs, *Urechis* oocytes use intravesicular sequestration as a second layer of protection. Further, based on our analysis of sea star oocytes, that are similar in maturational state to *Urechis* oocytes, but from a cleaner habitat similar to that of sea urchins, we conclude that the complexity of the MDR phenotypes observed in *Urechis* oocytes is likely the result of exposure to the chemically challenging mud burrow habitat of the adult worms.

***S11.3*** MCGUIGAN, K*; NISHIMURA, N; CURREY, M; HURWIT, D; CRESKO, WA; Univ. Queensland, Univ. Oregon; *k.mcguigan1@uq.edu.au*

***Environment, Additive Genetic Variance and Evolvability of Body Shape in Threespine Stickleback (Gasterosteus aculeatus)***

Numerous examples of rapid adaptation of populations to novel habitats have been documented. An unanswered question is to what extent populations in novel environments, to which they are not adapted, express greater genetic variation, facilitating rapid evolution. Environment-specific additive genetic variation violates a major assumption of evolutionary quantitative genetics: that variances are constant over the predictive timeframe. Evidence of environment-dependent additive genetic variation is equivocal, with some studies demonstrating increased and some decreased variation. Although quantitative genetic studies have historically focused on variance in individual traits, it is the genetic basis of the multi-trait phenotypes under selection that determines evolutionary response. We used an evolutionary model organism, the threespine stickleback, to ask whether environment altered the expression of additive genetic variation such that populations in novel environments might evolve more rapidly than predicted from estimates in the ancestral environment. Stickleback are characterized by a remarkable adaptive radiation following colonization of post-glacial freshwater lakes by oceanic fish. Freshwater and oceanic populations differ in many phenotypic aspects, including body shape, which contributes to swimming performance, predator evasion and foraging efficiency. We used a half-sib breeding design to determine whether oceanic stickleback expressed greater additive genetic variation in body shape when reared in fresh versus saline water, and whether these differences could have contributed to the rapid adaptation of marine stickleback to freshwater lakes.

***35.5*** MCGUIRE, JL*; DAVIS, E; ORCUTT, JD; Univ. of California, Berkeley, Univ. of Oregon; *mcguire@berkeley.edu*

***Using the fossil record to test phylogeographic and ecological niche model hypotheses about the locations of glacial refugia***

During the Last Glacial Maximum (LGM), continental ice sheets covered much of the northern portion of North America, reducing land area and altering climate regimes. As a result, plant and animal species were forced to shift their ranges to adjust to these conditions. Phylogeographic methods and ecological niche models (ENMs) have both been used model the ranges of plants and animals during the LGM. Phylogeographic efforts have focused on interpreting area cladograms based on the lineage structures of populations, with the assumption that each living population of temperate species has spread from a refugium since the LGM. ENMs apply environmental constraints derived from current species ranges to reconstructed LGM climate maps to determine the regions where the organisms could have lived in the past assuming niche conservatism. We have used fossil data compiled in the FAUNMAP II database to test the reconstructed glacial refugia of six small mammal species: *Blarina brevicauda, Glaucomys sabrinus, Glaucomys volans, Lepus arcticus, Martes americana, Myodes (Clethrionomys) gapperi*. Due to limitations in the FAUNMAP II database, we were unable to include Canada or Mexico in our analyses. When we compared refugial hypotheses from both phylogeographic and ENM reconstructions to the ranges of these species' fossils, we found mixed agreement with the hypotheses. LGM fossil specimens from two of the species (*G. sabrinus* and *G. volans*) were found outside of refugial ranges as predicted by both phylogeographic and ecological niche methods. Although many of the species ranges agree in some regards with either ecological niche or phylogeographic hypotheses, no clear pattern could be found regarding whether either method accurately predicted LGM refugia.

***56.6*** MCGUIRE, Nicolette L.*; KANGAS, Kristina; BENTLEY, George E.; Univ of California, Berkeley; *nicolette@berkeley.edu*
***A functional neuropeptide system in avian gonads***
Several hormone systems identified in the vertebrate brain and classified as neurohormones are synthesized in and have a localized action on the gonads. The expression and action of GnIH (gonadotropin inhibitory hormone) has been characterized in the hypothalamus and pituitary, respectively. The action of this neurohormone is to inhibit the synthesis and secretion of luteinizing hormone and follicle stimulating hormone from the pituitary. Despite knowledge of the presence of transcripts and mature forms of GnIH and GnIH receptor (GnIHR) in vertebrate gonads, a functional role for the gonadal GnIH system has remained unclear. The nature of this system in the gonads may be very different from its more characterized counterpart in the central nervous system. Here we present several lines of evidence for the expression and action of GnIH and GnIHR in the testis of house sparrow (Passer domesticus) and European starling (Sturnus vulgaris). Using coamplification RT-PCR with an endogenous control (β-actin), we show that the testes of photorefractory, non-breeding, European starlings produce significantly more mRNA for GnIH and GnIHR than the testes of photostimulated, breeding, starlings. Using house sparrow testis culture and EIA, we demonstrate that GnIH significantly reduces testosterone production. These data indicate a role for gonadal GnIH in maintenance of gonadal regression on a seasonal basis and rapid suppression of gonadal steroid release within the breeding season.

***78.4*** MCLEAN, K.E.*; VICKARYOUS, M.K.; Univ. of Guelph, Guelph ON; *kmclean@uoguelph.ca*
***Reparative regeneration in a novel amniote model***
Reparative regeneration is a dramatic phenomenon in which lost or injured structures and tissues are redeveloped. In extreme cases, reparative regeneration can reproduce entire appendages. We investigated the tissue level events that occur throughout redevelopment of the tail in the leopard gecko, *Eublepharis macularius*. Changes in tissue structure and composition of the regenerating tail were investigated at various times throughout regeneration using histochemistry and immunohistochemistry. Tail regeneration begins with a latent period during which time wound healing takes place. Once the wound is capped by epithelium proliferation begins, forming an aggregation of mesenchymal-like cells known as the regeneration blastema. Continued growth of the blastema is matched with angiogenesis, and regeneration of the nervous system (e.g., the ependymal tube and peripheral nerve axons). The skeleton is one of the last organ systems to form, although vertebrae are never redeveloped. Instead a cone-shaped cell condensation forms around the regenerating ependymal tube. This condensation matures into a cell-rich, matrix-poor cartilage that continues to proliferate during tail growth, primarily along the periphery and distal end of the cone. Our findings indicate that while the initial events of reparative regeneration are highly conserved among tetrapods, subsequent patterning gives rise to a functionally similar but structurally distinct appendage.

***1.5*** MEDINA-RUILOBA, Haydee; STILLMAN, Jonathon H.*; San Francisco State University; *stillmaj@sfsu.edu*
***Species differences in the effects of exercise on the stability of the glycolytic enzyme LDH in porcelain crabs***
Glycolytic activity in anaerobic tissues is maintained by the redox enzyme lactate dehydrogenase (LDH). In addition to generation of ATP, LDH activity allows glycolysis to continue during physiological hypoxia by the recycling of $NAD^+$ and production of lactic acid. Because enzymatic proteins are only marginally stable, acidification can destabilize enzymes and reduce their functionality. LDH stability in 22 species of porcelain crabs varies by over several orders of magnitude, and is due to both intrinsic differences in the LDH molecule and, in species with high-stability LDHs, LDH-specific extrinsic protein stabilizers. We hypothesize physiological hypoxia induces the protein stabilizers. Crabs were exercised to exhaustion on three consecutive days or held as controls. Two species of porcelain crab were studied, one with (*Petrolisthes donario*) and one without (*Petrolisthes cinctipes*) extrinsic protein stabilizers. Aliquots of claw muscle homogenate supernatant were heated at 70°C for intervals between 0 and 60min. Residual LDH enzymatic activity assessed spectrophotometrically and time to 50% activity loss (half-life) calculated. In *P. donario*, LDH stability was significantly increased by exercise; mean half-life ranged from 100min in control to 2000min in exercised specimens. In contrast in *P. cinctipes* LDH stability was not significantly affected by exercise; mean half-life was 48min in control and 67min in exercised specimens. Work is presently underway to determine specific protein-interactions affected by exercise using co-immunoprecipitation as well as gene expression responses following exercise using cDNA microarrays in the same specimens from which LDH stability was assessed. Supported by NIH SCORE grant S06 GM52588 to JHS.

***S11.12*** MEHTA, R.S*; WARD, A.B; ALFARO, M.E; WAINWRIGHT, P.C; Univ. of California, Davis, Adelphi University, Univ. of California, Los Angeles; *rsmehta@ucdavis.edu*
***Morphological Correlates to the Evolution of Elongation in Elopomorph Fishes***
Body shape has had profound effects on how organisms make their living. Long, slender body forms have evolved multiple times in teleosts and are associated with diverse behaviors such as undulatory locomotion, head-first and tail-first burrowing, and knotting around prey. Despite current interest in understanding the molecular, developmental, and anatomical basis for elongation, few studies have examined the diversity of elongation within a clade and what characters may be correlated with increases in vertebral number. Elopomorph fishes are an extremely diverse clade of teleosts that contain bone fish, tarpon and a large radiation of elongate and limb-reduced 'true eels.' A recent study revealed that at least two patterns of elongation have occurred in the Elopomorpha: an increase in caudal vertebrae with no increase in abdominal vertebrae and the converse. Here we use the Elopomorpha as a model for understanding the effects of elongation on morphology associated with feeding and locomotion. Using an elongation index, we examine 50 elopomorph taxa in an attempt to understand how characters such as head length, branchial arch displacement, and fin shape correlate with increases in vertebral number. Our preliminary results reveal that increases in vertebral number are correlated with head length but this relationship is not as strong as we anticipated. We also find a relatively weak relationship between branchial arch displacement and vertebral number. Lastly, using information from the literature, we will discuss how these morphological relationships relate to dietary breadth in Elopomorphs.

***95.1*** MEJIA-ORTIZ , L. M.*; LOPEZ-MEJIA, M.; Biospeleology & Carcinology Lab. Universidad de Quintana Roo, Evolutionary Biology & Population Genetics, Universidad de Quintana Roo; *luismejia@uqroo.mx*

***The progressive adaptation degrees in the lipid storage structure of cave crayfishes***

We made a histological analysis of hepatopancreas structure of three crayfishes species. Two from karst caves: *Procambarus cavernicola and Procambarus oaxacae reddelli, and the third from epigeal river nearby Procambarus olmecorum in order to determine the adaptation degree to cave life in relationship with this structure. The histology of the organ was examined by paraffin sections; the tissues were dehydrated in ethanol, and transferred through methylbenzoate into paraplast. Sections of 5 µm were stained with haematoxylin-eosin method (HE). We found that the cave species develop different tubules in their hepatopancreas structure. However, there are evident differences between Procambarus cavernicola and Procambarus oaxacae reddelli, because the former species shown more and larger tubules, in contrast, the epigeal crayfish not develop these tubules.*

***38.5*** MENDONCA, M.T*; PATTERSON, S.T.; Auburn University; *mendonca@auburn.edu*

***Relationship between corticosterone, immune response, and parasite load in two species of tropical anurans (Chaunus marinus and Agalychnis callidryas).***

There is little information on patterns of stress responsiveness and immunocompetence in amphibians in general and in tropical species of amphibians in particular. We explored the relationship between these two physiological parameters in two species, the cane toad, *Chaunus marinus*, and the red-eyed tree frog, *Agalychnis callidryas*, from La Selva, Costa Rica and related them to parasite load as well as sex and body condition. We bled wild individuals within 3 min of capture to establish baseline levels of corticosterone, complement activity (measured with a functional bacterial lysis assay), and blood leukocyte numbers as well to quantify blood parasite loads (the first two measures from plasma, the last two from whole blood smears). We then restrained these individuals in bags for 60 min, rebled them, and then measured changes in leukocyte profiles, bactericidal activity, and corticosterone. We found that, in the initial sample, cane toads had significantly more blood parasites and higher eosinophil numbers than red-eyed tree frogs though neutrophil/lymphocyte ratio did not differ significantly between the two species. There was a significant difference ($p=0.01$) between the species in bactericidal ability, with cane toads showing a higher ability to respond to a standard bacterial challenge (i.e. 60% vs. 38.1%). However, this low bactericidal activity in the red-eyed tree frogs was due to a significant sexual dimorphism in response: males exhibited much lower competence than females (28% vs 70%; $p=0.004$). There was no sexual dimorphism in bactericidal ability in cane toads. Corticosterone levels increased between the 0 and 60 minute sample period but the change was not significant in either species. Further relationships among corticosterone, blood profiles and bactericidal activity time courses will be discussed.

***20.2*** MENDOZA BLANCO, M.A.; PATEK, S.N.*; Univ. of California, Berkeley, Univ. of Massachusetts, Amherst; *marco_mendoza@berkeley.edu*

***Comparative muscle physiology of the mantis shrimp's raptorial appendage***

Some mantis shrimp (Crustacea: Stomatopoda) deliver forceful blows with hammer-like appendages (“smashers”), while other species use elongated spears to pierce or grab prey (“spearers”). To accomplish these incredibly fast movements, mantis shrimp use extensor muscles in the merus segment of their raptorial appendages to load elastic exoskeletal structures while flexor muscles engage latches to hold the system in place. Once ready to strike, the flexor muscles relax, the latches release, and the appendage rotates forward at remarkable speeds and accelerations. We examined variation in the lateral extensor muscle across stomatopods using physiological cross-sectional area (PCSA) and sarcomere length (SL). PCSA represents relative muscle force and was calculated by measuring the mean pinnation angle and apodeme area (15 species, 60 individuals). SL provides a relative measure of the rate of muscle fiber contraction, with longer sarcomeres yielding more forceful contractions and shorter sarcomeres yielding greater contraction speed. We measured muscle fibers sampled from 4 regions of the muscle (11 species and 30 individuals). PCSA and apodeme area were positively correlated with merus and body size in all species. “Smashers” had relatively larger merus lengths and associated PCSA than “spearers”; however, pinnation angle was similar (37-38°) across all measured taxa. Smasher sarcomeres were 11-13 µm long while spearer sarcomeres were 8-10 µm. In conclusion, smashers have both higher PCSA per body size and greater SL than spearers. These results suggest that smasher muscle physiology is tailored toward greater force whereas spearer physiology is geared toward higher speed contractions. Thus, mantis shrimp have evolved distinct patterns of muscle anatomy and physiology which may underlie their remarkable variation in prey-capture strategies.

***38.10*** MERRILL, L.*; ROTHSTEIN, S.I.; O'LOGHLEN, A.L.; WINGFIELD, J.C.; University of California, Santa Barbara, Univesity of California, Davis; *lmerrill@lifesci.ucsb.edu*

***Changes in the innate immune systems of male and female brown-headed cowbirds in response to CORT: why do the sexes differ?***

There is substantial evidence indicating that stress causes a reduction in immune function in many animals. Potential causes for this change in immune activity range from a reallocation of shared resources to the avoidance of immunopathology. To gain a better understanding of the relationship between stress and immune function we have been examining the effects of acute stress on innate immunity in Brown-headed Cowbirds (*Molothrus ater*). Stress responses were initiated via capture and handling, and also via artificially elevated levels of the stress hormone corticosterone (CORT). CORT was injected into mealworms which were fed remotely to cowbirds so as avoid an associated stress event. Male cowbirds exhibited a significant decrease in immune function (bactericidal capacity of the plasma) following both handling and CORT manipulation, whereas female cowbirds exhibited no change in immune function following either manipulation. We will be examining levels of corticosteroid binding globulins (CBGs) to determine if the differences in changes in bactericidal capacity are related to variation in levels of CBGs. Female cowbirds may exhibit elevated levels of CBGs to mitigate the effects of a stress response in order to maintain reproductive function during the breeding season.

***91.1*** MEYER, NP*; SEAVER, EC; Kewalo Marine Lab, PBRC, Univ. of Hawaii, Honolulu, HI; *nmeyer@hawaii.edu*
***Cellular and molecular mechanisms of brain development in the annelid Capitella teleta***
*Capitella teleta* (formerly *Capitella* sp. I) is a polychaete annelid whose central nervous system (CNS) consists of a dorsal, anterior brain, circumesophageal connectives and a ventral nerve cord with reiterated ganglia. This organization is similar to many other annelids and structurally resembles the basic arthropod CNS. However, recent phylogenomic data indicates that centralized nervous systems may have evolved independently between these two animal lineages. Much of our understanding of the mechanisms controlling CNS development comes from detailed studies in two of the three major bilaterian clades, ecdysozoans and deuterostomes. Consequently, it is important that we elucidate mechanisms of CNS development in the third bilaterian clade, the lophotrochozoans. To address this, we have assembled a detailed molecular and cellular description of early brain neurogenesis in the lophotrochozoan annelid *C. teleta* utilizing several different approaches. In *C. teleta* brain neurogenesis proceeds by the ingression of single cells from the anterior ectoderm to generate a stratified epithelial layer. Cell divisions are apically restricted, while neural differentiation markers are basally localized. Prior to and during neural precursor ingression, a proneural *achaete-scute* homolog, *CapI-ash1*, is apically expressed in patches of anterior ectoderm with varying levels of intensity. Furthermore, functional analysis indicates that *CapI-ash1* may be involved in fate specification of neural precursors and/or their differentiation, but not ingression. These results suggest that some cellular mechanisms of *C. teleta* brain neurogenesis are shared with arthropod CNS development, although the function of *CapI-ash1* may be more similar to proneural gene function during vertebrate neurogenesis.

***S9.1*** MEYER, N. P.; BOYLE, M. J.; MARTINDALE, M. Q.; SEAVER, E. C.*; University of Hawaii; *seaver@hawaii.edu*
***The complete cell lineage of the polychaete annelid Capitella teleta***
The polychaete annelid *Capitella teleta* (formerly *Capitella* sp. I) exhibits a spiral cleavage program, and has been the recent focus of several developmental studies aided by a fully sequenced genome. The life history of *C. teleta* includes formation of a lecithotrophic, metatrochophore larva with a simple metamorphic transition to the juvenile worm. Fate mapping in polychaetes has lagged behind maps generated for other spiralian taxa due to technical limitations. Using diI and confocal microscopy, we injected individual blastomeres through the formation of the fourth quartet of micromeres. Subsequent development was followed to characterize ultimate blastomere fates with single cell resolution during larval stages. Our results corroborate previous observations from classical studies and show a number of similarities with fate maps of other spiralians including: unique and stereotypic fates for individual blastomeres, presence of four discrete body domains arising from the A, B, C and D cell quadrants, and both ecto- and endo- origins of mesoderm. However, several features of *C. teleta* development show modifications of the typical spiralian fate map. For example, although 2d generates trunk and pygidial ectoderm, our analysis of the 2d sublineage reveals separate origins of the larval neurotroch and telotroch versus the definitive adult trunk ectoderm. In addition, we have identified at least five distinct cellular origins of mesoderm in *C. teleta*, including cells of the second quartet. The significance of these observations will be discussed by comparison with other annelid and spiralian fate maps.

***22.4*** MEYER, E*; MATZ, MV; University of Texas, Austin; *EliMeyer@mail.utexas.edu*
***Expression profiling coral responses to thermal stress and settlement cues using RNA-Seq***
Quantitative transcriptome analysis using next-generation sequencing methods (RNA-Seq) has become an important tool in functional genomics, but this approach has mostly been limited to a handful of model systems with sequenced genomes. Our recent sequencing and annotation of the transcriptome for a reef-building coral (*Acropora millepora*) has provided a set of reference sequences to allow RNA-Seq expression profiling for this species. We have developed a simple method for cDNA sample preparation for sequencing using SOLiD, a short-read technology with massive throughput (10s of millions of reads). Using this platform, we characterized the changes in global gene expression profiles of coral larvae in response to elevated temperatures and settlement cues. About one million reads from each sample were mapped to the transcriptome, providing quantitative estimates of expression levels for more than 10,000 genes in each treatment. These data revealed reproducible differential expression for hundreds of genes in response to a natural settlement cue and an artificial peptide inducer of metamorphosis, identifying candidates that include putative receptors and morphogens. Similarly, reproducible differences in expression profiles during short- or long-term thermal stress identified novel candidates for this widely-studied process. The changes in expression levels of selected candidates were validated by qPCR, confirming the utility of RNA-Seq for expression profiling in this system and supporting the involvement of these candidate genes in coral responses to thermal stresses and settlement cues. Because these traits are likely to be adaptively important for corals faced with increasing sea surface temperatures, these findings provide important new insights into the potential for survival and adaptation of corals during climate change.

***67.9*** MEYER, Erin; Univ. of California, Berkeley; *emeyer@berkeley.edu*
***Population structure of a snail caught in a matrix of culture, economics, and political geography***
The intertidal habitat is frequently overlooked in both terrestrial and marine conservation. In the West Indies, there are several hundred protected areas, but none of them extend into the intertidal. *Cittarium pica* is the largest rocky intertidal gastropod and has a geographic range restricted to islands of the West Indies, with an irregular distribution in the southern Caribbean. Since the region was first colonized, humans have harvested this long-lived snail as not only a food resource, but also as bait, tools, and ornamental shells. Because of its life history and the recent increase in fishing pressure on the species, *C. pica* is of growing concern to fisheries managers in the region. Although, it is currently included in a few management plans (e.g. Guadeloupe, Puerto Rico, Turks and Caicos Islands, U.S. Virgin Islands), there are no empirical data on the fishery. This study assesses 1) the level of fishing pressure in 13 island groups in the West Indies and 2) the effect of human demographic, social and economic factors on size structure of *C. pica* populations. These data combined with ongoing studies of population genetic structure and habitat preferences are vital to informing conservation and management decisions. Over three field seasons, I have traveled to 22 islands in 13 island groups, where I collected data on the size structure at 42 different sites, including five sites in Bermuda where *C. pica* is fully-protected. The largest size classes (≥70mm) were uniformly missing within all island groups, except for the Turks and Caicos Islands, the Bahamas, and Bermuda – the only location where individuals greater than 100mm were found. Preliminary results are thus far consistent with the hypothesis that human population density, socio-economic factors, and enforced fishing regulations may help to explain the presence or absence of the larger size classes.

***22.5*** MEYER, E; WANG, S; AGYAMOVA, G; MATZ, M*; University of Texas at Austin; *matz@mail.utexas.edu*
***Quantitative genetics and genomics of reef-building coral Acropora millepora***
Next-generation sequencing and genomic analysis are increasing the rate of biological discovery, but have often been limited to a handful of model systems with sequenced genomes. Their application has lagged behind for the many (potentially more interesting) organisms that exemplify important biological questions but lack completed genome sequences. Reef-building corals provide a prime example. The recent degradation of coral reefs raises important questions of genetic control of thermal tolerance and adaptation to elevated temperatures, but the genomic resources required to address these questions have been unavailable. To fill this void, and develop a framework for the application of genomic approaches to other emerging models, we are applying high-throughput sequencing methods to the branching coral Acropora millepora. We used 454 sequencing to assemble and annotate the transcriptome of a larval stage, identifying about 11,000 genes that include the complete sets of genes for many metabolic pathways. The availability of these cDNA sequences has enabled measurement of gene expression by qPCR. Polymorphisms detected in these sequences have enabled the construction of a high-resolution genetic map for this species, the first reported for any coral. The transcriptome sequence has also served as a reference for quantitative transcriptome profiling using SOLiD sequencing. We have used this approach to profile gene expression in coral larvae exposed to thermal stress and settlement cues, indentifying many novel candidate genes for these processes. These studies demonstrate the utility of applying genomic approaches to enable rapid biological discovery in non-model systems.

***27.6*** MICHEL, K.B.*; STEWART, W.; MULLER, U.; MCHENRY, M.J.; University of Groningen, Univ. of California, Irvine, California State University Fresno; *krijn.michel@gmail.com*
***The role of flow sensing in the undulatory swimming of teleost fish (Notemigonus crysoleucas)***
Fish use a variety of sensory systems to direct and control swimming. Although flow sensing aids a fish's ability to orient in their environment, it is unclear whether this modality provides information to control the swimming motion. We evaluated the role of flow sensing in locomotion by comparing the steady-swimming kinematics of fish (*Notemigonus crysoleucas*) before and after pharmacologically ablating the mechanosensory lateral line system. At higher speeds (1.1 and 2.2 body lengths/s), we found no significant difference between fish before and after the ablation. However, at low speed (0.45 body lengths/s) fish lacking lateral line signals moved with significantly greater lateral amplitude along the length of the body. Hydrodynamic theory suggests that these kinematics create greater drag, and consequently require an elevated energetic demand, relative to fish having an unaltered lateral line system. These results suggests that fish use the lateral line system to mediate swimming kinematics for enhanced efficiency at slow, but not fast, swimming speeds.

***5.2*** MIDDLEBROOKS, Michael L.*; BELL, Susan S.; PIERCE, Sidney K.; Univ. of S. Florida; *mlmiddle@mail.usf.edu*
***Chloroplast retention and satiation in the photosynthetic sea slug Elysia clarki***
Several species of Sacoglossan sea slugs can photosynthesize using sequestered algal chloroplasts. The duration that the chloroplasts retain function varies among slug species. One of the longer lasting examples of kleptoplasty is *Elysia clarki*, which can maintain chloroplasts for up to 12 weeks without feeding. While chloroplasts are present inside *E. clarki*'s digestive cells for that duration, the rate at which they decline has not been demonstrated. Nor has the relationship between satiation and feeding behavior of the slugs been examined. Therefore, the progression of chloroplast loss and the effect on feeding behavior in E. clarki over several months was tested using chlorophyll concentration as a proxy for chloroplasts. Slugs were starved for 4, 8, or 12 weeks and compared to a control group that had continuous access to food. Feeding behavior was determined as whether or not slugs would exhibit feeding behavior within five min after exposure to algae. Once feeding behavior was determined, chlorophyll was measured (µg chl/g dry wt). Slugs starved for 4, 8, and 12 weeks exhibited similar feeding behavior, but unstarved control slugs were less likely to feed, most likely due to satiation. Moreover, in slugs starved for 4 or 8 weeks or fed continuously there was no significant difference in chlorophyll concentration. However, the chlorophyll concentration of slugs starved for 12 weeks was statistically lower than slugs from other treatments. This suggests that chloroplast numbers remain constant in *E. clarki* for 12 weeks post feeding at which point the slugs must feed again. Over a 12 week period slugs will feed when food is available, but they are able to obtain energy from photosynthesis if food is absent. This is the first time that feeding behavior has been examined in regards to chloroplast retention in a photosynthetic animal.

***36.6*** MILES, D B; Ohio University; *dmiles2@ohio.edu*
***Climate Change Perturbs Activity Patterns, Social Structure and Population Dynamics of the Lizard Urosaurus ornatus.***
Climatic patterns in the arid southwest are characterized by cycles of normal or wet years interspersed by episodes of drought. One signature of global climate change in the southwest is an increase in frequency of El Niño-Southern Oscillation events, warmer temperatures and shifts in rainfall patterns. Climate change may profoundly influence species population dynamics by altering key life history traits, e.g., clutch size, social structure and survival. *Urosaurus ornatus* is a common lizard found throughout the arid southwest. Both males and females display a polymorphism in throat coloration. Lizards inhabit mesquite trees in the upper bajada habitats of the Rincon Mountains, Arizona; the availability of trees varies with ENSO events due to drought stress. Male morphs are characterized by three mating strategies: dominant, satellite males, and sneaker male. Each male morph varies in dominance status, activity patterns and attractiveness to females. The response to climatic variation is contingent on throat morph. Dominant males have a fitness advantage during wet years by virtue of attracting multiple females. However, survival in drought years is lower for these males relative to survival in wet years. Climatic conditions affects local density and frequency of morphs, the thermal environment as well as resource availability. During drought years, fewer trees are available for lizards raising lizard density per tree. Individuals also have reduced activity times, which limits social interactions, foraging success and energy acquisition, and survival probability. ENSO cycles drive temporal variation in natural selection that differentially favors throat morphs, individual body size and physiological characteristics (e.g., sprint speed and endurance). Differential patterns of natural selection are manifested as changes in adult body size, which in turn results in variation in population density.

***73.2*** MILLER, A/L; University of Tampa; *abraham.miller@ut.edu*
***Friend or Foe; Behavioral Responses to Pheromones of Conspecifics in the northern scorpion, Paruroctonus boreus***
I investigated the behavioral response of male Paruroctonus boreus to male and female conspecifics. Adult male scorpions actively search for females during the mating season, while lacking visual cues to direct their movement. Chemical cues (pheromones) are thought to be responsible for directing movement. In a series of laboratory experiments, in Y-mazes, males were exposed to areas that had contained males and females from the same population and areas that had contained conspecifics from different populations. Males spent significantly more time in areas that had contained females from the same population but did not show a preference for areas exposed to females from different populations. Males also significantly avoided areas exposed to males from the same population. My results suggest that P. boreus exhibits a sex specific response to pheromones and that this response may be population specific.

***11.5*** MILLER, C.E.*; REN, L.; HUTCHINSON, J.R.; Royal Veterinary College, University of London, Kings College, University of London; *cmiller@rvc.ac.uk*
***Cushioning the blow: Foot-substrate interactions in elephants***
Although the external features of the elephant's foot appear relatively simple, the underlying anatomy is far more complex, comprising a full complement of five 'true' digits, and a cartilaginous rod, known as the 'predigit'. These bones are embedded in a large, fatty, fibrous foot pad, which is in turn encased in a thick, highly keratinised slipper of skin. In walking the foot rolls over from heel to toe, with a lateral bias in pressure distribution, and a medial shift during toe-off, much like that seen in apes and humans. The fatty heel pad deforms significantly under the applied forces. But what happens below the surface? How do the digits and predigits react to load? Here we use computed tomography (CT) scanning to track the movements of the bones and cartilaginous structures of the elephant's foot under controlled load application. We assess these internal movements in the context of external deformations recorded using motion analysis techniques *in vivo*, and in cadaveric studies under controlled loading conditions. We focus on the movements of the predigits, whose function is postulated as support to prevent collapse of the fatpad under load. In addition we compare differences in fore and hindlimb loading conditions with differences in the underlying anatomy. By gaining a better understanding of the biomechanics of the elephant's foot, the area of interaction between the largest living land animal and the ground, we can gain insight into other, less extreme animal-substrate interactions, and gain a better understanding of the energy storage and vibration damping mechanisms involved.

***70.3*** MILLER, L. A.*; HEDRICK, T.; SANTHANAKRISHNAN, A.; ROBINSON, A.; University of North Carolina, Chapel Hill, California Institute of Technology; *lam9@email.unc.edu*
***Flying and parachuting in the smallest insects***
A vast body of research has described the complexity of flight in insects ranging from the fruit fly, Drosophila melanogaster, to the hawk moth, Manduca sexta. Over this range of scales, flight aerodynamics as well as the relative lift and drag forces generated are surprisingly similar. The smallest flying insects have received far less attention, although previous work has shown that flight kinematics and aerodynamics can be significantly different. In this presentation, we have used a three-pronged approach that consists of measurements of flight kinematics in the tiny insect Thysanoptera (thrips), measurements of flow velocities using physical models, and direct numerical simulations to compute lift and drag forces. From high speed videos, we find that thrips use clap and fling during flight and occasionally stop flapping and apparently parachute. Using physical models and CFD, we find that drag forces generating during clap and fling can be an order of magnitude larger than lift forces. The potential ecological consequences of flight performance will also be discussed.

***101.10*** MITCHELL, Terence RT; Johns Hopkins University; *tmitche9@jhu.edu*
***The role of binocular vision in mammalian locomotion***
Most vertebrates possess some overlap of the right and left visual fields. The region of overlap, the binocular field, contains visual cues that provide an accurate estimate of distance and three-dimensional shape. Primates have large binocular fields and theories of primate origins incorporate convergent eyes as part of the crown primate adaptational suite. Adaptational hypotheses must provide a functional role for a given trait if we are to believe evolution had a role in shaping any form – function complex. To date there is no experimental evidence demonstrating a role for binocular vision in ecologically relevant animal behavior. I predict that binocular vision is useful for guiding locomotion on complex substrates. I tested this by analyzing kinematic data of three Lemur catta, Felis catus, and Rattus norvegicus walking on continuous and discontinuous substrates under binocular and monocular conditions. All three species were effected by a loss of binocular cues. Lemurs exhibited the greatest change with a decrease in speed, increase in limb excursion, increase in crouching, and dramatic changes to wrist trajectory under monocular conditions. Guidance of locomotion on complex substrates provides one explanation as to why most vertebrates have some visual field overlap, and why all extant primates have large binocular fields. Primates have developed a host of adaptations related to locomotion in arboreal environments at large body size relative to substrate diameter. Long mobile forelimbs are used to bridge gaps and distribute weight in a complex discontinuous environment, and require a sensory system that can estimate distance and three-dimensional shape for the next few hand placements. Future theories of primate origins need to incorporate the growing body of evidence on primate locomotor adaptations.

***103.2*** MOLL, K*; FEDERLE, W; Cambridge University, UK; *km498@cam.ac.uk*

***Biomechanical Problems of Load Transport: How Grass-Cutting Ants Avoid Falling Over***

The influence of loads on running locomotion has been studied in many arthropods. However, most studies have only considered the effect of load mass but not mechanical problems associated with load shape. The challenge posed by load shape is particularly obvious in grass-cutting ants, where individual workers carry grass blades many times longer than the ants themselves. In this study we separately investigated the influence of fragment mass and length on walking and carriage behaviour in the ant *Atta vollenweideri*, using 3D and 2D high-speed video analysis. Ant workers were brought to transport standardized paper fragments of different mass but constant length and width, as well as fragments of different length, but constant mass. To avoid falling over, the ants transport the fragments in an upright position that is slightly tilted backwards. We found that longer fragments were held in a more upright position, thereby reducing the backward shift of the centre of mass. This change is achieved by controlled head movements. By contrast, fragments of different mass but constant length were carried with the same fragment angle. The ants' running velocity was significantly reduced when carrying the long but not when carrying the heavy fragments. Duty factor increased significantly for both mass and length, but fragment length had a stronger influence. Workers did not always lift their hind legs when moving them forward, but slid them on the surface to maintain stability. Consistently, sliding frequency only increased when ants carried long fragments. Our study demonstrates that mechanical problems such as the risk of falling over are crucial for load carrying performance.

***101.4*** MONGEAU, J.-M.*; JAYARAM, K.; LEE, J.; FULL, R.J.; COWAN, N.; University of California, Berkeley, Johns Hopkins University, Johns Hopkins University; *jmmongeau@berkeley.edu*

***Mechanical Feedback of Antenna-Substrate Interaction Simplifies Cockroach Antennal Navigation***

During high-speed wall following cockroaches rely on mechanosensory structures in their antennae to follow surface contours reliably, providing critical feedback for task-level control. The unactuated antenna flagellum assumes a characteristic inverted-J posture during this behavior. Results from our behavioral studies in *Periplaneta americana* suggest that antenna buckling is necessary for maintaining a steady body position relative to a wall surface. Sensitivity analysis predicts that this posture reduces the error in the estimate of wall distance when compared to a straight antenna. We hypothesized that mechanical feedback resulting from the interaction between large mechanosensory hairs on distal flagellar segments and surface asperities induce Euler buckling during wall following, thereby simplifying the control of preferred antenna posture. To test this hypothesis we compared antenna-buckling behavior in running, blinded cockroaches and in freshly ablated antennae. By varying surface roughness, we showed that antennae on smooth surfaces don't bend, while on rough surfaces, irrespective of orientation, antennae engage the surface producing J-shape bending, suggesting a passive mechanism. To test whether mechanosensory hairs are directly implicated in facilitating buckling, we performed single hair displacement experiments. We identified that distally pointing sensilla possess a limited range of motion (30-40°) facilitating engagement of rough substrates. We hypothesize that constraints on the range of motion promote buckling by maximizing the moment arm between the antenna flagellum and the substrate. Our results suggest that passive mechanical feedback can simplify control of antennal sensory structures.

***20.3*** MONROY, JA; UYENO, TA; GILMORE, LA; POWERS, KA; NISHIKAWA, KC*; Northern Arizona University; *Kiisa.Nishikawa@nau.edu*

***Activation changes the length and stiffness of elastic elements in soleus muscles of wild-type mice, but not in titin mutants.***

Here, we test the hypothesis that Ca2+-activation of muscle results in binding of titin to the thin filament, reducing its length and increasing its stiffness compared to passive muscle. To test the hypothesis, we used mdm mice, which carry an 83 amino acid deletion in the N2A region of titin. Mdm genotypes differ in both passive and active elasticity of the soleus muscles. Passive tension is greater in homozygous mdm mice than in wild-type mice, and intermediate in heterozygotes. We used load-clamp tests to quantify elastic recoil during rapid unloading. In contrast to passive stiffness, active stiffness in load clamp tests was lower in mdm homozygotes than in wild-type mice. To examine the effect of activation on elastic properties, we compared elastic recoil in active soleus muscle at 30% P0 to that observed in the same muscles passively stretched to a length at which the force was equal to that of the activated muscle. In wild-type mice, activation shortened and stiffened spring elements compared to passively stretched muscle at the same force. In mdm homozygotes, there was no change in spring length or stiffness. Results suggest that an epitope of titin binds to the thin filament upon Ca2+-activation in normal mice and this epitope is deleted in mdm mutants. The hypothesis that titin binds to the thin filament in active muscle also accounts for observations that the shape of the length-tension curve depends upon the level of muscle activation, and that muscle force depends on the phase of stimulation in work-loop experiments. It also provides an elastic mechanism for enhancement of force with stretch and depression of force with shortening.

***16.4*** MONTGOMERY, M.S.*; MUNRO, E.; SHERRARD, K.; ROBIN, F.; Univ. of Washington, Seattle; *monicm2@u.washington.edu*

***Initiation of Neural Tube Closure in Ciona Intestinalis***

Ascidian neural tube closure (zippering) is initiated by the assembling of cells and materials at a posteriorly located center we are calling the zipper origin. The zipper origin as a structure has not previously been described in the literature. To advance our understanding of the prospective identity and morphological change of cells in contact with the zipper origin, we created 3-D reconstructions through Amira and 3-D Virtual Embryo of early neurula we fixed and stained in phalloidin. We find that posterior-most muscle, neural plate, notochord, and epidermal cells meet as they extend towards the zipper origin. With time-lapse imaging and confocal microscopy, we show that initiation of neural tube closure occurs by three main events: 1) cinching of the apical ends of muscle cells lining the closing blastopore; 2) rolling-inward of the two posterior-most roof cells; and 3) crawling of posterior epithelial cells towards the zipper origin. We provide evidence that this gathering at the zipper origin is significantly driven by myosin contractility. We find the presence of monophosphorylated nonmuscle myosin II at the same time and location of blastopore closure and building of the zipper origin. We also find diphosphorylated nonmuscle myosin II concentrated at the zipper origin at earlier and later stages corresponding to the time of initiation of neural tube closure. We show further that inhibition of nonmuscle myosin II through the Rho kinase pathway causes a drastic disassembly of material already collected at the zipper origin and significant deformation of zipper-initiating cells. Our results show that activation of Rho kinase and myosin II is necessary to initiate tube closure. With reduced myosin contractility, formation of the neural tube does not occur, indicating the motor protein's role as an indispensable biomechanical device.

***59.6*** MOORE, I.T.*; VALIN, M.; CASASANTA, M.; EIKENAAR, C.; HUSAK, J.F.; Virginia Tech, University of South Dakota; *itmoore@vt.edu*

***Testosterone and latitude in reptiles and amphibians***

Latitudinal variation in life history characteristics has long been the focus of ecologists. One of the best examples has been latitudinal variation in clutch size with tropical vertebrates laying fewer eggs and having smaller litters than higher latitude species. More recently physiologists have also described latitudinal variation in a variety of processes that suggest tropical organisms exhibit a slower pace of life than their higher latitude counterparts. One prominent example has been the description of latitudinal variation in testosterone levels in birds. There is a positive relationship between testosterone and latitude in birds with tropical species typically having lower levels than higher latitude species. Similarly, a positive relationship between testosterone and altitude also exists in birds. However, it is unclear if these relationships are a direct result of abiotic factors associated with latitude and altitude or are rather associated with social factors such as mating system and degree of paternal care. It is also unclear if such a relationship exists in other groups of vertebrates. We are investigating if there is a relationship between testosterone and latitude and altitude in both reptiles and amphibians. Reptiles, in particular, have much less variety in mating systems than birds and thus provide an opportunity to investigate if the relationships between environmental factors and testosterone are direct or associated with related social factors. If similar relationships exist between testosterone and latitude and altitude in a variety of taxa, this suggests that environmental factors may be a stronger determinant of testosterone levels than social factors.

***103.6*** MOORE, T.*; BURDEN, S.; REVZEN, S.; FULL, R.J.; Univ. of California, Berkeley; *taliayuki@berkeley.edu*

***Adding Inertia and Mass to Test Stability Predictions in Rapid Running Insects***

A spring-mass model for the horizontal plane dynamics of sprawled running animals (Lateral Leg Spring Model) predicts that added inertia reduces stability and increases the time required to recover from a perturbation. To empirically test this model, we perturbed cockroaches while running across a platform inserted into a track. Cockroaches (*Blaberus discoidalis*; N=9, 2.17 g mass, 2.18 g*cm$^2$ moment of inertia) ran along the surface of the platform at 31±6 cm/sec with a stride frequency of 12.5±1.7 Hz. We accelerated the platform (10 cm x 25 cm) laterally at 0.6±0.1 g in a 0.1 sec interval providing a 50±3 cm/sec velocity change from the impulse. We affixed one of three backpacks on the cockroach to change its inertia distribution and mass. We used a computer vision-based tracking of body roll, pitch, yaw, leg position, and velocity on the translating platform. The control backpack increased the animal's mass by 36% and moment of inertia by 25%; the mass backpack increased mass by 84% and moment of inertia by 26%; the inertia backpack increased mass by 93% and moment of inertia by 865%. Animals equipped with the inertia backpack were not less stable than controls, thereby rejecting the prediction of the horizontal plane Lateral Leg Spring Model. Animals running with the mass backpack were least stable, showing greater body angular changes than other conditions. Larger angular body exercisions of the animals with mass backpacks were delayed by approximately one to two steps. Consistent with this delay was a lag in the change of lateral foot placement relative to the body axis along with its recovery to the pre-perturbation values. Results suggest that a three dimensional model is necessary even in sprawled- posture animals to test hypotheses of self-stabilization, and the role of both mechanical and neural feedback.

***S7.6*** MORAN, A.L.*; WOODS, H.A.; Clemson University, University of Montana, Missoula; *moran@clemson.edu*

***Temperature, Oxygen, and Body Size in the Southern Ocean: Why Might They Be Giants?***

In the Southern Ocean around Antarctica, many marine organisms have unusual life histories and physiological traits that are thought to be adaptations to low temperatures and high oxygen levels. One of these is ‘polar gigantism,’ in which some polar invertebrates reach much larger sizes than their temperate or tropical relatives. Using both nudibranchs and pycnogonids, we tested the hypothesis that polar gigantism is facilitated by cold-mediated low metabolic oxygen demands and high rates of diffusive oxygen delivery. We found that egg masses of Antarctic nudibranchs were on average >2X thicker than temperate masses, and contained embryos that were ~35-fold greater in volume. In addition, field and laboratory data showed that embryos in Antarctic masses were less oxygen-limited than those in temperate masses. However, a biophysical model predicted that Antarctic egg masses could reach substantially larger sizes, without greater internal hypoxia, than they in fact do. Using pycnogonids, which contain some of the best-known examples of polar gigantism, we found no effect of adult size on performance under hypoxia. A negative correlation would have demonstrated that larger animals cannot function under low-oxygen conditions, as would have been predicted if maximum body size were limited by oxygen diffusion. Thus, for both nudibranchs and pycnogonids, the oxygen-temperature hypothesis does not explain observed body size ranges; full explanations must be sought in the context of other ecological or evolutionary processes.

***101.11*** MORE, HL*; HUTCHINSON, JR; COLLINS, DF; WEBER, DJ; AUNG, SKH; CHEN, J; BEG, MF; DONELAN, JM; Simon Fraser University, Burnaby, BC, The Royal Veterinary College, London, UK, University of Alberta, Edmonton, University of Pittsburgh, PA, University of Alberta, Edmonton; *hmore@sfu.ca*

***Tradeoffs in responsiveness and resolution in the peripheral nervous system***

In order to investigate the physiological mechanisms used by small and large animals to coordinate their movements, we examined the effect of animal size on axon size, number, and conduction velocity. The time it takes an animal to sense and respond to stimuli (*responsiveness*) depends on axon diameter, and the ability of an animal to distinguish between sensory stimuli and generate graded muscle forces (*resolution*) depends on the number of axons per unit volume. Since nerve cross-sectional area depends on both these factors we hypothesized that, particularly in larger animals, there is a tradeoff between responsiveness and resolution in order to maintain nerve size within reasonable limits. To test our hypothesis, we used new electrophysiological experiments to determine maximum axonal conduction velocity in the sciatic nerves of the least shrew (*Cryptotis parva*) and Asian elephant (*Elephas maximus*), and combined these values with existing data for nine animals of intermediate size. We also used histological techniques and scanning electron microscopy to acquire and analyze images of shrew and elephant nerves. Our analysis demonstrated both that conduction velocity was nearly constant and that total axon number increased approximately with the cube root of mass over a 100-fold increase in leg length. These relationships result in longer delays and a decreased ability to precisely sense stimuli and control movement in larger animals, which may require larger animals to rely more on prediction to control movement and respond to their environment.

***103.4*** MORENO, C.A.*; BIEWENER, A.A.; Harvard University; *cmoreno@oeb.harvard.edu*

***A static model predicts the relationship between force and lean angle during dynamic turning in goats***

Evasive maneuvers and turning behaviors are critical components of a terrestrial animal's locomotor repertoire. To investigate the mechanics of such non-steady behaviors, we collected ground reaction forces (GRFs) and center of mass (COM) kinematics (speed, curvature) of goats as they trotted and galloped around a 90° turn. We first determined the roles of the individual limbs by comparing the linear and rotational impulses that each produced. In this study, we investigated the relationship between the lateral GRF produced by all four limbs and the body lean angle across a single turning stride. Body lean angle was defined as the angle between the global vertical and the vector from the goat's collective center of pressure (COP) to its COM. We found a strong correlation between the lateral GRF and the centripetal force calculated from the COM kinematics. We also found that the relationship between lateral GRF and body lean closely matched the curve predicted by a steady-state geometric model (lean angle = $\tan^{-1}$ ($GRF_{ML}/GRF_{VERT}$)). Interestingly, galloping strides fell above the predicted curve and trotting strides fell below the curve, possibly related to phase differences between the gaits. As predicted by the model, lean angle increased with speed for both trots and gallops. Comparing the body of a goat to a mechanical analog such as a car or a bicycle helps us understand the mechanism and trade-offs behind turning behaviors. At slow speeds, the animal acts more like a car: it simply redistributes forces among its four legs to produce the inward acceleration necessary to turn. At higher speeds, the animal becomes more bike-like: in addition to redistributing its limb forces, it also leans into the turn to a degree that is predicted by its mass, speed and COM trajectory.

***4.1*** MORGAN, S*; NGUYEN, M; ONOURA, C; TRAN, HT; DAVENPORT, IR; Xavier University of Louisiana; *idavenpo@xula.edu*

***Follicle Cell Processes in the bull shark Carcharhinus leucas***

Chondrichthyan fishes (sharks, skates, rays and chimeras) are apex predators in the marine environment. As such they have a life history strategy that favors few, but large offspring. The production of large, precocial offspring requires greater maternal input, either in the form of more yolk stored within the egg (lecithotrophy) or by maternal input directly to the embryo (matrotrophy). The progression towards matrotrophy also coincides with the switch from oviparity (egg laying) to that of viviparity (live bearing). Chondrichthyan fishes are a useful model for studying the evolutionary transition from oviparity to viviparity as they have species utilizing all the major steps. These steps include species that produce large externally laid eggs, large eggs retained within the female body cavity, production of uterine milk, oophagy and culminating in the yolk sac placenta. Our interests lie in the evolution of extremely large egg cells, namely the provisioning of these egg cells and in maintaining their structural integrity. Several years ago we showed the presence of a novel, actin-based, tube-like framework that might aid in the evolution of extremely large egg cells in two species of carcharhinid shark, the dusky smoothound *Mustelus canis* and the Atlantic sharpnose shark *Rhizoprionodon terraenovae*. We termed these structures, follicle cell processes (FCP). We are continuing to explore the phylogenic distribution of these structures and their ultimate role in oogenesis using light, fluorescence and electron microscopy. In the current study, we demonstrate the presence of FCP in a third species of carcharhinid, the bull shark *Carcharhinus leucas*.

***42.4*** MOUNTCASTLE, A.M.*; DANIEL, T.L.; University of Washington, Seattle; *mtcastle@u.washington.edu*

***Unsteady forces occur at ventral stroke reversal in the hawkmoth, Manduca sexta***

Insect wings are compliant structures that often yield to aerodynamic and inertial-elastic loads during flapping flight. In the hawkmoth, *Manduca sexta*, deformations of the wings are most extreme at ventral stroke reversal as they undergo a rapid pitch reversal and substantial spanwise bending. Although the extent to which such deformations affect flight forces in insects remains generally unknown, prior results show a significant aerodynamic consequence of wing flexibility, with greater induced flows for more compliant wings. The mechanisms underlying this difference, however, are unclear. To explore this issue, we combined computational and experimental approaches to examine the forces and flow fields associated with flapping compliant wings. We use a 2-dimensional ideal flow simulation of flapping wings. This simulation derives from a distribution of sources of vorticity (vortexlets) whose combined strengths determine the flow field around them. That flow field, in turn, is used to predict both steady and unsteady aerodynamic forces. We track wing kinematics of a hovering moth and model a series of chord-wise sections with waveform equations that describe their pitching motion relative to the rigid leading edge of the wing. Our results show that the rapid pitch reversal at ventral stroke reversal itself generates an impulse that is 5-10% of the total impulse required to support the animal's weight over an entire wing stroke. Furthermore, the forces generated during pitching in this time domain increase with pitch amplitude. These results are consistent with our prior experimental findings and suggest that transient forces arising at stroke reversals play an important role in insect flight.

***45.1*** MULCAHEY, Thomas I. *; HORSTMANN, Jan T.; HU, David L.; SABRA, Karim; WEISSBURG, Marc; Georgia Institute of Technology; *tom.mulcahey@gmail.com*

***Autonomous Cricket Biosensors for Acoustic Detection***

This project characterizes and utilizes the underlying signal processing mechanisms responsible for gaining useful acoustic information from cercal hair arrays on crickets. Whereas previous investigations explored crickets' neurological response to near field flows generated by single frequency steady-state sounds, our investigation focuses on impulsive waveforms, which better represent real world stimuli, and to which the cercal system appears to be most reactive. Extracellular recording electrodes are permanently implanted into a cricket's ventral nerve cord to record the action potentials emanating from the cerci. We process the signals to estimate frequency and directionality of near field acoustic sources. The resulting bionic cricket-computer system is capable of localizing low frequency near field acoustic signals (5 Hz – 600 Hz) while going about its natural activities such as locomotion. In order to calibrate this system, we attempt to find the relationships between the frequency/direction of acoustic stimuli and the neurological responses they elicit. The intention of this project is to design networked arrays of cricket biosensors capable of localizing sources such as footsteps within dangerous environments, and possible application to earthquake detection.

***95.5*** MULROY, E.; ALDENHOVEN, J.; OSBORNE, E.J.; STRINGHAM, S.; SHAPIRO, M.D.*; Univ. of Utah; *shapiro@biology.utah.edu*

***The origin of pigeons by means of artificial selection***

Darwin relied heavily on the dramatic results of artificial selection in domesticated pigeons to both conceive and communicate his theory of natural selection in wild populations and species. He noted that based on morphology alone, a taxonomist might be tempted to classify distinctive pigeon breeds not just as different species, but rather as completely different genera. Importantly, he also observed that all domesticated pigeons, no matter how morphologically or behaviorally divergent, could be interbred to produce viable offspring. He thus concluded that all breeds were simply variants descended from a single species, the wild rock pigeon (*Columba livia*). Thousands of years of artificial selection on the rock pigeon has produced over 350 recognized breeds with intriguing combinations of derived morphological, physiological, and behavioral traits. A major unanswered question in pigeon domestication is, do similar derived traits in different breeds result from common ancestry, or were similar traits selected multiple times in different lineages? We used molecular markers to examine genetic structure within and among breeds, and to generate a phylogeny of pigeon breeds. We found that many groups of breeds were highly structured, indicating high breeding fidelity, while others likely subjected to frequent outcrossing. Our molecular phylogeny contrasts with the morphological phylogeny proposed by Darwin in *Animals and Plants Under Domestication* and reveals repeated selection on similar skeletal and soft tissue traits in different lineages. Many of the traits under intense selection in domesticated pigeons have evolutionary and ecological relevance in other species of the pigeon family and birds in general. Thus, the domesticated pigeon is a potentially ideal – yet grossly underutilized – model of avian and vertebrate diversity.

***32.11*** MULVANY, SL*; MOTTA, PJ; Univ. S Florida, Tampa; *smulvany@mail.usf.edu*

***Feeding kinematics of three batoid species: Atlantic stingray (Dasyatis sabina), yellow stingray (Urobatis jamaicensis) and clearnose skate (Raja eglanteria).***

Many batoids utilize their body to pin benthic organisms against the substrate during feeding. While this general prey capture technique is well known, it is not known if there are any kinematic differences in prey capture and feeding among different batoids. Nor is it known if batoids are able to modulate feeding behavior with different prey types. This study compares the feeding kinematics of three batoids, *Dasyatis sabina*, *Urobatis jamaicensis* and *Raja eglanteria*, using elusive and non-elusive prey. A series of kinematic variables relating to prey capture and manipulation were quantified. All batoids exhibited a general feeding behavior of swimming over the prey and forming a tent around the prey with their anterior pectoral fin margin, trapping and repositioning the prey between the substrate and the anterior body. Once near the mouth, the animals would use suction and biting to capture and ingest prey. Preliminary results indicate that all species modulate feeding behavior depending upon prey type, with longer durations between capture and ingestion for elusive prey. Live prey are a greater distance from the mouth when batoids attempt bites and more bites are needed to orally capture elusive prey compared to non-elusive prey. *R. eglanteria* have a shorter bite duration, but take longer time to capture and maneuver prey into the mouth when compared to the other two species. *D. sabina* have a longer bite duration when compared to *U. jamaicensis*. The use of the pectoral fins in prey capture and the ability to modulate feeding kinematics allows these batoids to restrain and successfully feed on various prey types.

***80.5*** MUNK, Y; UC Berkeley; *yonatanmunk@berkeley.edu*

***Comparative gliding performance in wingless gliding ants and other arthropods***

Many wingless insects are capable of sophisticated aerodynamic control in the absence of obvious morphological adaptations for aerial behavior. We present comparative data on aerial maneuvers in worker ants, focusing on the genus *Cephalotes*, and in other wingless arthropods, including the basal hexapod lineage of wingless jumping bristletails (Archaeognatha). In all gliding ants tested to date, aerodynamic stability and control are effected through modulation of leg posture, with the legs raised above the longitudinal body axis to maintain a center of aerodynamic pressure above the center of mass. Typically the hindlegs move together as a unit and serve to adjust overall body pitch angle. In contrast, the mid- and forelegs are actuated asymmetrically to effect yaw and roll maneuvers. In some cases the antennae are also co-opted as aerodynamic stabilizers. All Myrmicine (including the genus *Cephalotes*) and Pseudomyrmecine ants tested to date glide with the abdomen leading, whereas all tested Formicines adopt a head-first gliding posture. In contrast to these ants and other wingless gliding arthropods, bristletails appear to execute maneuvers by adjusting the position of their long caudal filaments through abdominal flexion. We present 3D trajectories of ants performing targeted and controlled directed aerial descent in a natural Amazonian setting, measured using a tree-based synchronized camera array. We also compare gliding postures adopted by ant species of varying body size, obtained using a field-portable open-jet wind tunnel. Finally, we will present the first results from an ongoing series of physical modeling experiments designed to quantitatively assess how morphology and posture affect net aerodynamic forces and moments acting on gliding insects.

***30.0*** MUNSON, Donald A.; Washington College; *dmunson2@washcoll.edu*

***Acanthamoeba spp. Distribution in a Chesapeake Bay Tributary After Sewage Treatment Upgrade***

The large diversity of amoebae species in soils and sewage sludge reported by Singh and Hanumaih (Monograph No. 1 of the Association of Microbiologists of India, Indian Journal of Microbiology, 1979) was found to serve as a useful indicator of soil erosion and sewage pollution in soils and aquatic sediments. *Acanthamoeba* is a ubiquitous soil amoeba that is often associated with sewage pollution. Certain species of the genus are causative agents of human disease (GAE and keratitis). The Chester River is a tributary to the Chesapeake Bay on Maryland's eastern shore. The river, although not highly polluted is somewhat adversely impacted by two factors, sewage pollution and nutrient runoff from agricultural lands. Sediments from 11 sites along the river were collected and cultured for the presence of *Acanthamoeba*. All sites yielded amoebae, and many harbored potentially pathogenic, temperature tolerant ($39^0$C) species. Commonly isolated species were *A. polyphaga, A. rhysodes*, and several other unidentified isolates that belonged to either Group II or Group III of the genus. A larger number of species was isolated from sediments that were subjected to impacts from agricultural or sewage pollution.

***93.2*** MURPHY, D. W.*; WEBSTER, D. R.; KAWAGUCHI, S.; KING, R.; OSBORN, J.; YEN, J.; Georgia Institute of Technology, Atlanta, Australian Antarctic Division, Kingston, Tasmania, Australian Antarctic Division, Kingston, Tasmania, University of Tasmania, Hobart, Tasmania; *dwmurphy@gatech.edu*

***Krill Schooling: Defining the Structure of Antarctic Krill Schools and Swarms***

Antarctic krill (*Euphausia superba*) exhibit exceptional aggregative behavior and are known to form schools that may extend for several kilometers in the horizontal direction and for greater than 100 m in the vertical direction. These schools are generally characterized by synchronized and polarized swimming. Proposed benefits for school membership include increased hydrodynamic efficiency (drafting) and improved awareness of external environmental signals, such as those created by prey, predators, or mates. Determining the presence of structure within schools of krill would help to define the adaptive advantage of this behavior. Krill exhibiting both schooling and non-schooling (swarming) behaviors were filmed using a stereophotogrammetric camera system at the Australian Antarctic Division in Hobart, Tasmania. Three-dimensional trajectories of individual krill were then constructed from the image data. For both schooling and swarming krill, animal coordinates at multiple time points were interrogated for school parameters such as density, polarity, nearest neighbor distance, and nearest neighbor position. Preliminary analysis shows a mean nearest neighbor distance of slightly less than one body length (5 cm) and suggests an anisotropic school structure in which nearest neighbor positions are nonrandomly distributed. Previous measurements of flow fields generated by swimming Antarctic krill will be used to address the relationship between the hydrodynamics of krill locomotion and school structure.

***91.6*** NAKAMOTO, A.*; SHIMIZU, T.; Univ. of Arizona, Hokkaido Univ.; *monaka@email.arizona.edu*

***A Secondary Embryonic Axis Induced by Transplanted D-quadrant Micromeres in an Oligochaete Annelid***

In many animals, a specific region in the early embryo has a remarkable potential to act as an organizer. For example, the Spemann and Mangold's organizer not only instructs ectodermal cells to differentiate into neural tissues but also induces the secondary axis when transplanted to the ectopic position of the host embryo. In the embryos which undergo spiral cleavage (e.g., mollusks and annelids), it has been known that the one blastomere at the four cell stage, called D-quadrant, plays an important role in axial pattern formation. In annelids, various embryological experiments have suggested that the D-quadrant functions as an organizer of embryonic axis. However, so far, this long-held view remains to be demonstrated directly. To address this issue, we carried out a series of D-quadrant micormere transplantation experiments in the oligochaete annelid *Tubifex tubifex*. When D-quadrant micromeres (2d and 4d) were transplanted to an ectopic position in an intact host embryo, the resulting chimeric recombinant embryo formed a secondary embryonic axis with duplicated heads and/or tails. Cell lineage analyses show that neuroectoderm and mesoderm along the secondary axis are derived from the transplanted D-quadrant micromeres and the endoderm along the secondary axis originates from the host embryo. These results show that D-quadrant micromeres of *Tubifex* have a capability to organize embryonic axis, indicating the potential homology to other metazoan organizers.

***80.1*** NAKATA, T.*; LIU, H.; Chiba Univ., Japan; *nakata@graduate.chiba-u.jp*

***Aerodynamic Performance Enhancement by Insect Wing Flexibility***

Insect wings are deformable structures that change shape passively and dynamically due to inertial and aerodynamic forces during flight and the flexibility of insect wings often leads to complex fluid-structure interactions. The effects of dynamic shape changes on unsteady aerodynamic force production in flapping flight are important in micro air vehicles but still remain unknown yet. To tackle this problem, a computational framework has been established by coupling an insect dynamic flight simulator (H. Liu, J. Comput. Phys., 2009) and a recently developed structural dynamics solver (T. Nakata et al., Comp. Biochem. Physiol. A, 2009). Geometric and kinematic models for a hovering hawkmoth, *Manduca sexta* are constructed on a basis of the measurement data (A.P. Willmott et al., J. Exp. Biol., 1997). Realistic stiffness of hawkmoth wings is taken into account, which are based on the rotational test results (S.A. Combes et al., J. Exp. Biol., 2003). The computational simulation clarified that the wing flexibility is apparently responsible for increasing the strength of the wake and hence the aerodynamic force. We further proposed a method to estimate the hovering efficiency and found a lift-up compared with that of a rigid wing model. The enhancement mechanisms are as follows: Firstly, the wing twist delays the shedding of the leading-edge vortex and hence augments the lift; Secondly, the curved and twisted wings are flattened and deformed in an opposite direction during the latter half of each stroke and then, the acceleration, the additional rotation and the phase advance of rotation (M.H. Dickinson et al., Science, 1999) at wing tip are induced. Our results imply that the kinematics of hawkmoth wings is very likely modified adaptively and the aerodynamic performance is enhanced automatically as a result of the wing deformation.

***37.6*** NANCE, Holly/A*; MARKO, Peter/B; Clemson University; *hnance@clemson.edu*

***Demographic history and ecological connectivity of the scalloped hammerhead shark, Sphyrna lewini, in the Eastern Pacific***

Describing basic migration rates and patterns of large, marine predators is challenging, yet necessary for species that are overfished and at risk of extinction. To that end, we have used molecular data to characterize the population genetic structure of the globally endangered (IUCN Red List) *Sphyrna lewini* and to infer levels of connectivity, demography, and divergence throughout the Eastern Pacific (EP) range of this globally distributed shark. Using 15 microsatellite loci from nearly 400 sharks sampled at eight sites between Mexico and Ecuador, we found significant genetic differentiation with a global $F_{ST}$ of 0.005 ($P < 0.001$), and significant values for most pairwise comparisons. We did not detect significant structure at a 548 bp region of mtDNA control region, though this was probably due to very low diversity. Coalescent-based analyses indicated that each EP site we sampled was comprised of a genetically distinct population with low ecological connectivity. Despite this current genetic structure in the EP, the populations we sampled shared a common demographic history: mtDNA showed evidence of a population expansion roughly 230,000 years ago. Divergence genetics analyses based on both mtDNA and microsatellite loci showed that population divergence times were very recent (averaging only 540 years ago), and that effective sizes of all extant populations were several orders of magnitude smaller than ancestral population sizes. Overall, our results point to a relatively recent fragmentation of *S. lewini* populations throughout the EP, potentially driven by recent population declines.

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***Adaptive phenotypic plasticity in juvenile Scyphomedusae facilitates effective animal-fluid interaction***

Phenotypic plasticity enables animals to respond rapidly to environmental changes. Predictions of ecosystem dynamics in times of perturbation, such as climate change, need to take into account the varying capacity for such short-term adaptations among species. However, it is often difficult to evaluate whether morphological change in response to external factors has a functional benefit or merely constitutes abnormal growth. This is because modifications in animal shape might affect a range of behaviors and thus impede straightforward conclusions on overall fitness. Further, the physical impact of environmental change on a given organism can be difficult to establish. We investigate phenotypic plasticity in juvenile Scyphomedusae ("jellyfish"), as these animals display stereotypic swimming and feeding behaviors enabling us to assess fitness based on their performance. Further, the radial bauplan facilitates the use of methods adapted from fluid dynamics to visualize changes in animal-fluid interaction. We report that ontogenetic morphogenesis in Scyphomedusae responds to changes in water temperature in a way that facilitates effective animal-fluid interaction. In particular, altered proportional growth was found to exploit the increased viscosity of colder water by utilizing adhering water boundary layers as "paddles", effectively replacing tissue. This effect was documented by flow field visualization and further confirmed by behavioral assays of swimming performance. Our study suggests that phenotypic plasticity in juvenile Scyphomedusae allows for functional adaptation to ambient water temperature, a potential mechanism leading to robustness of Scyphozoan jellyfish populations to altered ocean temperature distributions.

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***Wnt signaling and appendage development in the sepiolid squid Euprymna scolopes***

The Wnt pathway is an evolutionary conserved signaling pathway, which plays a pivotal role in a large number of developmental processes, such as the establishment of the body axes and the establishment of limb polarity. During the development of the vertebrate limbs, members of the *wnt* gene family play a crucial role in the induction of limb formation, as well as the growth and the establishment of the dorsal-ventral axis. In *Drosophila melanogaster wnt* genes mediate the organizing activity of the dorsal-ventral boundary of the wings and specify the dorsal-ventral and proximo-distal axis of the legs, respectively. Therefore, despite the profound differences in the structure of adult appendages found in vertebrates and arthropods the Wnt pathway maintains a central role in the appendage development of both phyla. Cephalopods are a highly derived class within the mollusks. During the course of evolution members of this group underwent significant changes of their body plan, including subdivision of the ventral foot into prehensile arms, tentacles, and a funnel tube, which are considered true morphological novelties. In order to understand the molecular mechanisms that underlie evolutionary innovation we isolated a number of wnt homologs from the Hawaiian bobtail squid *Euprymna scolopes* and examined their expression by *in situ* hybridization. We will show that distinct *Euprymna wnt* paralogues are strongly expressed during the development of the arms and tentacles of the squid, suggesting that the Wnt pathway plays an important role in limb patterning within the cephalopod mollusks.

***105.5*** NOREN, S.R.*; WILLIAMS, T.M.; KENDALL, T.; CUCCURULLO, V.; Univ. of California, Santa Cruz, The Dolphin Experience, Freeport, Bahamas; *snoren@biology.ucsc.edu*

***Bradycardia Redefined: A Variable Cardiovascular Dive Response in Dolphins***

The textbook description of the dive response for marine mammals is marked decrease in heart rate (HR) upon submergence, stable bradycardia at depth, and anticipatory tachycardia on ascent. Based primarily on lab studies, it is difficult to evaluate the effects of routine underwater activities on this pattern for free-ranging diving mammals. We simultaneously recorded electrocardiographic signals and behavior, including stroke frequency (SF) as an index of exercise intensity, in 3 adult bottlenose dolphins (*Tursiops truncatus*) during rest on the water surface and during rest, low intensity activity, and swimming at 15 m depth in the ocean. Mean HR (±SD) in beats per minute (bpm) during rest at the surface was 105 ± 8 bpm (n = 25), more than double predicted rates based on allometric regressions for mammals. As expected for the dive response, resting HR during submergence (40 ± 6 bpm, n = 15) was significantly lower than recorded on the water surface. Underwater activity modified the level of bradycardia. Low intensity activity such as head bobbing resulted in a mean HR of 56 ± 7 bpm (n = 7) that was 40% higher than submerged rest. Furthermore, in contrast to previous reports for diving mammals, submerged HR was correlated with exercise intensity and was described by HR = 41 + 12 SF (range: 0 - 2.5 strokes $sec^{-1}$; r = 0.88, P = 0.0001, n = 25) where HR is in bpm and SF is in strokes $sec^{-1}$. These data demonstrate that the "dive reflex" is not an invariable response in dolphins. Rather, it is graded by activity, similar to the effect of exercise on HR in terrestrial mammals. In addition, based on HR predictions for other mammals, the "normal" resting physiological state of dolphins seems to occur when these mammals are under water. (Supported by ONR)

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***The energetic cost of surface active behaviors in dolphins***

Surface active behaviors (SABs), such as tail slaps and breaches, are performed by cetaceans over a range of behavioral contexts. Some cetaceans perform SABs in response to disturbance, including close approaches by vessels. This study aimed to determine metabolic costs of SABs to assess the energetic impact of performing these behaviors in response to vessels. Oxygen consumption of two trained adult male bottlenose dolphins were measured via flow-through respirometry after swimming the length of the research pool, 30 second bouts of tail slaps, and bouts of five and ten bows (proxy for breaches). Oxygen consumption and respiration rates differed across trial types. For example, swimming was less energetically costly than both five and ten bow bouts. Metabolic rates following ten bow bouts were higher than those after five bow bouts, while metabolic rates following tail slaps were the lowest. Respiration rates following ten bow bouts were 1.2 and 1.4 times greater than those following five bow bouts and 30 second bouts of tail slaps, respectively. Finally, oxygen consumption did not return to resting values until 10-20 minutes post behavior, and recovery time varied by trial type. Recovery time was greatest following ten bows and least following swimming, which was similar to the recovery time for tail slaps. The results show that energetic costs of SABs can be high and that tail slaps are the most energetically economical SAB to perform in response to disturbance. Thus, it is not surprising that tail slaps are the predominant SAB observed during close approaches by vessels. By quantifying behaviors in terms of energetic costs to the individual, we can begin to understand how short-term behavioral responses may have long lasting impacts on wildlife.

***27.5*** NOWROOZI, B.N.*; BRAINERD, E.L.; Brown University; *bryan_nowroozi@brown.edu*

***Lateral bending kinematics of the vertebral column in Morone saxatilis***

During axial undulatory locomotion in fishes, the intervertebral joints provide the vertebral column with the flexibility needed for lateral bending. However, due to the location of the vertebral column deep in the body, it has been difficult to measure precise intervertebral joint kinematics *in vivo*. Most studies of vertebral column function during locomotion in fishes have focused on *in vitro* bending mechanics and on body curvature. These studies have suggested that both the bending stiffness of the intervertebral joints and the maximum curvature of the body increase towards the caudal region of the fish. The current study investigates whether this pattern of longitudinal variation in mechanics and body curvature will be evident in the kinematics of the intervertebral joints. We used x-ray motion analysis of the startle response to quantify the kinematics of adjacent vertebrae along the length of three individual of striped bass, *Morone saxatilis*. Based on the vertebral kinematics, we calculated the average angle of bending between each set of three vertebrae along the length of the individual. On average, the intervertebral joints located in the caudal region of the body bent to a greater degree than those in the precaudal region. Typically, the most anterior vertebrae bend to an average of 4.8°, followed by a decline in bending angle in the precaudal vertebrae to an average of 4°, after which, the maximum angle of bending increases steadily through the caudal region to an average of 5.8°. We conclude that longitudinal variation of maximum intervertebral joint angle does exist with angles increasing towards the caudal region of the fish.

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***Transcriptome characterization via 454 sequencing of an oligochaete annelid (Pristina leidyi) used in regeneration research***

Recent advances in DNA sequencing technologies have made possible the development of genomic resources in non-traditional model systems. Here, we characterize via 454 pyrosequencing the transcriptome of an oligochaete annelid (*Pristina leidyi*) that we use to study the evolution of regeneration ability. Batches of worms collected at multiple timepoints during anterior regeneration and posterior regeneration were used to construct a cDNA library consisting of pooled normalized and non-normalized fractions. 454 sequencing of this cDNA library with a Roche GS FLX system and Titanium series reagents resulted in 1.48 million high-quality sequence reads with an average read length of 375 nucleotides. These reads were assembled into 88,358 contigs (average length = 709 nt) with 127,808 singletons (average length = 358 nt). The average contig is of sufficient length to generate an in situ probe without the need for additional sequencing via RACE. Transcript annotation using BLAST and EST2uni and subsequent in situ hybridization has identified a multitude of candidate genes and signaling pathways that may be involved in initiation of regeneration, blastema formation and growth, and morphogenesis in *P. leidyi*.

***104.1*** NYACK, A.C.*; HENRY, R.P.; SEIBEL, B.A.; University of Rhode Island, Auburn University; *alnyack@gmail.com*

***Carbonic anhydrase activity in gill and mantle tissues from Doryteuthis pealeii***

The enzyme carbonic anhydrase (CA) rapidly catalyzes the reversible reaction of $CO_2$ to $HCO_3^-$ and $H^+$ both at sites of production (tissues) and excretion (gills/lungs) in animals. CA is involved in several physiological functions (e.g. energy production, osmoregulation, and acid-base balance), and it is a vital component of the systemic transport and excretion of $CO_2$. Although CA has been examined in many organisms, it has not been characterized in squids. We compared total CA activity between gill segments (anterior, middle, and posterior), mantle, and fin, and within subcellular fractions (membrane, mitochondria, and cytoplasm) from *Doryteuthis pealeii*. Tissues were homogenized and subjected to differential centrifugation to separate subcellular fractions. CA activity of each fraction was measured using the ΔpH method. Total CA activity was significantly greater in all gill segments than in either mantle or fin ($P < 0.001$) as was CA activity within each subcellular fraction ($P < 0.001$). There was no significant difference between gill segments ($P = 0.26$), or between fin and mantle ($P = 0.35$). While the cytosolic fraction was significantly greater than other fractions within each tissue type, the mitochondrial fraction was greater than the membrane fraction only in middle and posterior gill segments ($P = 0.0015$ and $0.0006$, respectively). Low CA activity in the fin and mantle (sites of CO2 production) could help facilitate the large Bohr shift in the hemolymph typical of squids. We also hypothesize that the differences between fractions suggest different CA isozymes within each tissue, and differences between gill segment fractions may indicate a shift in predominant functions along the gill from respiratory to osmoregulatory, similar to functional differences observed in crab gills.

***56.2*** O'CONNOR, Constance M*; BARTHEL, Brandon L; GILMOUR, Kathleen M; PHILIPP, David P; VAN DER KRAAK, Glen; COOKE, Steven J; Carleton University, Ottawa, University of Illinois, Champagne-Urbana, University of Ottawa, Ottawa, University of Guelph, Guelph; *coconno4@connect.carleton.ca*

***Life history correlates of cortisol and androgen levels in a parental teleost fish***

For the past 10 years, researchers have monitored the reproductive ecology of smallmouth bass (*Micropterus dolomieu*) in an inter-connected lake and river system in eastern Ontario. Each year during the reproductive period, all parental fish are temporarily removed from the nest to determine identity. Scales are obtained to assess age, and fish are measured and monitored throughout the parental care period to assess annual reproductive success. During the summer of 2009, all parental fish (n=184) were subjected to an additional standardized capture-and-restraint protocol, and non-lethally sampled for blood to determine whether cortisol or androgen levels (testosterone and 11-keteotestosterone) are correlated with any life history characteristics. We revealed that the cortisol stress response is higher in fish from the river than from the lake. This likely reflects the difference in predation risk between the two locations, with fish from the river being more vulnerable to predation during parental care than fish from the lake. Furthermore, we found that androgen levels are correlated with a suite of life-history characteristics, including size and age of the parent, prior nesting experience, and the number of offspring in the nest. Collectively, this study contributes to our understanding of the interplay between the endocrine system and life history in wild animals, and represents the first such long-term study on wild fish.

***58.6*** O'CONNOR, J.L.*; MCBRAYER, L.D.; HIGHAM, T.E.; ROSTAL, D.C; Georgia Southern University, Clemson University; *jennifer_L_oconnor@georgiasouthern.edu*

***The role of testosterone and training on locomotor performance in a non-territorial lizard***

The effects of testosterone (T) on territorial lizards have been studied extensively; however, the effects of T on non-territorial lizards have not. In territorial lizards, T has been suggested as a possible mediator of seasonal increases in whole-animal performance capacities (i.e. sprint speed and bite force), which are important factors in maintaining territories and winning male-male competitions. Previous work in our lab has shown that in *Aspidoscelis sexlineata*, a common non-territorial lizard, bite force, locomotor performance (measured as the max. time until exhaustion), and T are each greatest during the breeding season; thereby suggesting that T also mediates seasonal increases in performance for this species. Furthermore, T implants have been shown to successfully elevate circulating T levels in *A. sexlineata*. However, the T implants failed to increase whole-animal performance capacities, and hence suggest a training effect. The current study will test the effects of training on locomotor performance capacities and morphology (i.e. locomotor muscle size & composition). Thirty adult male *A. sexlineata* were assigned to one of three treatment groups: T implant + training, empty implant + training, and empty implant without training. Training consisted of 3 performance measures: treadmill endurance, burst speed, and maximal exertion. At the end of the study, changes in muscle size, muscle fiber size, or fiber-type composition were assessed for multiple hindlimb muscles using histochemical analyses to determine the influence of treatment group (T, training regime). This research will further isolate the role of T and training on the morphological factors affecting seasonal locomotor performance in non-territorial species.

***104.3*** O'CONNOR, M.P.*; SUSS, J.; SOTHERLAND, P.R.; SPOTILA, J.R.; Drexel Univ., Kalamazoo Coll.; *mike.oconnor@drexel.edu*

***Diffusive and conductive effects of sand on gas exchange in sea turtle nests***

Sea turtles bury their nests deeply (25-100 cm) in beach sand, thus limiting nest predation and extremes of thermal and hydric conditions. But the sand overlying the nest can also limit respiratory gas exchange with the atmosphere. Empirical data suggest that the induced hypoxia affects egg metabolism, development times, and hatching success. Models indicate that tidally induced nest ventilation, the geometry of the nest, and nest density can all affect nest $O_2$ and $CO_2$ concentrations. Here we concentrate on the relative importance of diffusive (driven by gas concentration gradients) and convective (bulf flows driven by pressure gradients) limitations on nest respiration. Although sand structure can affect both diffusion and convection, interstitial water in the sand can affect convection and diffusion differently. Our models suggest that although convection can affect nest gas concentrations to some extent, diffusive resistances largely determine nest $O_2$ and $CO_2$ concentrations. We also examine sand structure from a series of loggerhead turtle nesting beaches for potential differences in resistance to convection and diffusion. Sand grain size distributions varied significantly among the beaches examined, particularly for grain sizes ranging from 0.1-2 mm. Resulting predicted diffusive and convective resistances to gas flux also varied among beaches.

***76.1*** O'NEAL, DM*; SWANGER, L; JAWOR, J; FRENCH, SS; KETTERSON, ED; Indiana University, University of Southern Mississippi, Utah State University; *daoneal@indiana.edu*

***Immune function across latitudinal and urban gradients in a differential migrant***

Recent changes in climate have had significant effects on the behavior, physiology and demography of many migratory species. In the dark-eyed junco (*Junco hyemalis*), for example, milder winter climate has resulted in significant changes in winter distribution from north to south in the winter range. Females are apparently making shorter migrations than previously, and, at the level of populations, sexual segregation is less well developed in winter. Less is known about whether urbanization has affected habitat selection by sex, either within or between latitudes, and whether changing climate or degree of urbanization have affected winter physiology. In this study, we evaluated the effect of winter habitat on fat stores and immune function (complement activity, bacteria killing ability, and total IgG) in juncos across a latitudinal and urban gradient. We predicted more robust immune responses in birds wintering at more southern latitudes and in rural environments because these areas are thought to have higher prevalence of disease and possibly disease transfer. Results show latitudinal differences in immune function and fat stores, with lower levels of total IgG but higher complement activity and greater fat stores in northern birds. However, there were no significant differences in immune function across the urban gradient despite birds in urban habitats having greater fat stores. These results indicate possible tradeoffs among immune components and potential latitudinal differences in the nature of infection. Additionally, results suggest that winter urban environments may not have detrimental effects on condition contrary to previous studies of urban populations.

***45.4*** OAKLEY, TH*; RIVERA, AS; OZTURK, N; FAHEY, B; PLACHETZKI, DC; DEGNAN, BM; LEYS, SP; SANCAR, A; Univ. of California, Santa Barbara, Univ. of Richmond, Univ of North Carolina, Univ of Queensland, Univ. of California, Davis, Univ of Alberta, Univ of North Carolina; *oakley@lifesci.ucsb.edu*

***Convergent evolutionary origin of an eye in the demosponge Amphimedon queenslandica***

All animal eyes examined to date utilize opsin-based phototransduction cascades. We report that the pigment spot eye of a larval sponge (*Amphimedon queenslandica*) provides an exception to this rule. Although *A. queenslandica* exhibits behavioral attributes of light perception and a morphological structure meeting the definition of an eye, its genome lacks opsin. Further, conserved transcription factor genes involved in eye development in a diversity of other animals are either absent from the sponge genome or not expressed near the pigment ring eye. We report that the genome of *A. queenslandica* possesses two cryptochrome/photolyase genes (aqCry1 and aqCry2), members of a light sensitive family of proteins common in eukaryotes. We find with *in situ* hybridization that one gene, aqCry2 is expressed near or in the pigmented larval eye, and (along with aqCry1) possesses DNA repair activity in an *in vitro* assay. We report the *in vitro* action spectrum of the protein aqCry2 and find it lacks characteristics of the behavioral action spectrum of the sponge larvae, reported previously. Taken together, our results indicate that sponge larval eyes represent a case of dramatically convergent evolution with the opsin-based eyes of other animals, but the molecular identity of the photoreceptor remains elusive. If cryptochrome is the photoreceptive gene, it must not act alone. We speculate that the aqCry2 expressed in the larval eye could act as a ‘timekeeper’ since phototaxis is temporary and correlated temporally with aqCry2 expression.

***24.2*** OLIVIER, T.J.*; BAUER, R.T.; University of Louisiana-Lafayette; *tjo1457@ull.edu*

***Downstream Hatching Migrations of the River Shrimp Macrobrachium ohione in the Lower Mississippi River System***

*Macrobrachium ohione* is the most widely distributed species of *Macrobrachium* in the United States. Historically found within the Mississippi River System as far north as the Missouri and lower Ohio Rivers, *M. ohione* is now only abundant within the lower Mississippi River and its major distributary, the Atchafalaya River. *M. ohione* has an amphidromous life history, in which larval development occurs in brackish and marine waters. Females of amphidromous shrimps may hatch out larvae in fresh water, which will then passively drift downstream to the sea. Alternatively, gravid females may deliver their larvae to coastal bays via a downstream migration. Recent studies report a reduction in *M. ohione* survival after 3-5 days of drifting in fresh water prior to reaching saline waters. In both the Atchafalaya and lower Mississippi Rivers, we hypothesize that embryo-bearing females migrate downstream to deliver (hatch out) larvae to estuaries. A female "hatching" migration will ensure that the larvae reach the required salinity in time for the critical molt to the second (first feeding) stage. To test the predicted downstream movement, we conducted an 18-month investigation on location, reproductive condition, and seasonality of reproductive-sized females. Shrimps were collected by trapping at upstream (Butte La Rose, La; St. Francisville, La) and downstream (Atchafalaya Delta WMA; Pass A Loutre WMA) locations within the Atchafalaya and Mississippi Rivers, respectively. We found higher proportions of reproductive-size females and females with embryos near hatching at the downstream locations during *M. ohione*'s reproductive season. Support from NOAA LA Sea Grant R/SA-04 is acknowledged.

***98.2*** OLSON, JM*; CARAGIULO, A; CZERWINSKI SHIELDS, BV; SOUCIER, D; Villanova University, Fordham University; *john.olson@villanova.edu*

***Prolonged Cold Exposure in Young Quail: avUCP, Ultrastructure and Catabolic Capacities in Skeletal Muscle***

Skeletal muscle is the site of both shivering thermogenesis (ST) and regulatory nonshivering thermogenesis (NST) through avian uncoupling protein (avUCP). Thermogenic capabilities may be upregulated in response to chronically cold ambient temperatures, especially during development. Japanese Quail were acclimated to cold (5°C) or warm temperatures (25°C) for three weeks starting at age 14d posthatch (CA and WA, resp.). Pectoralis muscle of CA birds possessed more avUCP, but, contrary to predictions, mitochondrial area (as % total fiber area) was not elevated in the CA birds, even though mitochondrial area did increase significantly with age in both groups. Interestingly, however, muscle mitochondria of CA birds possessed more cristae, suggesting the possibility that these birds could have concomitantly higher catabolic capacities to support both elevated ST and NST. Activities of three regulatory enzymes (pyruvate kinase, citrate synthase, and 3-hydroxyacyl-CoA-dehydrogenase) were assayed at three temperatures in pectoralis and gastrocnemius muscles from CA and WA birds. As predicted, enzyme activities increased with temperature, but catabolic capacities did not increase with CA in either muscle. Additionally, thermal sensitivities of catabolic enzymes did not differ in CA birds. This lack of significant differences, together with depressed growth and lower body temperature in CA birds, suggest birds acclimated in part through regulated hypothermia

***40.4*** ORCUTT, J.D.*; LEVERING, D.; DAVIS, E.B.; University of Oregon, Oklahoma State University; *jorcutt@uoregon.edu*

***Evolution of locomotion and predation in saber-toothed cats***

An understanding of the ecological roles of organisms within paleocommunities is critical to tracking ecosystem change through time. For many extinct mammalian taxa, these roles can be reconstructed through extrapolation from the behavior of related modern species. Some extinct taxa were morphologically and, presumably, ecologically distinct from any extant mammals, complicating reconstruction of their ecological roles. A classic example is the felid subfamily Machairodontinae (saber-toothed cats), species of which represent a morphotype with no modern analog. Several hypotheses of predatory behavior within this group have been suggested, largely based on skull biomechanics of its best-known member, *Smilodon fatalis*. We approach this debate from a novel perspective, using an already-developed morphospace model based on ratios of proximal and distal limb bones, to examine North American machairodontines. Our results suggest that all machairodontines were non-cursorial ambush predators, but that the degree of cursoriality does not remain constant through time. Early taxa, such as the Miocene *Machairodus*, show limb proportions more similar to those of modern felids, while the Pleistocene *Smilodon* approaches bears in its limb ratios. This apparent decrease in cursoriality may indicate a concurrent increase in sociality in *Smilodon*.

***9.2*** ORR, T.J.*; HYDE, T.C.; WOLF, B.O.; University of California, Riverside, University of New Mexico; *teri.orr@email.ucr.edu*

***How important are water developments to the Sonoran Desert bat community?***

The significant role water serves to desert vertebrates is intuitive, but in many cases remains to be fully quantified in the context of percent of water intake from a known water source. When bats from a single guild co-occur but have differing water concentrating abilities we might expect each species' utilization of free standing water to vary in accordance with these known physiologies. However, in extreme settings physiological differences may be masked by the overall scarcity of resources. We were interested in determining the relative contribution of known sources of water to total body water of the members of a sonoran bat community. We also wished to examine how reproductive state might impact water utilization. We predicted water use would be higher in pregnant females than non-pregnant females, and highest in lactating females, but would not differ between non-reproductive females and non-reproductive males, nor males at different reproductive stages. To assess these predictions, we netted the Sonoran Desert bat community at water developments at the Kofa Wilderness Refuge in south-western Arizona for 3 summers (2007, 2008, and 2009). By labeling water sources with known concentrations of stable isotopes of hydrogen (deuterium) we assessed percent of isotopes in the plasma of bats captured at watering holes. An average of 12% of total of total body water was derived from labeled sources of water. Given an insectivorous diet that constitutes a food source between 60 and 80% water, their large usage of water developments is likely due primarily to the abiotic environmental extremes these bats endure. Interesting water use patterns were noticed in females from different reproductive stages. By directly quantifying the use of supplemented water sources by the sonoran bat community we might determine the effectiveness of current wildlife man

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***The development and evolution of axial skeleton of the hagfish***

Extant jawless vertebrates consist of lampreys and hagfishes. According to recent molecular phylogenetic analysis, these two groups are clustered together into the same clade, so called “cyclostomes” and this clade is placed as sister to jawed vertebrates. Although the monophyletic relationship of extant jawless vertebrates is supported by a large amount of molecular sequence data, the apparently primitive morphology of hagfishes is a matter of debate. For example, the absence of vertebrae is still considered as strong evidence that hagfishes are placed at the basal position of the phylogenetic tree of vertebrates, in the field of paleontology. To address whether this morphology of hagfishes is the derived or ancestral condition, we conducted the developmental study in the Japanese inshore hagfish (*Eptatretus burgeri*), especially focusing on the somite derivatives. We performed a detailed histological observation and analyzed the expression patterns of *Pax1/9* and *Twist* genes in the different stages of embryos. Our results show that the ventral somite cells de-epithelized and expressed these two genes, suggesting that the animal has sclerotome which is known to differentiate into vertebrae in gnathostomes. Based on these evidences, we inferred the evolutionary history of the axial skeleton of the early vertebrates.

***94.1*** OUFIERO, C.E.*; ADOLPH, S.C.; GARTNER, G.E.A.; GARLAND, T.; Univ. of California, Riverside, Harvey Mudd College; *coufi001@student.ucr.edu*

***Variation in scale counts and body size in Sceloporus lizards in relation to latitude, temperature, and precipitation: a phylogenetic perspective***

Variation in physical aspects of the environment often leads to natural selection. Several phenotypic traits have been proposed to vary along a latitudinal/environmental gradient in squamate reptiles. In particular, body size has been proposed to decrease with increasing latitude and thus decreasing temperature at the intraspecific level; similarly, scale counts have been proposed to increase as latitude increases and temperature decreases. Previously, we examined the variation in body size and dorsal scale counts in relation to latitude among 106 species and populations of *Sceloporus*. We found support for the hypothesis that more/smaller scales are found at higher latitudes, and no support for the relationship between body size and latitude. Here, we re-analyze the data including environmental information, using both conventional and phylogenetic statistical analyses to examine dorsal scale counts and body size in relation to midpoint latitude, temperature, precipitation, and an aridity index (Q). Results suggest that body size increases with increasing mean and maximum temperatures, but not with latitude per se. Our results also suggest that although scale counts increase with latitude, they are significantly negatively related to minimum temperature, precipitation, and Q. Furthermore, the best overall fit model (based on AIC) included total precipitation as a predictor of scale counts. These results suggest that scale size and number variation may be important for such physiological processes as water loss.

***7.2*** OWENS, GL*; WINDSOR, DJ; ALLISON, WT; TAYLOR, JT; University of Victoria, University of Alberta; *thermalgibbon@gmail.com*

***The molecular contribution to bifocal vision in the four-eyed fish, Anableps anableps***

The “four-eyed” fish, *Anableps anableps*, possess morphological adaptations that enable simultaneous vision above and below water. These adaptations include a divided cornea, an oval shaped lens, and a retina with distinct dorsal and ventral sections that are exposed to aerial and aquatic light respectively. To better characterize the molecular adaptations for simultaneous above and below water vision, we have sequenced the *A. anableps* visual opsin gene repertoire and described the expression domains of these opsins using *in situ* hybridization. *A. anableps* has ten visual opsin genes: one rod opsin, RH1, and nine cone opsins including two genes in the RH2 subfamily, four LWS ospsin, one SWS1 and two SWS2 opsins. *In situ* hybridization using whole retinas and sectioned retinas shows expression throughout the retina for some genes and expression limited to specific regions of the retina for others. These data are discussed with respect to the different spectral properties of light entering the eye from above and below the water and with respect to opsin gene repertoire and expression in close relatives with 'normal' eyes.

***39.4*** OWERKOWICZ, T.*; ANDRADE, F.C.; ELSEY, R.M.; HICKS, J.W.; Uni. California, Irvine, Fullerton College, CA, Rockefeller Wildlife Refuge, Grand Chenier, LA; *towerkow@uci.edu*

***Atmospheric hypoxia increases bone robusticity in the American alligator***

Extinct animals’ body masses and growth rates have been inferred from the cross-sectional area and primary bone microstructure of their limb bones. These relationships are based on skeletons of extant vertebrates growing in an atmosphere containing 21% oxygen. In the past, however, atmospheric $O_2$ levels rose as high as 30% and fell as low as 12%, and $O_2$ supply to bone is known to affect its growth and mineralization. We tested the effect of atmospheric $O_2$ on skeletal growth in the American alligator. We incubated eggs and subsequently grew alligator hatchlings under chronic hypoxia (12% $O_2$), normoxia (21% $O_2$) and hyperoxia (30% $O_2$). Animals received monthly injections of fluorescent dyes to determine bone deposition rates. After three months, animals were sacrificed and their femora either sectioned at mid-diaphysis, or ashed. We found femora of hypoxic alligators to have significantly greater cross-sectional area (+15%), second moment of area (+20%) and polar moment of inertia (+23%) than those of either normoxic or hyperoxic hatchlings. Mineral content was also significantly higher (+6%) in femora of hypoxic animals. This suggests that exposure to chronic hypoxia, but not hyperoxia, resulted in increased resistance to compressive, bending and torsional stresses on the skeleton. Furthermore, the relationship between body mass growth and periosteal deposition rate was different between treatment groups, with hypoxic animals accruing more bone per unit body mass. We suggest that prevalent atmospheric $O_2$ level need be considered when reconstructing size and growth curves of extinct vertebrates. Supported by NSF grants IOB 04445680 and IOS 0922756 to JWH.

***1.4*** OWUSU-ANTWI, Y.; BENNETT, V.A.*; Clarion University of Pennsylvania; *vbennett@clarion.edu*

***Effects of Acclimation Temperature and Photoperiod on Antifreeze Protein Synthesis in the Hemolymph of Beetle Larvae (Dendroides canadensis)***

Overwintering larvae of the fire-colored beetle, *Dendroides canadensis* are known to produce antifreeze proteins as a means of preventing their intracellular fluids from freezing. To investigate the cues regulating production of antifreeze proteins, summer collected *D. canadensis* larvae were exposed to 25°C, 5°C or a stepwise decrease in temperature (5 to 0°C or 0 to -4.5°C) under summer or winter photoperiods. Freezing and melting points of individual hemolymph samples were measured to screen for thermal hysteresis activity (THA), an indicator of the presence of antifreeze proteins. All summer insects exposed to 0 to -4.5°C died, suggesting that this sudden exposure to cold temperatures did not allow sufficient time for antifreeze protein production. Larvae exposed to 3 weeks of cold temperature (5°C; 5 to 0°C) were found to have significant increases in hemolymph thermal hysteresis when compared to larvae kept at room temperature (25°C). Levels of thermal hysteresis observed in insects exposed to 0°C were equivalent to that observed in winter-collected insects. In addition, thermal hysteresis activity was slightly higher in insects exposed to winter photoperiods at any given temperature. We concluded that temperature is a primary factor in the regulation of antifreeze proteins in *D. canadensis* with photoperiod playing a secondary role.

***S3.3*** OYARZUN, FX*; GROSBERG, RK; University of Washington, Seattle; *foyarzun@u.washington.edu*

***Empirical evidence of familial conflict in the sea***

In sexually reproducing organisms, family conflict often forms a network of interactions in which the costs and benefits of conflict and cooperation may vary among pathways. Individuals are more related to themselves than to any other family member, however mothers are equally related to all of their offspring while offspring can have different degrees of relatedness with their siblings. Consequently, genetic conflicts of interest over resources are inevitable and strategies that maximize the fitness of one family member typically do so at the expense of other family members. Few experimental studies to date have expanded the analysis of conflict resolution into the domain of multiway conflicts of interest, leaving open the general question of the empirical importance of such approach. We analyze theory and data for marine organisms concerning the occurrence and resolution of multiway conflicts of interest between males and females over mating and care, parents and offspring over optimal allocation, and siblings over parental resources. We emphasize recent studies of two marine systems, the poecilogonous annelid *Boccardia proboscidea* and the marine snail *Solenosteira macrospira*. Both systems provide exceptional opportunities to examine observationally and experimentally multiple pathways of family conflict. We discuss the role that paternity might play in these systems and on how the interaction between mating systems, family conflict and environmental stressors could explain many apparent paradoxes of life histories and diversification in the sea.

***S7.8*** O'BRIEN, Kristin M.*; MUELLER, Irina; Univ of Alaska, Fairbanks; *kmobrien@alaska.edu*

***Pumping without iron: The unique architecture of cardiomyocytes in the hemoglobinless Channichthyids***

The lack of hemoglobin (Hb) expression in the Family Channichthyidae is perhaps one of the most striking physiological features amongst Antarctic fishes. Since their discovery more then 50 years ago, physiologists have identified many modifications in the cardiovascular system of icefishes to compensate for the loss of Hb and in some species, myoglobin (Mb) in the heart ventricle. One alteration correlated with the loss of Hb and Mb is an increase in mitochondrial volume density in cardiomyocytes. Mitochondria occupy a stunning 36% of cell volume in hearts of species lacking Hb and Mb. In addition, the loss of Hb and Mb is correlated with substantial changes in mitochondrial architecture. We have sought to determine the molecular basis of differences in mitochondrial structure between red- and white-blooded notothenioids and to determine if differences in mitochondrial structure impact function. We have determined that the high density of mitochondria in icefish hearts does not arise through a canonical mitochondrial biogenic pathway, but rather through an increase in the size of individual mitochondria via the proliferation of outer mitochondrial membranes. An analysis of the mitochondrial proteome of red- and white-blooded notothenioids revealed a significant difference in the expression of 28 unique proteins, some of which are known to regulate mitochondrial morphology. Functional studies of isolated mitochondria have shown that state III respiration rates do not significantly differ between red- and white- blooded notothenioids. However, the rate of proton leak is lower in mitochondria from icefishes compared to red-blooded species. Current studies are aimed at understanding the potential impact of elevated temperature on mitochondrial function and thermal tolerance in Antarctic notothenioids.

***11.4*** PACE, C. M.*; GIBB, A. C.; VAN WASSENBERGH, S.; Northern Arizona University, University of Antwerp; *Cinnamon.Pace@nau.edu*

***Locomotion in catfishes: are catfishes exapted for walking on land?***

Walking catfishes are known to move on land; however, key questions about this behavior remain unanswered: (1) how do walking catfish produce forward movement on land? (2) how similar is terrestrial locomotion among walking catfishes? (3) is terrestrial locomotion distinct from aquatic catfish locomotion? and (4) is terrestrial locomotion distinct from the terrestrial movements of nonwalking catfishes? We recorded dorsal views of two walking catfishes (*Clarias batrachus* and *Clarias garieppinus*) moving terrestrially, a nonwalking catfish (*Ictalurus punctatus*) moving terrestrially, and a walking catfish (*C. batrachus*) swimming. Terrestrial locomotion appears similar in the two walking catfish species and distinct from both swimming in *C. batrachus* and terrestrial locomotion in *I. punctatus*. Terrestrial locomotion of *Clarias sp.* is characterized by contact between a pectoral fin spine and the ground, while the axial musculature and tail push against the ground to elevate the catfish over the spine. Pectoral fins are adducted during the aerial (swing) phase and subtends an arc >70&deg. The tail oscillates twice during each pectoral fin stride and the tip is placed far anteriorly. In contrast, during swimming the pectoral fin moves <30°, while the body axis and caudal fin produce carangiform undulation. The nonwalking catfish was ineffective in generating forward movement and its pectoral fins did not engage with the ground, although the pectoral girdle oscillated and the tail produced a similar tail motion to that of walking catfishes. This suggests that emergence may elicit a similar motor pattern for many catfishes, but it is the addition of effective pectoral spine movements that enables forward propulsion to occur during terrestrial locomotion.

***86.4*** PADIAN, Kevin*; MAZIN, Jean-Michel; BILLON-BRUYAT, Jean-Paul; Univ. of California, Berkeley, Univ. of Lyon1, France, Canton Jura, Switzerland; *kpadian@berkeley.edu*
***How pterosaurs landed and why they evolved from bipedal ancestors***
There is continued controversy about how pterosaurs, the flying reptiles of the Mesozoic Era, walked on land. Major bauplan changes occurred with the evolution of pterodactyloids, the clade that succeeded basal pterosaurs in the Late Jurassic – Early Cretaceous until the end of the Cretaceous. Quadrupedal pterodactyloid pterosaur tracks from the Late Jurassic show that the hindlimbs moved parasagittally, whereas the hypertrophied forelimbs could make tracks both close to the body wall and far outside it. A landing track from this locality, the first ever recorded, shows in detail how the animal flapped to stall, landed with a stutter-step, and ambled off. This sequence reflects their highly developed capacity for flight control and maneuverability. The origin of pterosaur locomotion on the ground has also long been questioned: notably, whether pterosaurs evolved from bipedal or quadrupedal ancestors. Most analyses have concluded that pterosaurs are basal ornithodirans, the sister group to dinosauromorphs. Phylogenetic analyses suggest that basal archosauromorphs were quadrupedal, whereas basal ornithodirans were bipedal. Morphometric comparisons suggest that basal pterosauromorphs were bipedal; that compared to their pseudosuchian outgroups their hindlimbs became longer than the trunk, and the forelimbs later lengthened as flight evolved. The forearm lengthened even faster than the humerus, and was usually one of the longest wing elements in non-pterodactyloids. Trackways also show that quadrupedal pterodactyloids modified their footfall patterns from the traditional reptilian condition, suggesting that the habit was secondary.

***S10.5*** PADILLA, D.K.; Stony Brook University; *dianna.padilla@sunysb.edu*
***Impacts and consequences of an invasive ecosystem engineer, Crassostrea gigas***
The introduction of non-native species is presently one of the most important anthropogenic impacts on natural communities around the globe. Once introduced, species are difficult if not impossible to remove, and can spread and have wide-ranging impacts in areas distant from their original source of introduction. This is especially true for species with dispersal larvae, including aquaculture species such as the Pacific oyster, *Crassostrea gigas*, the most widely cultured bivalve in the world. Similarly, ecosystem engineers are readily recognized to have important impacts on systems where they inhabit. Thus introduced species that are ecosystem engineers are predicted to have extremely large impacts on the systems they invade. Although *Crassostrea gigas* does not generally build reefs like other oysters, it is an engineering species. It modifies the substrate and space for other species, displacing some and offering habitat for others. In addition, it can alter the thermal environment experienced by associated species, potentially altering species-species interactions and local biodiversity. The directions and types of impacts of this ecosystem engineer are also density, habitat and site specific, and may provide an opportunity for us to determine more general drivers of patterns of diversity and interactions in the communities they invade.

***31.3*** PAGE, L.R.; University of Victoria; *lpage@uvic.ca*
***Cone snail metamorphosis: differentiation of the venom apparatus from the foregut of the planktotrophic larva.***
Highly derived adult gastropods with complex life cycles, such as members of the genus *Conus*, have circumvented potential constraints of larval functional needs to achieve post-metamorphic specialization of the adult feeding apparatus. The radular teeth of cone snails are hollow harpoons, impaled into prey by a proboscis, that deliver a cocktail of immobilizing neuromuscular toxins elaborated by a venom gland. I reared larvae of *Conus lividus* through metamorphosis and cut histological sections through developmental stages to determine how this highly derived adult morphology is built within the body of the phytoplanktivorous larva. Results showed that the post-metamorphic venom gland differentiates as a channel of secretory cells along the ventral wall of the larval mid-esophagus. Within 48 hours after the onset of metamorphosis, this ventral channel of secretory cells peels away from the mid-esophageal wall; the separated tube of epithelium is the definitive venom gland that remains attached to the esophagus by a very narrow connection immediately posterior to the radular sac. The muscular bulb of the venom gland forms by 4 days after the onset of metamorphosis. Metamorphosis also involves total destruction of the distal larval esophagus and mouth. The buccal tube that extends down the post-metamorphic proboscis forms during metamorphosis by rapid proliferation and expansion of a nest of cells embedded within the ventral wall of the larval foregut, anterior to the radular sac. Comparison of events of foregut metamorphosis in *Conus lividus* and the buccinid gastropod, *Nassarius mendicus*, provides a developmental explanation for differences in the position of the radular sac relative to the probosicis in these two neogastropods.

***78.2*** PAGE, J.L.*; LINDSAY, S.M.; University of Maine, Orono; *jennifer.page82@gmail.com*
***Effects of repeated injury on the activity and condition of a maldanid polychaete***
Polychaetes and other marine infauna frequently experience tissue loss to browsing predators. Such non-lethal tissue losses can represent a significant energetic input to higher trophic levels. Past research and modeling have shown that tissue loss has immediate effects on the organism and secondarily reduces sediment disturbance rates. The degree to which sediment disturbance and the community are affected will depend on the frequency of injury, whether injured individuals can regenerate and the speed at which they do so. Similarly, the degree to which infauna provide a "renewable" food resource for consumers higher in the food chain will depend on their capacity to regenerate after repeated injuries, and on the energetic quality of regenerated individuals. The goal of this study is to test the effects of repeated injury on the activity and nutrition of a head down deposit feeding polychaete, *Clymenella torquata* (Maldanidae). In laboratory experiments, we examined the effects of repeated anterior or posterior injury on the survival, activity, growth, and nutritional condition of *C. torquata*. Loss of anterior segments in single or repeated events resulted in higher mortality, less defecation and tube building, and low to no growth in both juvenile and adult worms. One-time loss of posterior segments resulted in increased defecation and tube building by both juveniles and adults. Survival and growth of injured juveniles was greater than or equal to that of controls. In contrast, adults that lost posterior segments once experienced higher mortality and lost weight compared to controls. Losing posterior tissue multiple times decreased weight gain but increased defecation and tube building by both juveniles and adults. Analysis of glycogen and lipid content in regenerating and intact worms is ongoing.

***9.1*** PAKES, M. J. *; WRIGHTON, K. C. ; THRASH, J. C.; SANTIS, T. D. ; ANDERSON, G. L. ; ILIFFE, T. M. ; COATES, J. C. ; LINDBERG, D. R. ; CALDWELL, R. L. ; Univ of California, Berkeley, Lawrence Berkeley National Laboratory, Texas A&M, Galveston; *pakes@berkeley.edu*

***Anchialine Cave Ecology: A Multi-Disciplinary Approach***

In anchialine caves, a marine layer flows beneath one or more layers of less saline water. Water exchange with nearby oceans is severely restricted, creating stable physico-chemical gradients often characterized by anoxia and high sulfide levels. The resulting unique environment has lead to the evolution of endemic fauna, including the ancestral crustacean class Remipedia. Little is known about basic anchialine ecology; many questions remain about the structure and stability of their microbial communities and isolated bacteria have not been reported in the literature. We introduce a multidisciplinary approach to examining the ecology of anchialine caves in Quintana Roo, Mexico. We aimed to assess I) whether chemoautotrophic bacteria and archaea were present in the cave sediment and water column, and II) whether such microorganisms were major contributors to the food web. Successful isolation of anaerobic chemoautotrophic bacteria from cave sediment and subsequent community analysis of cave microorganisms using oligonucleotide phylogenetic microarrays (PhyloChips) confirmed the presence of these organisms. Stable isotope analysis of carbon and nitrogen isotope ratios revealed spatial variation in trophic dynamics between caves. These analyses support microbial input into the diets of some but not all cave animals studied. *In situ* behavioral studies have not yet been reported in the literature and here we present preliminary videotape analyses of individuals feeding on shrimp in their natural environment. Through these varied approaches to anchialine study, we have a better understanding of the micro and marcofaunal interactions of this ecosystem.

***68.4*** PALACIOS, MG*; SPARKMAN, AM; BRONIKOWSKI, AM; Iowa State Univ., Ames; *mgp@iastate.edu*

***Life history and immune defense in two garter snake ecotypes II - A common garden experiment***

Recent ecoimmunological theory proposes a link between pace of life and immune defense, such that fast-living species/populations are predicted to rely more on innate immunity (and less on acquired immunity) than slow-living ones. We previously found support for this prediction in two life-history ecotypes of the garter snake, *Thamnophis elegans*. Fast-living snakes that live in lakeshore habitats have higher levels of natural antibodies, complement-mediated lysis, and bactericidal competence (all measures of innate immunity) than slow-living snakes that live in meadow habitats. In this study, we conducted a common garden experiment to test whether the observed differences in immune defense between ecotypes are fixed (under genetic control) or are mainly plastic responses to different environmental conditions in lakeshore and meadow habitats. Wild-caught gravid dams were brought into the lab, gave birth, and their offspring were raised in a common environment. Four-month- old snakes reflected their original habitat immune phenotype for natural antibodies and complement activity, with lakeshore snakes having higher levels of both immune measures. These differences, however, were no longer detected when the snakes were measured at sixteen months of age. Bactericidal competence (measured only at sixteen months) did not differ between ecotypes. Our results suggest that differences in immune activity at an early age are due to maternal effects that disappear after several months in a common environment. Thus, the observed variation in immune defense between these two life-history ecotypes seems to be a plastic response to environmental factors. We discuss these results in the light of differences in temperature and food availability between the lakeshore and meadow habitats.

***S3.4*** PALMER, A. Richard; University of Alberta; *rich.palmer@ualberta.ca*

***Learning, developmental plasticity and the evolution of morphological asymmetry***

Evolution by natural selection requires three steps. New variants of organisms: must arise, must have an impact on fitness (survival or fecundity), and must (ultimately) be heritable. The first step - how new variants arise - remains controversial. Traditionally, the most significant source of new phenotypes was believed to be novel genotypes (mutants or recombinants) - a ‘genotype-precedes-phenotype’ mode of evolution. But developmental plasticity - the same genotype yields different forms in different environments - may be a more important source of new variants than generally recognized. The absence of heritable variation for direction of asymmetry in species that show a random mixture of asymmetric forms (i.e., equal numbers of right- and left-handed forms), identifies a unique phenotype - ‘direction of asymmetry’ - for which there is no genotype and which therefore permits tests of alternative modes of evolution. A wide-ranging survey of asymmetry variation within and among species of animals and plants offers some of the strongest evidence to date for widespread occurrence of a 'phenotype-precedes-genotype' mode of evolution. In addition, the tendency of many animals to learn (e.g., handed behavior) may facilitate both the origin and the amplification of right-left morphological differences via developmental plasticity. Such an interplay between learning and developmental plasticity might greatly enhance the rate of morphological evolution. Anecdotal observations, experimental studies, and both ontogenetic and phylogenetic evidence all suggest that handed behaviors play (or played) an important role in the development and evolution of phenotypically significant morphological asymmetries.

***S1.5*** PANI, A; DARRAS, S; ARONOWICZ, J; LOWE, C J*; University of Chicago, IBDML-CNRS - UniversitÃ© de la MÃ©diteranÃ©e; *clowe@uchicago.edu*

***Early deuterostome origins of the vertebrate head***

The early evolution of chordates has long been a subject of intense debate in zoology, and despite over one hundred years of comparative biology, there is still little consensus on the early events in deuterostome evolution that led to the establishment of the chordate body plan. This lack of consensus is largely due to the vast morphological disparity between the major adult body plans of the major deuterostome phyla, and a poor early fossil record. Developmental genetics has recently provided a new influx of data that can be used to readdress issues of chordate origins. As an out-group to the chordates, hemichordates are a very promising group for addressing hypotheses of chordate origins. We have been investigating the role of secreted proteins, with conserved early developmental roles in neural plate polarization and the establishment of the vertebrate head, during the development of the hemichordate *Saccoglossus kowalevskii*. We have revealed considerable developmental similarities in early patterning between the vertebrate head and the anterior of the hemichordate body plan, despite the morphological disparities between the two groups. Surprisingly, the extent of the similarities between hemichordates and vertebrates are far more extensive than between ascidians and vertebrates, or amphioxus and vertebrates, and suggest that the early chordate lineages have lost some of the ancestral developmental complexity of head patterning. It also implies that many of the developmental innovations of head development, previously attributed as vertebrate innovations, evolved far deeper in deuterostome evolution, and were not coupled to vertebrate morphological innovation.

***45.3*** PANKEY, M.S.*; SUNADA, H.; SAKAKIBARA, M.; University of California, Santa Barbara, Tokai University; *mpankey@lifesci.ucsb.edu*

***Dermal photoreception in the pond snail Lymnaea***

Light perception in many animals, even those lacking eyes, is assisted by a diffuse system of photoreceptive neurons. Such nonvisual photoreception may represent an ancient mechanism predating the origin of eyes. Indeed, nonvisual photoreceptors have been implicated in several biological roles ranging from predator avoidance to circadian rythmicity and migration to bioluminescence regulation. Despite such tremendous biological and evolutionary significance, many aspects of nonvisual photoreception are poorly characterized. We investigated the molecular basis of the light sensitivity in the dermal photoreceptors of the pond snail *Lymnaea*. To identify the underlying phototransduction pathway, we undertook behavioral and electrophysiological tests using pharmacological agents known to target the distinct pathways of vertebrate and invertebrate visual cells, respectively. From both approaches we find evidence of cyclic-nucleotide mediated phototransduction in the snail's dermal photoreceptors.

***S1.3*** PARIS, M*; ESCRIVA, H; SCHUBERT, M; BRUNET, F; BRTKO, J; CIESIELSKI, F; JAMIN, E; CRAVEDI, JP; RENAUD, JP; SCANLAN, TS; HOLLAND, ND; LAUDET, V; Univ. of California, Berkeley, Lab. Arago, Banyuls sur mer, Ecole Normale Superieure de Lyon, Ecole Normale Superieure de Lyon, Inst. of Experimental Endocrinology, AliX, Illkirch, INRA, Toulouse, Oregon Health and Science Univ., Portland, Scripps Inst. of Oceanography, La Jolla; *mparis@berkeley.edu*

***Amphioxus thyroid hormone signaling pathway and the evolution of metamorphosis in chordates***

Metamorhposis is a spectacular post-embryonic developmental stage, allowing a larva to become a juvenile. In the chordate lineage, that comprises vertebrates, urochordates like tunicates and cephalochordates like amphioxus, the morphological changes during larva-to-adult transitions vary extensively from one species to another, suggesting that metamorphosis may have arisen several times in the chordate lineage. Does the molecular determinism of metamorphosis in this group reflect this morphological diversity? In the well-studied vertebrates, metamorphosis is triggered by thyroid hormones (THs) binding to their receptor TR, member of the nuclear hormone receptor superfamily. In order to get better insight into the evolution of the molecular determinism of metamorphosis in chordates, we focused on the most basal chordate amphioxus. Combined biochemical and phylogenetic approaches allowed us to establish that amphioxus produces various THs through metabolic pathways homologous to vertebrate ones. Then we showed that TH production as well as TH-dependent TR activation are essential for metamorphosis induction in amphioxus, like in vertebrates, with the slight difference that the active TH is not T3, the classical vertebrate TH, but possibly its derivative TRIAC. Consequently the homology of metamorphosis in chordates is revealed by the conservation of its triggering mechanism. This suggests that the evolution of metamorphosis in chordates is marked by the conservation of the couple TH/TR whereas other parts of the regulatory network may change to underlie the morphological diversity observed nowadays.

***59.3*** PARKER, M ROCKWELL*; MASON, ROBERT T; Oregon State Univ., Corvallis; *parkermi@science.oregonstate.edu*

***Novel mechanisms regulating a sexual signal: testosterone inhibition of pheromone production in red-sided garter snakes***

Most vertebrates coordinate reproduction using multiple signals, but species that utilize single signals to encode multiple pieces of information are powerful models for understanding the regulation of signal production. Red-sided garter snakes utilize a single cue, the sexual attractiveness pheromone, to signal sex, season, condition, and reproductive state to conspecifics. This powerful sexual signal is regulated by estrogen: males given estrogen implants produce female sex pheromone. However, the presence of testicular androgens may inhibit pheromone production since castrated males produce low quality female sex pheromone. She-male garter snakes, naturally occurring males who produce a low quality female sex pheromone, have high aromatase activity in their skin resulting in local, feminizing estrogens. Since castrates exhibit the same "intermediate" pheromone phenotype as she-males, we tested the aromatase pathway hypothesis. We created seven experimental groups: SHAM, E2 (estrogen implant), GX (castrated), GX+ATD (aromatase inhibitor), FLUT (androgen inhibitor), T (testosterone), and GX+T. We found that castration induced attractivity (GX males were courted more than SHAM and wild males in the field), but blockage of aromatase activity in castrates (GX+ATD) resulted in unattractive males. The GX+T group was also unattractive, suggesting that T inhibits aromatase activity that can be induced by castration (T implants given a month post-castration). Collectively, we have shown that pheromone production in garter snakes is primarily signaled by estrogen, but these results suggest testosterone actively inhibits a quiescent pathway involving aromatase that may be the underlying source of sexual signal evolution in this system.

***9.6*** PARNELL, N F*; STREELMAN, J T; Georgia Tech; *gth877n@mail.gatech.edu*

***The macroecology of rapid adaptive radiation***

A long-standing topic in ecology addresses whether natural communities are the result of stochastic factors or if assembly rules generate community structure. Non-random communities have been attributed to species interactions and more specifically competition – a driving force in adaptive radiations. Here we examine the macroecology of the recently radiated cichlid fish assemblage in Lake Malawi, Africa at a spectrum of increasingly fine spatial scales. Cichlid communities were not different from random until examined at the finest resolution (depth within sites) where a strong signal of community structure was evident. An analysis of pair-wise interactions among a ‘core’ group of cichlids revealed repeated patterns indicative of interspecific interactions as structuring mechanisms. Targeting a highly diverse and rapidly radiating assemblage for this analysis provides insights into how community structure emerges at different spatial scales and lends credence to the importance of fine-scale species interactions in community assembly.

***50.1*** PARSONS, KJ*; MARQUEZ, E; COOPER, WJ; ALBERTSON, RC; Syracuse University, Florida State University; *kevpar66@gmail.com*

***The genetic basis of modularity in the African cichlid mandible***

Most organisms are comprised of anatomical units recognizable from their developmental origins, or function. An emerging area of interest to biologists involves understanding how organisms are partitioned into units or modules. Modularity suggests clusters of connectivity, whereby a module represents a unit that is tightly integrated but relatively independent from other such modules. The structure of this connectivity could have major evolutionary implications but until recently methods of quantitatively determining modularity have been elusive. Here we use recent advances in morphometrics to investigate modularity in the mandible of African cichlids from lake Malawi. The cichlid mandible exhibits an extraordinary level of diversity that is associated with a variety of ecological niches. Currently little is known about patterns of modularity that may exist in this adaptively important trait. Patterns of modularity could be especially important for determining the rate and direction of adaptive divergence in cichlids. We tested for patterns of modularity in members of the genus Labeotropheus, which consist of algae-scraping specialists, and Metriaclima, who are relative ecological generalists. We also assayed modularity in a genetic mapping panel of their F2 hybrids. We then extended our methods to produce an individual-based metric of modularity by selectively removing individuals from our analysis and recalculating a goodness of fit. This metric was used in a quantitative trait loci approach to map the genomic regions associated with modularity. This approached identified genomic regions specific to patterns of modularity in each group. This powerful set of techniques will be valuable for uncovering the genetic architecture of modularity, which may ultimately lead us to a greater understanding of its role in evolution.

***21.4*** PASCH, Bret; University of Florida; *bpasch@ufl.edu*

***Role of song in the altitudinal replacement of Neotropical singing mice (Scotinomys)***

Understanding the role of biotic and abiotic factors in limiting species distributions is a fundamental goal in biology. On the highest mountains of Costa Rica and Panamá, the Chiriqui singing mouse (*Scotinomys xerampelinus*) abruptly replaces Alston's singing mouse (*S. teguina*). Singing mice are diurnal insectivorous rodents that inhabit montane cloud forests of Central America, and males commonly emit stereotyped songs that appear to function in male-male aggression. Comparative biogeographical surveys, reciprocal removal experiments, and interspecific behavioral trials demonstrate that *S. teguina* is limited by the presence of dominant heterospecifics, whereas *S. xerampelinus* is limited by abiotic factors. Here, I ask how song mediates intra- and interspecific interactions among males by broadcasting conspecific, heterospecific, and control stimuli to both species in the field and laboratory. *S. teguina* responded to conspecifics but not heterospecifics, whereas *S. xerampelinus* responded to both. Such behavioral responses to song match interspecific dominance interactions and appear to reinforce altitudinal distributions of singing mice.

***91.5*** PASSAMANECK, Y.J.*; HEJNOL, A.; MARTINDALE, M.Q.; Univ. Hawaii, Kewalo Marine Lab; *yale@hawaii.edu*

***The development of mesoderm in the brachiopod Terebratalia transversa***

Classical observations of articulate brachiopods have presented a range of interpretations regarding the formation of the mesoderm, including coelomic spaces, although there is general agreement that endomesoderm is derived from the lateral regions of the archenteron during gastrulation. In the larva of terebellid articulate brachiopods, mesodermal derivatives constitute a complex network of muscles throughout the mantle and pedicle lobes, however little is know about the cellular or molecular origins of these structures. We have analyzed in *Terebratalia transversa* the expression of a number of candidate genes associated with mesoderm specification and differentiation in other bilaterians (e.g. *dpp*, *FoxC*, *FoxD*, *mef2*, *msx*, *NK4*, *Pax1/9*, *snail*, *tropomyosin*, *twist*). Consistent with the complexity of mesodermal derivatives in the *Terebratalia* larva, a wide variety of gene expression patterns are observed, with most genes displaying dynamic patterns of expression over the course of larval development that appear to be associated with the origins of mesodermal derivatives.

***59.10*** PATTERSON, S.H.*; BREUNER, C.W.; Univ. of Montana; *stephen1.patterson@umontana.edu*

***Corticosterone as a mediator of reproductive effort***

Reproductive effort varies among individuals and can have a profound effect on fitness. The physiological mechanisms underlying this variation are important to understanding inter-individual differences in reproductive effort and, by extension, fitness. Individuals with access to greater energetic resources tend to invest more in reproduction and also tend to have lower levels of corticosterone (a "stress" hormone involved in energy regulation and behavior modulation). This relationship between energetic resources / reproductive effort and corticosterone leads to the plausible hypothesis that corticosterone functions as a physiological mechanism linking resource availability and reproductive effort. However, experimental evidence for this connection is lacking. In this study, we manipulated energetic resources and plasma corticosterone concentrations in female Tree Swallows (*Tachycineta bicolor*), aerial foraging insectivores. We also measured offspring feeding rates as a proxy for reproductive effort. We manipulated energetic resources by clipping 3 primary feathers per wing to reduce foraging and locomotor efficiency. We manipulated corticosterone levels using corticosterone-soaked dermal patches. Analysis is ongoing, and results will be discussed in the framework of physiological mechanisms of reproductive effort decisions.

***37.11*** PAVLICEV, M.*; CHEVERUD, J. M.; HANSEN, T.F.; University of Oslo, Norway, Washington University, St. Louis, MO; *pavlicev@pcg.wustl.edu*

***The relationship between pleiotropy and evolvability***

The question of what kind of genetic architecture maximizes evolvability of the system is central to the evolution of complex organisms. Modularity of pleiotropic effects has been proposed as one of the main architectural features of evolvable organisms. Thereby the lack of simultaneous genetic effects on unrelated traits is suggested to free the modules from constraints due to correlated response. However restricting the pleiotropic effects also reduces genetic variation of traits (Hansen 2003) and it is the balance of the two forces that determine the maximum evolvability of the system. The constraining covariance between unrelated traits is generated only by the pleiotropic genetic effects that are biased towards the same direction. High variability of pleiotropy across loci with respect to sign can thus diminish the constraining genetic correlation and increase evolvability in spite of pleiotropy, while retaining the variance. Nevertheless, even this so-called antagonistic pleiotropy has been shown to be disadvantageous if there are correlated effects on variances of the traits (Baatz and Wagner 1997). The advantages and disadvantages of different pleiotropic architectures are complex. Here we explore the distribution of pleiotropy in the empirical data, using QTL based effects, measured for 11 differently related morphological traits in an intercross of two mouse strains, large (LG/J) and small (SM/J).

***S11.2*** PEICHEL, Catherine L; Fred Hutchinson Cancer Research Center; *cpeichel@fhcrc.org*

***Genetic architecture of body shape divergence in sticklebacks***

Fishes exhibit enormous diversity in body shape. The ability to evolve such different shapes may have contributed to the successful radiation of fishes and their ability to exploit a wide variety of aquatic habitats. Yet, little is known about the genetic basis underlying the evolution of diverse body shapes in fishes. The stickleback fishes (Gasterosteidae) are an excellent group in which to investigate the genetics of body shape. There is a great diversity of body shape among different stickleback species, as well as within a single species. In particular, populations of threespine stickleback (*Gasterosteus aculeatus*) have repeatedly and independently evolved different body shapes that are specific to different habitats. Furthermore, there is often sexual dimorphism in body shape within threespine stickleback populations. Because extensive genetic and genomic tools have been developed for the threespine stickleback, genetic linkage mapping approaches can be used to uncover the genetic architecture of body shape divergence between sexes and populations. Using this system, we are beginning to ask whether many or few genes are responsible for body shape divergence, whether the sex chromosomes are important for sexual dimorphism in body shape, whether the same genes underlie similar changes in body shape across independent populations, and whether the genes that underlie changes in body shape also control changes in other traits that are important for adaptation to a specific environment.

***59.7*** PERFITO, Nicole*; JEONG, Sunny; BENTLEY, George E.; SILVERIN, Bengt; HAU, Michaela; Max-Planck Institute for Ornithology, Germany and Univ. of California, Berkeley, Univ. of California, Berkeley, Univ. of Gothenburg, Sweden, Max-Planck Institute for Ornithology, Germany; *nperfito@berkeley.edu*

***First –day release and Dio2: a test of latitudinal variation in photoperiodic control of reproduction in great tits Parus major***

In Europe, the species' range of the great tit has expanded northward over the last 60 years. The threshold for photo-induction varies latitudinally among populations of great tits, with northern populations requiring longer days to induce gonadotropin secretion and testis growth than southern populations. We make use of these population differences in photoperiodic threshold to test the recently proposed model of photo-induction in quail. Namely, that gonadotropin-releasing hormone release is mediated by a local increase in triiodothronine (T3) as a result of up-regulation of type 2 iodothyronine deiodinase (DIO2) and down-regulation of type 3 iodothyronine deiodinase (DIO3) enzymes within cells in the basal hypothalamus. As southern populations are photostimulated by shorter day lengths, we predict that the increase in expression of key genes involved in the photo-induction pathway will occur earlier after lights on in southern than in northern population birds during one long day of photostimulation. We isolated total mRNA from brain tissue punches through the medial basal hypothalamus taken from alternate sides of 40-micron sections. We measured expression of several genes relative to a housekeeping gene using quantitative real-time PCR. These data will be the first to characterize changes in gene expression during photo-induction in any wild population. Furthermore, we aim to pin-point with these data at which point in this physiological cascade that natural selection has acted to alter timing of breeding.

***27.4*** PERLMAN, B.M.; Moss Landing Marine Laboratories; *bperlman@mlml.calstate.edu*

***Swimming performance, as indicated by $U_{crit}$ and C-start escape responses, in surfperches (Embiotocidae)***

Surfperches are enigmatic labriform swimmers. Angle of insertion of the pectoral fin varies among species and theoretically allows for differing amounts of thrust to be generated, putatively affecting swimming performance. We predicted that speed and maneuverability trade-off in this clade of nearshore fishes. Specifically, we hypothesized that surfperches with lower fin angles would achieve a faster critical swimming speed ($U_{crit}$), but were less maneuverable, as indicated by bending during the C-start escape response. To address this hypothesis, we collected four surfperch species each with different pectoral fin angles (range: 35 to 51°). $U_{crit}$ was measured in a flume. After acclimation, flow was set to 0.5 body lengths per second (BL/s) for 30 minutes, then increased by 0.25 BL/s every five minutes until $U_{crit}$ was reached, as indicated by the onset of burst-and-glide behavior. We recorded maximum fin beat frequency and $U_{crit}$. In separate experiments, we elicited C-starts from individual fish, recording the escape response with a high-speed digital camera at 250 fps. We measured maximum angle of body curvature during Stage 1, duration of Stage 1, duration of C-start escape response, escape trajectory angle (ETA), and peak angular velocity. ANOVA revealed differences among species in that surfperches with lower fin angles achieved a faster $U_{crit}$ and a higher maximum fin beat frequency. For the five C-start variables, we conducted a PCA to reduce the dimensionality of the dataset. PC1 described duration and angle of Stage 1 and ETA. PC2 described C-start duration and peak angular velocity. ANOVA performed on these PCs revealed that species with lower fin angles turned faster and had greater body bending. Contrary to our prediction, species with lower fin angles reached both faster $U_{crit}$ and greater body bending than species with higher fin angles.

***31.10*** PERNET, B.*; MCHUGH, D.; California State University, Long Beach, Colgate University; *bpernet@csulb.edu*
***Differences in the timing of development of feeding structures and the acquisition of feeding ability between small-egg and large-egg larvae of Streblospio benedicti (Annelida, Spionidae)***
In marine invertebrates with planktonic larval development, evolutionary changes in per-offspring maternal investment are commonly associated with changes in larval nutritional mode. These coordinated shifts are thought to have occurred many times in many taxa. However, for most taxa we lack detailed understanding of the developmental changes that link changes in maternal investment to changes in larval nutritional mode. We are studying these developmental changes in larvae of the spionid polychaete *Streblospio benedicti*. Females of this species produce either small eggs that develop into planktotrophic larvae, or large eggs that develop into facultatively planktotrophic larvae. Feeding experiments show that larvae developing from large eggs acquire the ability to feed at a later stage (as indicated by segment number) relative to larvae developing from small eggs. We used comparative analyses of larval form to identify developmental correlates of this difference in the timing of acquisition of feeding ability. Specifically, we describe the timing of development of particle capture and digestive systems in both types of larvae, relating these developmental events to segment number as an indicator of developmental stage. Identification of morphological changes associated with differences in larval nutrition permits us to begin to apply the tools of developmental biology to explain linkages between maternal investment, larval morphology, and larval functional biology.

***62.11*** PEROTTI, Elizabeth A.; University of Hawai'i, Manoa; *eperotti@hawaii.edu*
***The effects of substratum on patellogastropod size, abundance, and recruitment in a geologically complex temperate region***
Understanding the abiotic and biotic factors that influence spatial and temporal variation in the rocky intertidal is important for conservation of communities that face increasing alteration and degradation on a global scale. Variation in patellogastropod communities, which directly affects other trophic levels, is easily observed in body size and abundance. Limpet abundance, size, and number of limpet recruits were recorded along vertical transects on basalt, chert, sandstone, granite, and rip rap in the San Francisco Bay Area for all sympatric species observed at these sites. Vermeij (1972) proposed that upper intertidal species will exhibit a positive relationship with size and tidal elevation, whereas lower intertidal species should have the opposite trend. These predictions of shore-level size gradients for upper and lower intertidal species were generally supported; however, the relationship between size and tidal elevation differed by rock type. Most limpets recruited to middle or lower tidal elevations, suggesting that larvae of at least upper intertidal species recruit to lower elevations and migrate to adult habitats as they grow. Genetic variability made species identification difficult, but preliminary results highlight the promise of a molecular approach for recruit identification. There was also large annual variation in recruitment, including a year of extremely low recruitment driven by atmospheric anomalies during the upwelling season, which may account for the genetic variability of newly settled limpets.

***85.3*** PESPENI, M.H.*; PALUMBI, S.R.; Stanford University; *mpespeni@stanford.edu*
***The purple sea urchin genome suggests local adaptation along a latitudinal gradient despite high gene flow.***
Identifying adaptive genes is a central challenge in evolutionary biology, especially when high dispersal disrupts the signal of local adaptation. Here we develop a new SNP genotyping method with >99% accuracy and scan the genome of a species with a highly open population structure, the sea urchin *Strongylocentrotus purpuratus*. We assayed 50,935 loci, identifying 12,431 SNPs, and finding approximately 100 - 300 (1 - 2.5%) with excess divergence. Gene ontology and stage-specific expression data show a greater proportion than expected of these diverged genes act strictly during larval development. Our SNP detection method shows that adaptive evolution in purple urchins occurs across a small but significant fraction of the genome and suggests that early life history stages are a critical place to search for the action of environment on fitness.

***6.2*** PETT, Walker*; KAYAL, Ehsan; LAVROV, Dennis; Iowa State University; *willpett@iastate.edu*
***Mitochondrial genome rearrangements in animals: An update with perspectives on computational tractability***
Animal mitochondrial genomes are typically small circular molecules, in the range of 15 – 20kb, with an almost invariant set of 13 protein coding genes, 22 transfer RNAs and 2 ribosomal RNAs. It compactness of size and economy of content has made it an attractive model for whole genome evolution. In particular, evolutionary patterns in the rearrangement of this highly conserved suite of genes can be especially difficult to equivocate, as the astronomical number of possible arrangements makes it unlikely for common arrangements to arise by convergent evolution. In the last decade, the rate at which complete animal mitochondrial genomes are being published has increased by more than 7 times, with at least 1746 available to date. The comparison of animal mitochondrial genome arrangements has proven itself as a valid technique for phylogenetic inference, lending strong support to numerous relationships among a wide variety of animal groups, and has in many cases challenged the conventional wisdom regarding the mechanisms of mitochondrial rearrangement and recombination. At the same time, a burgeoning field of computational biology has been developing more efficient and useful methods for reconstructing phylogenies using genome arrangement data, which are both of interest from an evolutionary point of view, and as mathematical problems in their own right. In this review, we will briefly summarize the patterns of mitochondrial genome rearrangements within Metazoa and address the computational problems associated with gene order data and their utility in resolving relationships deep within the animal tree of life.

***11.3*** PEYER, S M*; HERMANSON, J C; LEE, C E; Univ. Wisconsin-Madison, Forest Products Laboratory, Madison, WI; *smpeyer@wisc.edu*

***Morphology and the Mechanics of Zebra and Quagga Mussel Movement***

While the invasive zebra mussel initially colonized shallow habitats in the Great Lakes, the invasive quagga mussel is becoming the more dominant species in both shallow and deep water habitats. In contrast to zebra mussels, quagga mussels have greater variation in shell morphology, particularly between shallow rocky and deep soft sedimentary habitats. Such morphological variation might have functional consequences that affect the ability of each species to colonize diverse substrates. We examined the effect of shell morphology on movement of zebra and quagga mussels across hard and soft substrates. We quantified movement of mussels with rotational ($K_{rot}$) and translational kinetic energy ($K_{trans}$), and shell morphology with the polar moment of inertia ($J$), a variable in $K_{rot}$ that describes resistance to rotation. On hard substrate, $K_{rot}$:$K_{trans}$ did not differ between zebra and shallow quagga mussels, but was 4 times higher for deep quagga than zebra and shallow quagga mussels. On soft substrate, $K_{rot}$:$K_{trans}$ of deep quagga mussels was 1/4 of that on hard substrate and did not differ significantly from zebra and shallow quagga mussels. $J$, contributed significantly to the mechanics of movement and might also affect the ability of mussels to float on or burrow into soft substrate, depending on their shell orientation. The orientation of deep quagga mussels increased $J$ and resulted in higher $K_{rot}$ on hard substrate, but might improve floatation on soft substrate. By reorienting and minimizing $J$, deep quagga mussels increased $K_{trans}$ relative to $K_{rot}$ and might also achieve greater burrowing efficiency on soft substrate. Thus, quagga mussels, with shallow and deep morphology, might have greater ability to utilize hard and soft sedimentary substrates and colonize a wider range of habitats than zebra mussels.

***62.4*** PHILLIPS, N.E.*; SHIMA, J.S.; OSENBERG, C.W.; Victoria Univ. of Wellington, New Zealand, Univ. of Florida, Gainesville; *nicole.phillips@vuw.ac.nz*

***Reproductive and larval ecology of the tropical Vermetid gastropod, Dendropoma maximum***

Sessile gastropods of the family Vermetidae are common inhabitants of temperate and tropical reefs. *Dendropoma maximum* is the largest vermetid species and is common across its Indo-Pacific range, yet little is known of its basic biology. Here we report studies from Moorea, French Polynesia on reproduction in *D. maximum*, and results from experiments examining the interaction between larval *D. maximum* and coral. From adults collected in the field we found that the sex ratio became increasingly dominated by females as body size increased, suggesting protandric hermaphroditism. Probability of brooding, number and size of brooded egg capsules, and the number of embryos per capsule were all positively related to female size. Reproduction may occur year round, and egg capsules of different developmental stages are brooded simultaneously. Females released large veliger larvae that lived without food for up to 10 days, but fed when offered cultured phytoplankton on the final day. This is the first direct observation of feeding by larvae in this genus. Larvae were repeatedly offered live and dead coral rubble but did not settle in any of our trials. Larvae that came into contact with some species of coral polyps, even for a short period, were killed: 47% of larvae that had been in contact with *Porites lobata*, and 18% that contacted *Pocillopora* sp., were unable to recover. Taken together, our work sheds light on reproduction and life history strategies of *D. maximum* with implications for dispersal, recruitment and population dynamics, as well as coral reef ecology.

***85.1*** PIERCE, S. K.*; CURTIS, N. E.; SCHWARTZ, J. A.; Univ. of South Florida; *pierce@cas.usf.edu*

***Chlorophyll synthesis by a sea slug (Elysia chlorotica)***

The intracellular chloroplast symbiosis between the sea slug, *Elysia chlorotica*, and chloroplasts of the chromophytic alga, *Vaucheria litorea*, is supported by functional, algal nuclear genes that have been transferred into the slug genome and are expressed in the slug cell. Presently, we have found 11 transferred algal nuclear genes in the slug genome, most of which code for proteins involved in photosynthesis, which proceeds almost unabated for months while the symbiotic plastids reside in the animal cytoplasm. Several of these transferred genes code for enzymes in the *V. litorea* chlorophyll a synthesis pathway. We have located the genes in slug genomic DNA and/or RNA, so they are not only present in the genome, but transcribed as well. In addition, we have discovered that chlorophyll a is synthesized from 5-amino-levulinic acid by the slugs, for as long as 6 months in the absence of any opportunity for chloroplast replacement. Although chlorophyll a is synthesized within the chloroplast and must be continuously produced to sustain photosynthesis, the replenishment of the chlorophyll synthesis pathway enzymes is dependent upon the nuclear genome. Our results clearly show that, inside the slug cell, long term chlorophyll a synthesis is accomplished using transferred algal nuclear genes.

***51.5*** PLACE, N.J.*; CRUICKSHANK, J.; Cornell University, Ithaca; *njp27@cornell.edu*

***Reproductive aging in Siberian hamsters: greater litter success in older females when short photoperiod is initiated after rather than before puberty***

Fertility and fecundity decline with age in female mammals, and in Siberian hamsters, *Phodopus sungorus, litter success rate was markedly lower in 12-mo-old than in 4-mo-old females. However, when hamsters were exposed to short photoperiod (SP) for a duration of 6 months, their litter success at 12 months of age was significantly greater than in females maintained in long photoperiod (LP). The timing of the SP exposure relative to sexual maturation had a significant effect on litter success in older females. Because SP exposure retards postweaning growth and delays sexual maturation in juvenile hamsters, we expected hamsters exposed to SP before puberty (from conception to 6 months of age) to have greater reproductive success than females exposed to SP after puberty (from 3 to 9 months of age). To our surprise, SP after puberty was associated with significantly greater litter success (77%) than was SP before puberty (35%). Regardless of which SP regime was used, litter success of SP females at 12 months of age was substantially greater than females held continuously in LP (6%). These results definitively demonstrate that pubertal delay is not an essential mechanism for the deceleration of female reproductive aging by SP. Possible explanations for the greater benefits of SP after puberty will be discussed.*

***28.5*** PLACE, S.P.; University of South Carolina; *splace@biol.sc.edu*
***Linking physiological traits across rocky intertidal communities through ecological genomics***
Along the Oregon coast, a host of ecological differences in rocky intertidal communities have been documented for two capes separated by less than 70 km. These differences are in large part attributable to oceanographic and coastal geomorphological differences between these regions. In addition, several physiological traits also differ between these regions, suggesting a mechanistic link between physical and ecological processes: among other traits and organisms, Cape Foulweather mussels reproduce less, have lower expression of heat shock response to stress, and have lower growth potential as indexed by RNA/DNA ratios than Cape Perpetua mussels. The tight linkages between oceanographic conditions, ecological performance, and physiological variation suggest that these rocky intertidal systems may be highly sensitive to climatic variation, including global climate change. In an effort to understand the complex molecular underpinnings of these linkages, we have been taking a genomics based approach to characterize gene expression patterns within *Mytilus californianus* populations inhabiting these dynamic capes. We expect that variation in these gene expression patterns may highlight the drivers of phenotypic plasticity within these ecosystems. In this integrative study we highlight the potential for these new approaches to meet the urgent need to understand the mechanistic linkages between multiple drivers of physiological responses in critical habitats.

***97.4*** PLACHETZKI, D/P*; FONG, C/R; OAKLEY, T/H; University of California, Davis, University of California, Santa Barbara; *plachetzki@ucdavis.edu*
***On the Origin and Evolution of Animal Vision: Insights from an Eyeless Cnidarian.***
Opsin-based phototransduction underlies all known visual phenotypes in animals. In bilaterians these protein cascades translate light information into changes in either *cyclic nucleotide gated* (CNG) or *transient receptor potential* (TRP) ion channel activity. Cnidarians are the earliest branching animal lineage to possess opsin-based photosensitivity but little is known about the ion channel component of the cnidarian system or its function. Such data are vital if we are to understand the evolution of phototransduction and the apparent dichotomy that exists in bilaterians. Here we combine studies of comparative genomics, gene expression and behavioral pharmicogenetics to show that a CNG-based photosystem functions in the hydrozoan *Hydra magnipapillata*. Opsin, CNG and other phototransduction genes are specifically co-expressed in hydra sensory neurons and battery complex cells. Both contraction responsiveness and nematocyte discharge are modulated by ambient light intensity and the former is perturbed by the CNG inhibitor cis-diltiazem. We combine our results with previous data on phototransduction cascade composition from a broad sample of animal taxa to show that that the ancestral pathway –that which gave rise to all present modes of animal vision- also utilized a CNG ion channel in phototransduction. Our results contrast the deep evolutionary history of CNG-based phototransduction, today used in the visual systems of various animal lineages including vertebrates, with the more recent evolutionary origin of TRP-based systems that are common to the visual systems of modern invertebrates. Our results also add a new dimension to our understanding of the sensory biology of the nematocyte, a cellular lineage already known to express both chemosensitivity and mechanosensitivity.

***19.6*** POPE, D. S.*; CHANG, K. H.; Mount Holyoke College, Massachusetts; *dspope@mtholyoke.edu*
***Hood-building behavior by the fiddler crab Uca musica differs with sediment type and time exposed at low tide***
When animals build structures, it is not surprising that their building behavior might be affected by the construction materials available. Fiddler crabs are an excellent example of structure-builders; structures built of sand or mud next to or around individual burrows have been described in several fiddler crab species. Structures called hoods are built exclusively by males and increase their attractiveness to females, and can also serve as a guidepost for the male if he ventures too far from his burrow in pursuing potential mates. We studied the hood-building behavior of the fiddler crab *Uca musica* in Sonora, Mexico. At our field site, we found males of this species building hoods in two sites: on the sandy slope of the upper intertidal area of the shore, and on a lower sandbar, less than 1 km away, separated by a shallow channel from the shore. The two locations differ in two obvious ways: the sediment grain size on the sandbar is smaller and therefore holds more water than the larger-grained sandy sediment on the slope, and the males on the slope have a longer time of exposure at low tide. The slope is also exposed at every low tide, which is not true for the sandbar during low-amplitude (neap) tides. When comparing hood size, we found that the average height of hoods did not differ between sites, but the hoods on the slope were significantly wider and deeper; this difference may be due to sediment differences. Males on the sandbar started hood-building later in the day, and were less likely to rebuild their hoods if they were destroyed; these differences are likely due to the difference in exposure time between the sites. Males on the sandbar also built their hoods more quickly – this may be because the sediment was easier to handle, or because they had less time available.

***14.4*** PORTER, M.E.*; EWOLDT, R.H.; LONG, J.H; Vassar College, University of Minnesota; *meporter@vassar.edu*
***Non-linear Viscoelastic Properties of Squalus acanthias Vertebral Columns Bending Dynamically***
In engineering, any system is expected to behave linearly if the mechanical inputs are sufficiently small, even if the individual elements are non-linear. The properties of linear systems are the same at both largest and minimum strains within each testing cycle but may vary among cycles. In non-linear systems, properties vary within cycles. However, we often describe biological systems in terms of linear viscoelastic properties even when we are working with large inputs that may produce non-linear viscoelasticity. Our goal was to analyze the non-linear viscoelastic properties of vertebral column segments (ten centra) of *Squalus acanthias*, the spiny dogfish. Segments were dynamically bent on a MTS Tytron 250 at cycle frequencies ranging from 0.25 to 2.0 Hz and at various curvatures. We hypothesized that columns would stiffen at higher frequencies and curvatures and that during those high-input tests the system would become increasingly non-linear. We found that the linear elastic modulus (MPa) increased significantly with increasing frequency and curvature, as did the non-linear modulus at largest strain. However, the non-linear minimum elastic modulus was frequency-independent and curvature-dependent. The linear and non-linear viscous moduli (Pa s) are all significantly frequency- and curvature-dependent. These data contribute to the growing understanding of how cartilaginous skeletons respond to loads, and how those responses are correlated with swimming performance. This work was supported by NSF DBI-0442269 and IOS-0922605.

***63.2*** POSTAVA-DAVIGNON, Marielle A.*; ROSENGAUS, Rebeca B.; Northeastern University; *postava-davig.m@husky.neu.edu*

***The role of nest architecture as a mechanism of disease resistance in termite species with different nesting strategies***

Homeostatic nests are a ubiquitous characteristic of termites. Nest building behavior can be unique to species, with some being identifiable by their nest structure. Previous studies have analyzed in detail the nest architectures of various social insects, and some have examined specific behaviors evolved to defend the nest from predators, pathogens, and parasites. As of yet, the importance of nest structure itself being a mechanism of defense against pathogenic pressures has not been demonstrated experimentally, despite the high occurrence of these pressures in social insect habitats. To test the effect of nest architecture on termite survival, five artificial structures designed from natural termite nests were constructed from corrugated cardboard. Twenty termites per nest from three species (*Zootermopsis angusticollis*, *Reticulitermes flavipes*, and *Nasutitermes corniger*) with different natural nesting strategies were exposed to either a control or conidia suspension of the generalist entomopathogen *Metarhizium anisopliae*. Following a 20 day census, the results show that nest architecture is a significant and independent predictor of survival in all three species. The nest that exhibited the highest survival rate varied across species, and it appears that termite survival relies upon the particular nest structure a species is adapted to. This research makes important implications as to the adaptive role of nest architecture in termite evolution.

***98.10*** POTTER, K. A.*; DAVIDOWITZ, G.; WOODS, H. A.; University of Arizona, Tucson, University of Montana, Missoula; *kap15@email.arizona.edu*

***Fried eggs: long-term consequences of egg temperature for insects***

While insects are well-known for their sophisticated mechanisms of temperature control, all insects begin life as eggs, at which point they lack the ability to thermoregulate and are isothermal with their surrounding microenvironment. While we understand much about the thermal biology of larvae and adults, the ubiquitous egg stage has been relatively neglected. How do eggs survive in thermally-stressful environments? Does temperature during the egg stage have long-term consequences for an individual's performance? We are examining these questions in the context of a plant-insect relationship in southeastern AZ *(Datura wrightii – Manduca sexta).* Insect eggs that are laid on leaves experience a thermal microenvironment, and thus a body temperature, that is strongly influenced by the leaves themselves. Here we examine whether *D. wrightii* leaves buffer eggs from extreme ambient temperatures, and how that buffering benefits eggs. We found that *D. wrightii* leaves protect *M. sexta* eggs from fatally high ambient temperatures. However, small differences in leaf temperature profiles cause large variation in embryo metabolism and development, and this embryonic experience continues to have long-term effects through adulthood.

***28.4*** POWERS, S.D.*; ANDERSON, R.A.; Western Washington University; *seandpowers@gmail.com*

***How Does Spatial Variation in Climate Cause Spatiotemporal Patterns in Lizard Energetics?***

A lizard’s ability to be active and to acquire food for growth, storage, and reproduction is expected to be seasonally constrained by the complex, dynamic set of phenomena that comprise climate. Hence variation in climate among locales should vary in how they constrain lizard activity and production. The western fence lizard (*Sceloporus occidentalis*) occupies a diversity of ecosystems from southern California to central Washington. Two locales that contrasted markedly in climate in Washington state, in the northern end of the species’ geographic range, are coastal temperate forest and the warm, dry pine-oak woodland of the state’s interior. How *S. occidentalis* is affected by this geographic “climate change” was examined by correlating daily and seasonal patterns of temperature, precipitation, and cloud cover with the patterns of lizard daily activity and energy expenditure, feeding rates and food availability along with related aspects of lizard population structure. The woodland population appears to have longer activity season and more daily activity time compared to the costal population. The longer activity seems to provide more time for these lizards to allocate more energy towards growth and reproduction. While it would seem the woodland population has a more optimum climate, the warmer summer months are more energetically expensive in comparison to the coastal population, which has a more productive environment than the dry pine-oak woodland. Currently, the optimum climates for this species are not known, but future investigations of elevational and mesic-xeric gradients may enable predictions of population structure and population density patterns in the face of climate change.

***20.1*** POWERS, KL*; GILMORE, LA; MONROY, JA; UYENO, TA; NISHIKAWA, KC; Northern Arizona University; *Krysta.Powers@nau.edu*

***Using trypsin digestion to determine the relative contributions of titin and collagen to passive elastic properties of whole muscles.***

Several elastic proteins contribute to spring properties of resting muscle, including the giant titin protein, located within muscle sarcomeres, and collagen which constitutes the endomysium, perimysium, epimysium and tendinous attachments of muscle to bone. In this study, we investigated the relative contributions of collagen and titin to elastic recoil of passive muscle using trypsin digestion. Titin is particularly sensitive to digestion by trypsin. In a single muscle fiber or cardiac myocyte, nearly all titin is digested after incubation in trypsin for 30 min. In contrast, collagen is highly resistant to digestion by trypsin, and no measurable digestion of collagen can be detected after 16 hours of incubation with trypsin. After incubating a whole soleus muscle in trypsin for 16 hr, only a collagen ghost remains, allowing quantification of the contribution of collagen to muscle elastic properties. To test for a contribution of titin to passive elastic recoil, whole soleus muscles from mouse were incubated in trypsin for 1 hr or 16 hr prior to stretch and/or passive load clamp tests. We compared the elastic properties of individual soleus muscles during passive stretch and passive elastic recoil in load clamp tests before trypsin digestion, after 1 hour of trypsin digestion, and after 16 hours of trypsin digestion. Preliminary data suggest that titin contributes significantly to passive tension of whole soleus muscles, and that the contribution of titin to passive stretch is greatest at resting length, and declines relative to the contribution of collagen with increasing stretch. These data will be used to estimate parameters for a constitutive model of mouse soleus muscle that can be used to predict the contributions of these elastic proteins to active as well as passive stretch and recoil.

***1.6*** POWERS, M.L.*; HADDOCK, S.H.D.; University of California, Santa Cruz, Monterey Bay Aquarium Research Institute; *mpowers@mbari.org*
***A Novel Luciferase from the Deep-sea Cephalopod Vampyroteuthis infernalis***
Bioluminescence is almost ubiquitous in the deep-sea environment, where organisms use luciferase enzymes to catalyze light emission from their associated luciferin substrates. Luciferases are a diverse group of proteins which mediate luminescence emission in many deep-sea taxa including chaetognaths, scyphozoans, copepods, and cephalopods. However there are only a limited number of chemical studies examining their unique properties and applications as molecular tools, possibly due to the difficulty in obtaining intact animals from depth. In this study we investigate the luciferase-luciferin system of the deep-sea cephalopod *Vampyroteuthis infernalis*, sole member of the Order Vampyromorpha. Light is emitted from fin-based photophores and from all eight arm tips, from which bioluminescent material is secreted. These light organs were harvested from individual specimens collected in the oxygen-minimum zone, between 500 -1000 m, off the coast of Monterey, CA using remotely operated vehicles (ROVs). Here we describe the purification methods and some biochemical characteristics of this novel luciferase, which utilizes the widely distributed luciferin coelenterazine.

***24.5*** PRICE, RM*; ELAHI, R; Univ. of Washington, Bothell, Univ. of Washington, Seattle; *becca.price@uwb.edu*
***Emersion limits short term growth rates in intertidal Nucella lamellosa***
Many environmental factors affect the growth of marine invertebrates, but the way these factors interact remains poorly understood. For example, tidal emersion may limit the size of intertidal invertebrates directly by interfering with the physiological mechanisms of growth, indirectly by limiting foraging time, or through a combination of both factors. We used mesocosm experiments to isolate the effects that foraging and exposure have on the growth rates of the whelk *Nucella lamellosa* collected from intertidal, wave-protected locations. Two treatments exposed snails to air for two hours and for five hours each day. In two other treatments, snails remained underwater but were deprived of their food source for two hours and five hours each day. Snails in a control group were kept submerged and fed *ad libitum*. We measured the change in tissue weight, shell weight, height and the total degrees of new growth after 24 days. Snails in control mesocosms grew faster than snails from all four treatments, and the snails from the five hour exposure treatment grew most slowly. There was no significant difference in growth among snails from the two hour exposure treatment and either of the food removal treatments, suggesting that the decrease in growth rate from two hours of emersion is consistent with the indirect effect of restricting diet. Growth in the food removal treatments did not differ, so the act of interrupting foraging may be more influential than the duration of foraging. The slow rate of growth in the five hour exposure treatment suggests that exposing *N. lamellosa* to air retards soft and hard tissue growth directly by interfering with shell deposition and indirectly by limiting food intake. The direct and indirect consequences of emersion could explain the observation that some intertidal marine invertebrates with calcium carbonate shells are smaller than subtidal conspecifics.

***44.4*** PRICE, Edwin R.*; GUGLIELMO, Christopher G.; University of Western Ontario; *eprice3@uwo.ca*
***Fueling flight with fat: substrate selectivity of avian CPT***
Carnitine palmitoyl transferase (CPT) catalyzes the conversion of fatty acyl CoA to fatty acyl carnitine which can then be transported across the mitochondrial membrane. This is often considered the rate-limiting step in fatty acid oxidation; preference of CPT toward particular fatty acyl CoA substrates could thus determine maximal rates of fat utilization when different fatty acids are supplied to muscles. We used spectrophotometric assays to examine CPT enzymatic rates when supplied with different fatty acyl CoA substrates using pectoralis muscles from white-throated sparrows (*Zonotrichia albicollis*). To determine if the CPT selectivity changes with migratory state, we examined captive birds held on a 'winter' short day light cycle, as well as those that were photoperiod-stimulated to be in 'migratory' condition. Within a chain length, monounsaturates demonstrated higher CPT activity than saturated fatty acids. CPT activity decreased with chain length, with low activity in 18:0 and undetectable activity with 20:0. Within the 18 carbon series, activity was higher with polyunsaturates, although activity of 18:3 was not significantly greater than that of 18:2. Pattern of selectivity did not vary between 'winter' and 'migratory' birds. The observed pattern of selectivity is similar to that found previously in rats, but the high CPT activity with polyunsaturates contrasts with previous findings in fish. We conclude that the selectivity of CPT can affect maximal rates of fatty acid oxidation, which in turn can affect migratory performance.

***102.4*** PROCTOR, Joshua/L*; HOLMES, Philip; Princeton University; *jproctor@princeton.edu*
***Chasing the Cockroach: How reflexes enhance running***
Neuromuscular systems are stabilized and controlled by both feedforward and feedback signals. Feedforward pathways driven by central pattern generators (CPGs), in conjunction with mechanical reaction forces and nonlinear muscle properties, suffice to produce stable stereotypical gaits. (1) These preflexive mechanisms combine with neural reflexes originating in proprioceptive sensors to yield robust behavior in uncertain environments. Experiments, though, have shown that feedback is present and important for both slow and rapid running. (2,3) The focus of the current study is to understand how neural feedback, reflexes, can affect the motor program of the cockroach. We have developed a one dimensional neuromechanical model that represents a single actuated joint consisting of a neural system periodically activating agonist/antagonist muscles. We consider two types of feedback representative of sensory feedback in the cockroach: phasic or spike-timing, and tonic or firing rate. Phasic feedback encodes state information, such as position, in the timing of individual spikes. In contrast, firing rates can encode graded measures of force or other continuous variables. Using this single actuated joint model, we can investigate how the output of the neural system is changed by different sensory feedback. Results show that both phasic and tonic feedback can shift the relative phasings of the motoneurons thereby affecting the motion of the joint. These changes seen in the model can be qualitatively matched to experimental observations in the cockroach. These sensory systems have also been implemented in a complex hexapedal model and demonstrates that the system with feedback is more robust than the one without. References (1) P. Holmes, R.J. Full, D. Koditschek, and J. Guckenheimer. (2) S. Sponberg and R.J. Full. (3) S.N. Zill, A.L. Ridgel, R.A. DiCaprio, and S.F. Frazier.

***S2.7*** PROMISLOW, Daniel; University of Georgia; *promislow@uga.edu*
***A network perspective on metabolism and aging***
Metabolic rate and longevity are both correlated with body size across species. However, after one controls for size, the correlation between the two is less clear. In a comparative study in the genus *Drosophila*, we found that longevity was not correlated with metabolic rate. Somewhat more surprising was the observation that metabolic rate was relatively constant throughout life for most of the species that we analyzed. However, these measures were based on gross estimates of $CO_2$ output. With the advent of high throughput –omics approaches, we can now begin to ask how the function of individual physiological components, and of networks of interacting components, change with age. Here we discuss the use of systems biology approaches, and of metabolomics in particular, to study age-related changes in metabolic function.

***88.1*** PROWSE, M; WILKINSON, M; MAYER, G; AUTUMN, K*; University of Washington, Seattle, Lewis and Clark College; *autumn@lclark.edu*
***Effects of humidity on the mechanical properties of gecko setae***
The mechanism of adhesion in gecko setae has been the topic of scientific scrutiny for over two centuries. Previously, we discovered that van der Waals forces are sufficient for strong adhesion and friction in gecko setae, and that water-based capillary adhesion is not required. A van der Waals mechanism does not rule out a role for water in gecko adhesion under some conditions. Other studies have shown that adhesion increases at high relative humidity (RH), raising the possibility that capillary forces or other surface hydration effects may contribute to adhesion. However, the presence of true capillary forces involving a water meniscus is difficult to reconcile with prior data showing only sub-nanometer gaps between spatula and substrate. How then can a humidity-related increase in adhesion and friction be explained? It is well known that the stiffness and damping of structural proteins such as keratins are affected strongly by humidity. In this study we tested the hypothesis that an increase in RH causes changes in the mechanical properties of setal keratin that promote adhesion and friction. We measured the effect of RH on forces of deformation and dynamic mechanical response of single isolated tokay gecko setae in tension. The mechanical properties of gecko setae were affected strongly by RH. The complex elastic modulus (measured at 5 Hz) of a single seta at 80%RH was 1225 MPa, only 39% of the value when dry, 3095 MPa. The loss tangent increased significantly with humidity, suggesting that viscoelastic losses increase due to water absorption. The changes in mechanical properties were concomitant with increases in contact forces, supporting the hypothesis that an increase in RH softens setal keratin, which increases adhesion and friction. Support: NSF-IOS-0847953 (KA), NSF-NBM-0900723 (KA).

***37.3*** PURITZ, J.B.*; KEEVER, C.C.; ADDISON, J.A.; HART, M.W.; GROSBERG, R.K.; BYRNE, M.A; TOONEN, R.J; Hawaii Institute of Marine Biology, University of Hawaii at Manoa, Simon Frasier University, University of New Brunswick, University of California, Davis, University of Sydney; *jpuritz@gmail.com*
***Contrasting Population Structure between Two Sympatric Sea Stars with Differing Life History Strategies***
The genetic connectivity of an organism not only determines the patchiness and density of local populations but also their evolutionary independence and persistence. Here, we present results from a study designed to examine the most obvious organismal trait to affect connectivity: life history. We use mitochondrial DNA, microsatellites, and nuclear intron sequence data to examine the population structure of two sympatric sea stars, *Parvulastra exigua* and *Meridiastra calcar*, with contrasting life histories. Both species are found in the rocky shallows of Southeastern Australia and Tasmania; however, *P. exigua* lays benthic egg masses with crawl away juveniles while *M. calcar* is a broadcast spawner with lecithotrophic larvae. We show that this difference in life history affects population structure by an order of magnitude as well as profoundly influencing genetic diversity and effective population size. In contrast, we will also show that despite such differences in contemporary connectivity, that both species show similar patterns of post-Pleistocene dispersal. Implications of these results will be discussed in a broader marine conservation context.

***64.8*** PUTMAN, N.F.*; SHAY, T.J.; BANE, J.M.; LOHMANN, K.J.; UNC Chapel Hill; *nputman@email.unc.edu*
***Using behavioral processes to predict geographic distributions: Implications of hatchling sea turtle migration on spatial patterns of nest abundance***
Variation in individual abundance across a species' reproductive range is often correlated with factors that increase offspring fitness at a given location. However, for highly mobile species it may be important to specifically consider how the movement of migratory offspring might also influence which areas within a region are used for reproduction. To investigate, two nesting assemblages of sea turtles were considered: loggerhead turtles (*Caretta caretta*) along the southeastern U.S. and Kemp's ridley turtles (*Lepidochelys kempii*) along the western Gulf of Mexico. Using loggerhead nesting data that spanned two decades, a simple regression model considering only distance hatchlings must migrate from the beach to the Gulf Stream System (which assists their migration across the Atlantic) can account for nearly all of the spatial variation in loggerhead nest density at regional scales and almost half at the smaller scale of Florida counties. For the Kemp's ridley, standardized nesting records are not available across their reproductive range; additionally there is no stable ocean current to which they migrate. Thus, for this analysis, hatchling dispersal was simulated across the Kemp's ridley nesting range and recruitment to nursery habitat was tracked. Dispersal from the region where most nesting presently occurs allowed for more recruitment to juvenile foraging grounds than did dispersal from surrounding regions. These studies provide insight into what may be a fundamental ecological principle: natural selection shapes the geographic distribution of migratory animals by favoring reproduction in areas that facilitate migration while simultaneously selecting against the use of areas from which successful migration is difficult.

***103.1*** QIAO, Mu; JINDRICH, Devin L*; Arizona State University; *devin.jindrich@asu.edu*

***How do humans stabilize running?***

The control strategies used to stabilize running are not well understood. However legged robots are capable of stable running based on three simple control rules: maintain running speed, height, and pitch angle. We tested whether humans use the same rules. Specifically: 1) humans control running height by modulating leg force (not stance duration), 2) humans control running speed by changing stance leg placement relative to a "neutral point", and 3) whether humans control body attitude using hip torques. We used a VICON® 3-D motion tracking system, and two force platforms (Bertec) covered by rubber mats to obscure the force platforms. 19 male participants (age = 27.2 ± 4.2years; body weight = 70.8 ± 8.3kg; body height = 178.9 ± 7.3cm) performed 6 trials in each of five running tasks: constant velocity running, acceleration, deceleration, stepping up and stepping down. All procedures were approved by the Institutional Review Board in Arizona State University. Leg force scaled by weight was linearly related to running height scaled by body height during up stepping tasks ($R^2 = 0.63$). In contrast, loading time was not correlated with running height ($P = 0.003$). Running speed was controlled by adjusting foothold placement relative to a neutral point (NP), which equals one half of the product of touch down velocity and subsequent stance duration. There was a significant linear relationship between center of pressure (COP)-to-NP displacement and velocity increment ($R^2 = 0.78$; $P < 0.05$). Finally, joint hip moments was linearly related to body pitch angle and its corresponding time derivative ($R^2 = 0.79 \pm 0.20$; $P < 0.05$). Although humans are morphologically more complex than robots, the simple control laws successful for robot stability could potentially also be employed by humans.

***91.4*** RABINOWITZ, J.S.*; LAMBERT, J.D.; University of Rochester; *jrabinow@mail.rochester.edu*

***Asymmetric RNA segregation as a patterning mechanism in Ilyanassa***

Asymmetric cell divisions are required by multicellular organisms to generate tissue diversity during early development. Spiral cleaving embryos undergo highly stereotyped divisions where large macromeres divide asymmetrically to produce several small micromeres with specified fates. In at least one representative of this group, the snail *Ilyanassa*, RNAs localize to macromere centrosomes and become asymmetrically segregated into the daughter micromeres. ~3% of RNAs in *Ilyanassa* undergo this mode of asymmetric cell division, suggesting that these RNAs may be important for normal micromere development. We have been examining one segregated RNA, IoLR5 (*Ilyanassa obsoleta* Localized RNA 5), to see if it is required for the development of the cells that inherit it. IoLR5 RNA segregates to the first quartet micromeres, which are specified to become the eyes and parts of the velum. The IoLR5 protein is translated in cells from this lineage and is later detected in specific cells in the developing head near the eye primordia and several other regions of the head and velum. Knockdown of translation using morpholino oligonucleotides (MOs) has demonstrated a role for IoLR5 in development of the eyes and the velum. Injected animals typically develop with either 1 or 0 eyes and small velar lobes. The eye and velum defects seen in IoLR5 MO injected animals are rescued by coinjection of a MO-resistant IoLR5 mRNA. As IoLR5 RNA segregates to the first quartet during development, this finding provides evidence that asymmetrically segregated RNAs are important for the lineages that inherit them.

***68.2*** RAGLAND, GJ*; FEDER, JL; BERLOCHER, SH; HAHN, DA; University of Florida, University of Notre Dame, University of Illinois; *gragland@ufl.edu*

***Waking the beast: identifying candidate genes and pathways for dormancy termination via transcriptome profiling***

Diapause, or dormancy, is a developmentally arrested, stress resistant stage that constitutes a major climatic adaptation common to nearly all insect taxa. The timing of diapause initiation and termination are critically important life history traits that synchronize life cycles with seasonal fluctuations. Further, variation in diapause timing can serve as a potent isolating mechanism, as is the case in speciating host races of the apple maggot fly, *Rhagoletis pomonella*, that exploit different host fruits at different times of the year. We investigated the mechanistic basis of diapause termination in the apple maggot fly to identify candidate genes and physiological pathways that may influence adaptive differences in timing among native hawthorn and derived apple host races. R. pomonella diapause as pupae, and we used a respirometric assay to sample at developmental landmarks prior to, during, and after diapause termination and resumption of active development. To assess patterns of differential gene expression, we performed competitive hybridizations comparing the developmental landmarks on cDNA microarrays constructed from an extensive EST library. We present results from this experiment, highlighting tests of differential expression in a priori pathways including ecdysone metabolism, stress response, and insulin signaling. We also present a comparative analysis of a similar experiment conducted on diapausing pupae of the flesh fly, focusing on evolutionarily conserved pathways.

***S6.2*** RAMENOFSKY, Marilyn*; MOFFAT, John; GUGLIELMO, Christopher; University of California, Davis, University of Washington, Seattle, University of Western Ontario; *mramenofs@ucdavis.edu*

***Endocrine and metabolic parameters track daily changes in behavior of a captive migrant***

Nocturnal migrants alternate between states of anabolism and catabolism daily. Gambel's White-crowned Sparrow, *Zonotrichia leucophrys gambelii* (GWCS), a short-bout, long-distance migrant, follows this pattern with nocturnal flight followed by daytime rest or stop-over for refueling. Previously, we identified daily behaviors in captives relating to activities observed in the field. GWCS held on 18L:6D feed during the day, enter a quiescent period prior to lights out, display migratory restlessness (MR) at night and resume feeding in the morning. Using this diel pattern of behavior, we examined whether physiological parameters alter as rapidly as changes in behavior. Specifically, we hypothesized that anabolic measures elevate in plasma when birds feed during the day but catabolic components predominate with expression of MR. Furthermore, prolonging the night phase of the photocycle, extends MR. Thus, we predicted further elevations of catabolic parameters as an indication of increased fuel demand with extended MR. We found, baseline corticosterone parallels activity, low levels by day when birds feed but elevated with MR. Daytime activities are characterized by anabolic measures of elevated lipid and protein deposition. MR is represented by catabolic metabolism of elevated uric acid and ß-hydroxy-butyrate. Using PCA, the ratio of uric acid to ß-hydroxy-butyrate explained most variation and was significantly greater during the anabolic stage ($F=18.9, P< 0.001$). Prolonged MR resulted in further elevations of catabolic measures. In support of the hypothesis, results indicate rapidity with which endocrine and metabolic systems react to energetic demands of MR on a daily basis and may serve as a model for energy flow during migratory flight in free-living birds

***34.5*** RANA, M*; HAMARNEH, G; WAKELING, J.M; Simon Fraser University, Burnaby; *mrana@sfu.ca*

***In- vivo determination of 3D muscle architecture of the human triceps surae using free hand ultrasound***

Muscle fibre architecture is one of the main factors that determine muscle function. Muscle fascicles can follow complex 3D paths through a muscle, but, to date, no method is available for detecting these orientations non-invasively. Here, we present a method to image the 3D orientation of the muscle fascicles using B-mode ultrasound, a position tracking system and automated computer algorithms. Ultrasound data were collected from the triceps surae of a subject's right leg using ultrasound and external magnetic position tracking system. Images obtained from multiple scans of the muscles were analyzed for fascicle orientation in the image plane using automated methods: multi-scale vessel enhancement filtering (a technique used to enhance tube-like structures), followed by wavelet analysis to determine local fascicle orientations. The pixels in the 2D scan were transformed to voxels in 3D space and fascicle orientation at those pixels in the ultrasound image were converted to direction cosines at voxels in 3D space based on the position and orientation of transducer for a particular scan. Although each voxel potentially contains many estimates of fascicle orientation based on the different scans, the best orientation was determined by inspecting the coefficients for vesselness and convolution that were obtained from the different scans. This method results in a set of direction cosines for the local fascicle orientations at each voxel within the muscle. Our experimental data showed that the fascicle orientations changed in a systematic manner along the proximo-distal axis of the muscle. The proposed method can be used to quantify complex 3D muscle architecture within the skeletal muscle in man.

***69.6*** RASCH, J.A.*; BAUER, R.T.; Univ. of Louisiana, Lafayette; *jennrasch@gmail.com*

***Reproductive biology and population ecology of the sea grass shrimp Ambidexter symmetricus.***

*Ambidexter symmetricus* is a caridean shrimp which dwells in sea grass meadows in tropical and subtropical waters. We collected samples at night from St. Joseph's Bay in northwestern Florida by pushnet in 1986/87 and 2009, as well as from St. Andrew's Bay in 2009. We examined the sexual morphology of males and females. Males of this species have the typical cincinnuli and appendix masculina, while females have the unusual feature of a theylcum. The presence of a theylcum is unique among carideans to the Processidae. Reproductive structures were observed with light microscopy and SEM. The theylcum may allow for short or long term storage of spermatophores by females. We examined the ovarian and embryonic condition of all females from each sample. We hope to determine if females in this subtropical population have seasonal or year-round reproduction. Our preliminary data indicates females can carry successive broods during their reproductive periods. We analyzed the population ecology of this species using past and current sampling data. We determined infestation rates of parasitic isopods for each sample, size of females at sexual maturity, and preliminary population structure, the latter of which is suggestive of partial protandric hermaphroditism. This type of sexual system is rare but has been documented in another member of the family. Knowledge of the reproduction and population ecology of this species can be used to answer larger questions about evolution not only this species, but along the several genera in the Processidae.

***1.10*** RATHBURN, CK*; SHARP, NJ; BURNETT, LE; BURNETT, KG; College of Charleston; *kolo.rathburn@gmail.com*

***Dynamics of Gene Regulation in the Penaeid Shrimp Litopenaeus vannamei Exposed to Hypoxia and Hypercapnic Hypoxia***

Many crustaceans inhabit estuarine ecosystems where they are frequently exposed to hypoxia (H) and elevated levels of $CO_2$ (hypercapnia). These factors may impair the abilities of crustaceans to maintain optimal metabolic processes and immune defense. Marine crustaceans employ various tactics to cope with environmental hypoxia and hypercapnia, which can involve metabolic depression possibly by regulating their gene expression. The present study tested the hypothesis that H and hypercapnic H (HH) elicit down-regulation of genes associated with metabolic depression, specifically protein synthesis and transcription, as well as immune defense. Shrimp were held in H, HH, or normoxia (N) for 4 h or 24 h. RNA from hepatopancreas of individual animals was hybridized to microarrays containing 21,864 unigenes expressed by *L. vannamei*. Transcriptional profiles of H and HH animals were compared to respective 4 and 24 h N controls. Genes involved in amino acid metabolism, RNA metabolism, and translation (including numerous tRNA synthetases) were down-regulated in 4 h H, 24 h H and 4 h HH shrimp. Few regulated genes could be assigned to immune defense, except for several in 24 h H shrimp, which included crustins and penaeidins. Additionally, unique patterns of gene expression such as increased lipid metabolism and initiation of apoptosis were tied to specific treatments and times, revealing effects of duration and added $CO_2$ stress in altering the transcriptome of *L. vannamei*. These results suggest that crustacean molecular responses to environmental changes in $O_2$ and $CO_2$ pressure involve both general and stress-specific gene sets and contribute insight to the effects human perturbations might have on estuarine organisms. Supported by NSF IBN-0212921 and NOAA OHH at HML.

***91.3*** RAWLINSON, Kate A; Smithsonian Marine Station; *rawlinsonk@si.edu*

***Embryonic and post-embryonic development of the polyclad flatworm Maritigrella crozieri, and the homology of lophotrochozoan larval characters***

There is a patchy distribution of ciliated planktonic ("larval") stages across the Lophotrochozoa, and these stages share many morphological characters. This broad distribution of larval characters can be interpreted either as the result of convergent evolution, or as the retention of primitive lophotrochozoan larval features. Polyclad flatworms exhibit a continuum of developmental modes, with direct development at one extreme, and indirect development via a trochophore-like planktonic larval stage at the other. Here I present embryological and larval anatomical data from the indirect developing polyclad *Maritrigrella crozieri*, and consider these data within a comparative lophotrochozoan context. The planktonic stage of *M. crozieri* possesses a transient ciliary band and apical organ, and these show significant developmental differences relative to those of trochophore larvae. Unlike the prototroch of some mollusks and annelid larva, the ciliary band of *M. crozieri* lacks a specific ciliary band muscle. The dense ciliary band nerve net of *M. crozieri* bares more resemblance to the extensive nerve net of larval polyplacophorans and ectoprocts than to the prototroch nerve rings of larval polychaetes, bivalves and nemerteans. *M. crozieri* larvae posses a well-differentiated neuropile, above which sits an apical plate. This differs considerably from the larval apical organs of many lophotrochozoan taxa. Overall, polyclad larval myo- and neuroanatomy more closely resembles that of direct developing and juvenile polyclads than that of other trochophore larvae. This raises the possibility that the polyclad planktonic life stage is not homologous with the trochophore, though further embryological and developmental genetic studies are needed to test the homology of lophotrochzoan larval characters at the morphological and/or developmental genetic levels.

***33.3*** RAYFIELD, EJ; University of Bristol; *e.rayfield@bristol.ac.uk*

***How accurately does finite element analysis reproduce strain in the ostrich mandible during simulated pecking behavior?***

Using finite element analysis (FEA) to model the musculoskeletal behavior of animals poses particular challenges, such as determining appropriate elastic properties, loading conditions, and capturing relevant geometry. In order to assess how accurately FEA can represent actual bone strain, a study was conducted to compare experimentally derived strain to FE-derived strain in the mandible of extant ostriches. A peak pecking force of 39 newtons (N) was recorded in live ostriches. Dissected ostrich mandibles were clamped at the condyles and loaded at the beak tip with 50 N of force in a hydraulic testing machine. Strains were recorded using gauges at four locations: lateral surangular, medial surangular, dorsal and ventral dentary. Strains were consistently highest in the ventral dentary, and lowest in the lateral surangular. Specimen-specific FE-models were created from CT data, and loaded identically. Models were isotropic and homogenous. Despite this inaccuracy, similarity was achieved between experimental and FE-derived strain. Patterns, orientation and peak strain locations were consistent with experimental data. Comparable magnitudes could be achieved by modifying Young's modulus in the FE-model. Gauges bonded to the dentaries were more accurate than postdentary gauges. This may be due to intramandibular sutures modulating the bending behavior of the mandible, or increased cancellous bone in the posterior jaw (neither which were modeled at this stage using FE). This study implies that FE-models, even with simple material properties, may have the potential to reproduce reliable patterns of strain. These models may be informative in comparative and hypothetical studies, but one must be sure of functional loads, material properties and the effect of sutures and cancellous tissue in order to comment on absolute strains.

***54.3*** RöTTINGER, E*; DUBOC, T; MARTINDALE, MQ; Kewalo Marine Laboratory, University of Hawaii; *rottinge@hawaii.edu*

***Investigating the role of the Nodal signaling pathway in a indirect developing hemichordate, Ptychodera flava***

Deuterostomes are a group of animals composed of chordates, echinoderms and hemichordates, and perhaps xenoturbellids. A historically unresolved and controversial question in evolutionary biology is the nature of the deuterostome ancestor and the origin of the chordate body plan. Hemichordates are a highly informative group because of their unique phylogenetic position among deuterostomes and the morphological similarities they share with chordates. In chordates, the genes encoding the TGFβ family member Nodal appear to play conserved roles in mesoderm and endoderm formation and patterning of the embryo along the dorso-ventral (D/V) and left-right (L/R) axes. Recently, the first non-chordate orthologs of Nodal have been described and analyzed in echinoderms and gastropods. Gene expression data and functional experiments in echinoderms have revealed that while the Nodal pathway in echinoderm is - like in chordates - involved in the patterning of the D/V and L/R axes, it does not appear to be involved in endomesoderm (EM) induction. Interestingly, in gastropodes, Nodal function seems to be required to trigger left or right handed coiling of the shell, suggesting an ancestral role of this pathway in establishing L/R asymmetries, co-opted in deuterostomes to pattern the D/V axis and in chordates to induce EM formation. In order to analyze the role of the Nodal signaling pathway in hemichordates, we cloned the main actors of this pathway from the indirect developing Hawaiian acorn worm, *Ptychodera flava*. Data using inhibitor and activation experiments, combined with gene expression analysis, suggest that the Nodal pathway is involved in mesoderm formation and D/V axis specification during early development, but no role in L/R asymmetry has yet been found.

***94.6*** REDMOND, N.E.*; COLLINS, A.G.; DIAZ, M.C.; THACKER, R.W.; Smithsonian Institution, National Museum of Natural History, Washington, DC, National Systematics Laboratory of NOAA's Fisheries Service and Smithsonian Institution, National Museum of Natural History, Museo Marino de Margarita, Venezuela, University of Alabama at Birmingham, AL; *redmondn@si.edu*

***Resolving species identities in the Porifera Tree of Life: a comparison of mitochondrial and nuclear barcodes***

The Porifera Tree of Life (PorToL) project is a large, collaborative effort investigating phylogenetic relationships among sponges at multiple taxonomic levels. One of the main aims of this project is to address numerous outstanding species-level questions, such as species identity and generic and subgeneric affiliations. The low number of morphological characters highlights the importance of establishing informative DNA barcoding markers for this phylum. The 5' end of the mitochondrial cytochrome oxidase I (mtCOI) marker is the chosen genetic marker for DNA based identification of species or 'DNA barcoding'. However, strong evidence suggests that this gene region evolves at a slower rate in early diverging metazoans (e.g. anthozoan cnidarians and Porifera), rendering it less informative for sponges at the species level than it is for many other clades. In an effort to improve signal derived from the mtCOI gene, we are routinely sequencing approximately 600 additional basepairs of mtCOI. In addition, we are investigating the potential use of variable regions of the 28S rRNA gene in our species-level analyses. Results from preliminary analyses of mtCOI and 28S rRNA gene sequences from a variety of taxa (representing multiple sponge orders) indicate that the D1-D3 region of this gene evolves faster than mtCOI. We conclude that the 28S D1-D3 region may be a better alternative for studies seeking to discriminate between closely related sponge species.

***90.9*** REED, D.A.*; PORRO, L.B.; HOLLIDAY, C.M.; LEMBERG, J.B.; METZGER, K.A.; ROSS, C.F.; The University of Chicago, The University of Missouri, Hofstra University; *dreed@uchicago.edu*

***Multidimensional analysis of mandibular function in Alligator mississippiensis using geometric morphometrics and finite element modeling***

Quantifying deformation patterns in the vertebrate mandible allows hypotheses relating morphology to function to be tested. Deformation patterns were quantified in the mandible of a sub-adult *Alligator mississippiensis* using both finite element analysis (FEA) and in vivo strain gage analysis. FEA compliments *in vivo* strain gage analysis by allowing hypotheses of functional morphology to be extended to global deformation patterns tested under repeatable and controlled conditions. Additionally, FEA can produce results in hypothetical models, such as models of identical geometry but varying elastic material properties and anisotropy. Forty such hypothetical models were loaded under identical initial conditions, varying only in the elastic material properties or anisotropy of the bones and sutures. Variance in the global deformation pattern was evaluated using geometric morphometric analyses. Principal component plots of the deformed models found each to occupy a distinct area of the plot. Increases in the stiffness of both bone and sutures resulted in decreases in PC1, toward the space on the plot occupied by the undeformed model. When anisotropy was introduced to the deformed model, it was found to occupy an area of the plot distinct from that of isotropic bone and sutures. These results indicate that both the stiffness and anisotropy of bones and sutures impact the global deformation of the model in distinct and measureable ways.

***86.2*** REFSNIDER, Jeanine*; JANZEN, Fredric; Iowa State University; *refsnij@iastate.edu*
***Can nest-site choice compensate for the effects of climate change on reptiles with temperature-dependent sex determination?***
Numerous effects of climate change on ecosystems have been demonstrated. Reptiles with temperature-dependent sex determination may be particularly threatened, as increasing temperatures could lead to skewed sex ratios. A potential compensatory mechanism is nest-site choice, with females selecting nest-sites to match incubation conditions to their latitude. I examined nest-site choice in *Chrysemys picta* to determine the extent to which local adaptation in nesting behavior is genetically and environmentally based. Gravid females from four transplanted and one local population were housed in a common garden in 2009. Nest-site choice was compared among populations to evaluate variation in nesting phenology, shade cover over the nest, and nest depth. Mid-latitude populations nested earlier than northern and southern populations, but this difference was likely due to variation in life-history traits, as the mid-latitude populations nested 2-3 times, while other populations nested only once. The populations did not differ in shade cover over nests, indicating that, when exposed to novel climatic conditions, females from transplanted populations chose nest-sites with similar shade cover to those of local females. Nest depth was strongly correlated with limb length and, after accounting for variation in female size, populations did not differ in nest depth. These results suggest that while maternal selection of shade cover over a nest-site may be relatively plastic, nest depth is a more rigid character. Therefore, selection of shadier nest-sites may be a mechanism by which female turtles could compensate for climatic warming, whereas alteration of nest depth in response to changing temperatures is less likely and may require a shift in overall female size.

***26.5*** REFT, A.J.; Ohio State Univ.; *reft.1@osu.edu*
***Form, function, and evolution of holotrichous isorhiza nematocysts***
Although Cnidaria consists of a diversity of body forms and life cycles, all members produce nematocysts, which provides the phylum with a strong synapomorphy. Understanding the evolution of nematocysts, intracellular capsules important for the capture of prey, defense against predators, and intraspecific aggression, is an important component of understanding the morphological evolution of cnidarians. Although nematocysts display a high degree of morphological variation (with over thirty identified types), most hypotheses of the sequence of evolution of nematocysts have focused on the holotrichous isorhiza (holotrich), the simplest morphology of spine-bearing nematocyst. However, there have been few studies quantitatively evaluating these hypotheses of evolution. To begin to address various ideas of nematocyst evolution, I used various forms of microscopy to study the form and function of holotrichs across the phylum to identify how this nematocyst type varies within Cnidaria. I find that the category holotrich consists of a higher degree of variation than previously speculated and I can begin to evaluate suggested scenarios of nematocyst evolution.

***43.3*** REILLY, S. M.*; JORGENSEN, M. E.; ESSNER, R. L. ; Ohio University; *reilly@ohio.edu*
***A New Look at the Evolution of Jumping in Frogs***
Frog jumping is one of the most enigmatic and paradoxical evolutionary transitions in vertebrate evolution. The current hypothesis for the evolution of jumping in frogs follows from the work of Emerson which proposed that the Anura possess 3 different iliosacral configurations that are correlated with locomotor mode, ecology, and phylogenetic groups as well. One configuration (with bowtie-like moderately expanded sacral diapophyses) is mostly a lateral bending system in walker/hoppers and some burrowers. Another configuration (with greatly expanded sacral diapophyses) is predominantly a fore-aft sliding system in derived aquatic forms but is also scored for some climbing and burrowing forms. The third (with non-expanded diapophyses) is hypothesized to function as a sagittal-hinge, limiting the iliosacral movement to a vertical rotation and is related to long distance jumping. The correlation of the sagittal-hinge joint with long distance jumping (as in ranoid frogs) has led to the hypothesis that ranoid-like long distance jumping is the basal condition for anurans on the basis of scoring the most primitive living (Ascaphus) and extinct (Prosalirus) taxa as having the sagittal-hinge jumping system. New data from a re-examination of the pelvis in basal frogs shows that Ascaphus and Leiopelma, the two most primitive living frogs and all of the more basal living (Bombina, Discoglossus) and extinct species (with sufficient skeletal material) do not possess the characteristics of the sagittal-hinge iliosacral system well known in the ranoid frogs. This discovery leads to a new hypothesis that the transition from walking and hopping to sagittal-hinge jumping occurred well within the frog radiation rather than early in the evolution of frogs.

***66.2*** REITZEL, AM; BEHRENDT, L; TARRANT, AM*; Woods Hole Oceanographic Inst., WHOI; *atarrant@whoi.edu*
***Circadian oscillations in gene expression in the sea anemone Nematostella vectensis: the evolution of the animal circadian clock***
Circadian clocks provide biochemical cues for diurnal variations in physiology and behavior. In animals, circadian clocks are generally entrained by oscillations in light that are detected by photoreceptive cryptochromes. This leads to variable expression and degradation of a suite of genes, including several members of the bHLH-PAS family. Circadian regulators in the bHLH-PAS family affect gene expression by binding to conserved E-box sequences in the promoters of target genes. While many circadian regulatory genes are deeply conserved, the signaling pathways differ among animal lineages. Characterizing circadian regulation in a cnidarian provides insight into the origins of animal circadian rhythms and into regulation of environmentally cued behaviors, such as gametogenesis and spawning. We have identified homologs of circadian regulatory genes in the sea anemone *Nematostella vectensis*, including five cryptochromes, a suite of genes involved in phosphorylation and proteosomal degradation, and homologs of clock, timeless and cycle. We maintained *Nematostella* either in complete darkness or in a 12 hour light: 12 hour dark cycle and measured expression of cryptochromes, kinases, timeless, and bHLH-PAS genes. Gene expression varied in response to light cycle, with a particularly strong pattern observed for the clock homolog. We predict that clock signaling is mediated through dimerization with bmal/cycle and binding of the heterodimers to E-boxes. We have identified E-box sequences in the promoters of two genes (clock, one cryptochrome), both of which showed strong transcriptional cycling, further supporting a hypothesis that these elements are important for regulating gene expression . Experiments are in progress to characterize dimerization patterns among *Nematostella* bHLH-PAS proteins and their interactions with E-boxes and natural promoter sequences

***38.2*** RENSEL, M.A.*; SCHOECH, S.J.; Univ. of Memphis; *mrensel@memphis.edu*

***Road disturbance and its impact on stress physiology and growth in young Florida scrub-jays***

Anthropogenic disturbance can be a major source of physiological stress that may go undetected in avian species. Understanding the impact of human influence on stress in threatened or endangered species is also critical to the development and implementation of conservation programs. A two-lane highway bisects the area occupied by our study population of Florida scrub-jays. We investigated the influence of this highway on nestling growth and baseline corticosterone, as well as the relationship between the proximity to the road and juvenile stress responsiveness. Our results indicate that young jays that were raised close to the road exhibited neither signs of chronic stress nor reduced growth. In addition, juveniles residing close to the road do not differ in their stress responsiveness from individuals residing far from the road. Juveniles that resided near the road tended to be in poorer body condition than those farther from the road, however, and mortality rates were higher for individuals close to the road, most likely as a result of collisions with automobiles.

***S1.8*** RETAUX, S*; OSORIO, J; GUERIN, A; XIAO, JH; KANO, S; CNRS Institut A. Fessard, Gif sur Yvette, France; *retaux@inaf.cnrs-gif.fr*

***Midline signaling and the evolution of the lamprey forebrain***

The forebrain is the brain region which has undergone the most dramatic changes through vertebrate evolution. Analyses conducted in lampreys are essential to gain insight into the broad ancestral characteristics of the forebrain at the dawn of vertebrates, and to understand the molecular basis for the diversifications that have taken place in cyclostomes and gnathostomes following their splitting. We have studied the embryonic expression patterns of 43 lamprey genes, coding for factors involved in cell proliferation, stemcellness, neurogenesis, patterning and regionalization in the developing forebrain. Systematic comparisons with model organisms highlight conservations likely to reflect shared features present in the vertebrate ancestors. They also point to changes in midline signaling systems –pathways which control the growth and patterning of the neuroepithelium-, which may have been crucial in the evolution of forebrain anatomy at the origin of vertebrates. We have therefore investigated further the regulation one of them, the Hedgehog (Hh) system. Genomic analyses in the river lamprey L. fluviatilis and the sea lamprey P. marinus were performed. Long-distance alignments and phylogenetic footprinting, together with local alignment of putative regulatory motifs show that lamprey Hhs do share non-coding regulatory elements with other vertebrates Hhs, however with significant divergence. Thus, lamprey Hh genes have evolved in a “lamprey-specific” way ever since the split between the last common ancestor of cyclostomes and gnathostomes, and allow discussing the emergence of conserved non coding regulatory sequences in vertebrate genomes.

***92.2*** REVELL, Liam J.*; LOVELY, Karen R.; MAHLER, D. Luke; National Evolutionary Synthesis Center, Harvard University; *lrevell@nescent.org*

***Predation and tail autotomy in Anolis lizards***

Caudal autotomy is common in reptiles, where it is most often used as a defense mechanism against predatory attacks. We used the distribution of caudal vertebrae number from large collections of five species of Puerto Rican *Anolis* lizards to fit and compare alternative models for tail loss. These models contained different attributes including a parameter describing the relative probability of mortality vs. autotomy during a predatory encounter, and the relative strength of the lizard tail across its length. We found, in general, very good fit between our mathematical models and empirical data. We also found some evidence that ecologically and morphologically similar anoles were also more similar in their best-fitting predation models. Both results suggest that our methods might yield interesting insights if applied to a broader sample of lizard species.

***21.1*** RICE, Aaron N.*; LAND, Bruce R.; BASS, Andrew H.; Cornell Univ.; *arice@cornell.edu*

***Novel Toadfish Swimbladder Morphology Creates Nonlinear Acoustic Complexities***

Repeated morphological specializations of vocal structures across vertebrates have independently facilitated increased complexity in acoustic signals by generating nonlinear features. Such nonlinear acoustic complexity has been observed in vertebrate lineages including amphibians, songbirds, and mammals, but fishes have remained a notable exception. Nonlinear calls are produced by coupled peripheral vocal structures. However, most fishes only have a single swimbladder used to amplify sounds produced by sonic muscles, which constrains the ability to produce calls with such features. The toadfish, *Batrachomoeus trispinosus*, is unique among fishes in that it has two separate swimbladders, which may allow for an increased complexity and diversity of its vocal repertoire compared to other fishes. Detailed analysis of conspecifically and experimentally elicited *B. trispinosus* calls reveals that both courtship and agonistic vocalizations exhibit several classes of nonlinearities, including deterministic chaos, biphonation, subharmonics, and frequency jumps. Nonlinear time series analysis reveals that the deterministic chaos in *B. trispinosus* calls is consistent with chaotic calls from other tetrapods. When one of *B. trispinosus*' vocal motor nerves is transected, their calls lose these nonlinear features, and both frequency and amplitude properties of the sound are altered (compared to pre-operation and sham-operated animals). This experimental manipulation provides an *in vivo* behavioral and physiological demonstration that the dual swimbladder system is responsible for nonlinear features present in *B. trispinosus* calls. The convergent, bilateral nature of peripheral vocal structures suggests a strong selection force favoring complex acoustic communicatory signals among all vocal vertebrate groups, including fishes.

***34.6*** RICHARDS, Christopher/T; Harvard University; *richards@fas.harvard.edu*

***Building a robotic link between muscle dynamics and hydrodynamics***

Physiologists have long appreciated that the temporal pattern of muscle force depends on the level of neural activation and the shortening velocity against a load. This well-established relationship has enabled modeling of interactions between muscle activation and muscle force that determine limb motion in terrestrial animals. Analogous principles governing muscle mechanics during swimming are less well known, in part, because of the difficulty of modeling forces against limbs moving in water. To address this problem, a frog-inspired robotic platform was built to measure both muscle force and hydrodynamic force required to translate and rotate a rigid model frog foot in water. A software-controlled servo drives fore-aft foot translation while a frog plantaris muscle, isolated from *Xenopus laevis* , powers foot rotation. The robotic foot will reach a peak translational velocity of ~0.8 to 1.0 m/s, which is within the range observed in frogs swimming at moderate speed. Varying the timing and magnitude of foot translation as well as varying muscle activation parameters (timing, magnitude and waveform pattern) will determine how hydrodynamic forces (due to both foot translation and rotation) influence the muscle work and power required for effective propulsion. Additionally, custom force transducers will measure hydrodynamic forces on the foot. Using this rig, I aim to bridge the understanding between neural input and muscle mechanical output by analyzing the time course of muscle force and velocity in response to observed hydrodynamics.

***15.7*** RICHMOND, J.P.*; KEOGH, M.; ATKINSON, S.; ZINN, S.A.; University of Connecticut, Storrs, University of Alaska Fairbanks; *julie.richmond@uconn.edu*

***Seasonal changes in leptin and ghrelin concentrations associated with intake and body condition of captive Steller sea lions***

Leptin and ghrelin are peripheral endocrine signals that regulate body fat and appetite in mammals, and are involved in photoperiod-mediated, seasonal regulation of food intake. While intake is known to vary seasonally in Steller sea lions (SSL; *Eumetopias jubatus*), seasonality of hormones that regulate intake is not known. The objectives of this study were to 1) validate assays that accurately and precisely quantify serum concentrations of leptin and ghrelin, 2) determine the seasonal pattern of these hormones, and 3) quantify their relationship to body composition and intake in SSL. Blood samples were collected monthly for 18 mo from captive adult SSL (n=4). Intake was recorded daily. Hormones were quantified using kits for Human ghrelin RIA and Canine leptin ELISA. Sensitivity, recovery of mass, assay precision, parallelism and dilution linearity were determined for each assay. Both ghrelin and leptin immunoassays exhibited validation parameters indicating both assays provide accurate and precise quantification of serum hormone concentrations. Intake and ghrelin were greatest (P=0.02) in the winter (2332±139 pg/ml) and declined in the summer (1048±191 pg/ml). In contrast, leptin followed the opposite pattern with the greatest concentrations (P=0.01) observed in summer (8.5±0.7 ng/ml; winter 4.9±0.9 ng/ml) when animals' intake was reduced. These results suggest that ghrelin and leptin are strongly influenced by season in SSL. The insensitivity of ghrelin and leptin to intake in the winter may facilitate SSL foraging by stimulating appetite. The contrasting pattern in summer may inhibit appetite during the summer breeding season when SSL typically fast for extended periods of time.

***88.5*** RISKIN, D. K.*; RACEY, P. A.; Brown University, University of Aberdeen; *dkr8@brown.edu*

***Why does Madagascar's sucker-footed bat roost head-up?***

Most bats hang head-down by their toes, but Madagascar's endemic sucker-footed bat (*Myzopoda aurita*) clings head-up inside the furled leaves of trees by means of adhesive pads on its wrists and ankles. Based on previous anatomical studies, the pads were thought to function by means of suction, but no studies of attachment or detachment by live animals have been performed. We investigated the adhesive performance of 28 individuals to determine the mechanism of attachment, and found that adhesion to brass was not affected by the presence or absence of a seal around the pad-surface interface. Also, on smooth Lexan the wrist pads were more than nine-fold weaker when pulled perpendicular to the surface than when pulled parallel to it. Suction requires a seal, but wet adhesion does not, and that directional force dependence on a smooth surface is characteristic of wet adhesion, but not of suction. Thus, we conclude that despite its name, the sucker-footed bat grips smooth surfaces by means of wet adhesion. Furthermore, we found that while the wrist pads gripped strongly when the bat was pulled posteriorly along a surface, they unpeeled easily when the bat was pushed anteriorly. This occurred because the rolling of the pads caused their surfaces to be lifted perpendicular to the surface plane, the direction in which wet adhesion is weak. This unpeeling mechanism of detachment probably permits rapid crawling locomotion, but would also cause passive detachment if bats roosted head-down. This is the most likely explanation for the head-up roosting posture of *Myzopoda aurita*. Our results give insight into the morphological specialization that corresponds to novel roosting habits, linking biomechanics, behaviour, and roosting ecology for an enigmatic Malagasy endemic.

***42.6*** RISKIN, DK; IRIARTE-DíAZ, J; MIDDLETON, K; BREUER, KS; SWARTZ, SM*; Brown University, The University of Chicago, California State University San Bernardino ; *sharon_swartz@brown.edu*

***How do bats accelerate?***

Analysis of the wing kinematics of bats flying at constant speed has provided understanding of mechanisms of thrust production. In contrast, the kinematic correlates of acceleration have not been studied for any bats, although such data would provide further insight into aeromechanics. Horizontal accelerations should be good indicators of thrust production, and vertical accelerations should reflect lift production. We studied the flight kinematics of 28 pteropodid bats, spanning six species and a 45-fold range in body masses to determine the influences of flight speed ($V_{horiz}$), horizontal acceleration ($A_{horiz}$), and vertical acceleration ($A_{vert}$) on wing kinematics. Bats were painted with 17 reflective markers on the body and one wing, then flown in a wind tunnel or flight corridor, and filmed with three phase-locked high-speed cameras. A single wingbeat cycle was isolated from each of five separate flights for each individual. For each of several kinematic parameters, we used multiple regression analyses to quantify the influences of $V_{horiz}$, $A_{horiz}$, and $A_{vert}$ on that parameter. Those analyses were done separately for each of the six species. We found that as $V_{horiz}$ increased, bats exhibited decreased wing extension, decreased wingbeat frequency, decreased stroke plane angle, decreased angle of attack, and decreased camber. As $A_{horiz}$ increased, bats increased wing extension, amplitude, and angle of attack, and decreased stroke plane angle. As bats increased $A_{vert}$, they increased wing extension, wingbeat frequency, angle of attack, and camber. Each of these changes was significant in one or more species, and no species showed any trend opposite those seen in other species. These results provide a clear picture of how thrust and lift are produced by bats, and demonstrate that these trends are robust across a broad range of body sizes.

***42.5*** RISTROPH, L.*; BERGOU, A. J.; GUCKENHEIMER, J.; WANG, Z. J.; COHEN, I.; Cornell University; *ic64@cornell.edu*
***How flying insects recover from in-flight "stumbles"***
Just as the Wright brothers implemented controls to achieve stable airplane flight, flying insects have evolved behavioral strategies that ensure recovery from flight disturbances. Here, we directly investigate control and stability through the application of torque impulses to free-flying fruit flies and measurement of their behavioral response. High-speed video and a new motion tracking method capture the aerial 'stumble', and we discover that flies respond to gentle disturbances by accurately returning to their original orientation. The insects take advantage of a stabilizing aerodynamic influence and active torque generation to recover their heading to within 2° in less than 60 milliseconds. To explain this recovery behavior, we form a feedback control model that includes the insect's ability to sense body rotations, process this information, and actuate the wing motions that generate corrective aerodynamic torque. Thus, like early man-made aircraft and modern fighter jets, the fruit fly employs an automatic stabilization scheme that reacts to short time-scale disturbances.

***62.5*** RITSON-WILLIAMS, R.*; PAUL, V. J.; ARNOLD, S. N.; STENECK, R. S.; Smithsonian Marine Station at Fort Pierce, University of Maine, Darling Marine Center, Maine, University of Maine, Darling Marine Center, Maine; *williams@si.edu*
***Do coral larvae choose between species of coralline algae?***
Coral reefs throughout the Caribbean are experiencing an unprecedented decline in coral populations. To determine what habitats are required by coral larvae we tested the settlement specificity of three spawning Caribbean corals, *Acropora palmata*, *A. cervicornis* and *Diploria strigosa*, and the brooding coral *Favia fragum* by measuring their rates of larval settlement and metamorphosis in response to crustose coralline algae (CCA) and other substrata. In choice experiments the coral larvae were offered two species of CCA in the same dish, giving them 5 substrata to settle on; The CCA surface of either species, the rock under either species, or the dish that held the experiment. When given a choice, *A. palmata*, *A. cervicornis*, *D. strigosa* and *F. fragum* larvae had more settlement and metamorphosis on the surface of *Hydrolithon boergesenii* or *Titanoderma prototypum* or clean rock than onto the surface of *Paragoniolithon solubile* or the dish. When given a choice between *H. boergesenii* and *T. prototypum* there was no difference in the amount of settlement and metamorphosis onto the CCA and rock substrata available for any of the larvae except for *A. palmata*, which had higher rates of settlement on the surface of *H. boergesenii* than on the surface or rock of *T. prototypum*. There is a hierarchy of settlement substrata that coral larvae prefer for settlement and metamorphosis, which is critical information to increase coral recruitment on reefs.

***60.6*** RITTSCHOF, C.C.; University of Florida; *critter@ufl.edu*
***The effect of male group size on female multiple mating and male reproductive success in the golden silk spider***
Across a variety of animal taxa, the outcome of male-male contests depends on size. Winners are larger or have bigger weapons. However, in some cases, large-male advantage changes with density of males. For example, if high male density increases the intensity and frequency of male-male contests, increased male density increases large-male competitive advantage. Conversely, in some cases, at high male densities, defending or guarding females is no longer a successful strategy, and small males who are quicker at finding females copulate more successfully than larger males. In the golden orb spider *Nephila clavipes*, large males have a competitive advantage in male-male contests. However, male body size and male density are highly variable. In order to test how male density affects large-male advantage, I manipulated male density on female webs and used behavioral observations and molecular paternity analysis to address how density affects the rate of male-male challenges, the body size of successful fathers, and the ability of the mated-male to prevent other males from copulating with the female. I found that large males have a reproductive advantage in higher male density where fighting among males is intense, but small and large males are equally likely to successfully copulate at low male densities where fighting rates are low. Because large-male advantage in *N. clavipes* is a function of male density, small males could overcome their competitive disadvantage by employing mating strategies that avoid female webs with high numbers of competitors.

***99.1*** RIVERA, Ajna*; CIENIEWICZ , Brandon; DANKA, Elizabeth; WINTERS, Ian; RUED, Anna; WARNER, Lisa; GENTILE, Lisa; HILL, Malcolm; HILL, April; University of Richmond; *arivera2@richmond.edu*
***Evolution of Gene Regulatory Networks: Pax/Six in Ephydatia muelleri (Porifera; Demospongiae)***
The evolution of complexity from simpler forms has lead to much of the organismal diversity that we find astounding in nature. Modern genomics, phylogenetics and developmental biology techniques now allow us to dissect possible evolutionary routes from the simple to the complex. One promising way to do this is to study the evolution of gene-regulatory networks and their developmental functions. For example, many animals use the Pax/Six/Eya/Dac (PSED) network to specify eyes and other sensory organs. Complex interactions between multiple members of these four gene families, integration of other gene-families into the network, and absence of specific PSED interactions from several developmental contexts make the evolutionary history of this network extremely difficult to trace. To begin to understand this evolutionary history, we examine PSED members in simple animal, the sponge Ephydatia muelleri (Demospongiae). While sponges (phylum Porifera) lack sensory organs in the traditional sense, they do have at least two components of the PSED network: Pax and Six. Here, we show developmental expression, gene-knockdown, and chromatin-binding data in an attempt to understand the origins of a ubiquitous metazoan gene-regulatory network.

***86.6*** ROBERTS, S*; HIROKAWA, J; GUTIERREZ, A; ROSENBLUM, H; STICKLES, E; SAKHTAH, H; PORTER, M.E.; LIEW, C; ROOT, R; LONG, J; Vassar College, Lafayette College; *soroberts@vassar.edu*

***Simulating Evolutionary Processes: Swimming Robots in a Predator-Prey Ecology***

To test hypotheses about how predation and foraging acted as selection pressures on early vertebrates, we created a predator-prey ecology in which a population of autonomous surface-swimming robots competed. Our aquatic ecosystem was populated by one predator robot, whose traits remained constant, and six prey robots, whose three evolvale traits were genetically coded: (1) span of the caudal fin, (2) number of vertebral elements, and (3) predator detection sensitivity. The prey robots were programmed to seek light, a behavior meant to imitate foraging. When a prey robot detected the prey-seeking predator, foraging behavior was over-ridden by an escape response. We evolved the population of six prey individuals over ten generations. Individual fitness was proportional to the distance from the predator, the inverse of the distance from the food source, peak acceleration during the escape, and the number of escape responses. The three individuals with the highest fitness were sexually reproduced in software using a genetic algorithm. We found significant directional increases in caudal fin span and number of vertebral elements, indicating that the selection pressures might have been sufficient to drive the evolution of these traits. Predator detection sensitivity showed a different pattern, with a significant directional decrease and oscillating variation, indicating that there may have been several predator detection sensitivities adaptive in our artificial ecosystem. This work was supported by NSF DBI-0442269 and IOS-0922605.

***17.5*** ROBERTS, S.P.*; WANG, X.; DE BELLE, J.S.; Central Michigan University, University of Nevada Las Vegas; *stephen.roberts@cmich.edu*

***Environmental Effects on Drosophila Brain Development and Learning***

Brain development and cognition are sensitive to environmental perturbations experienced by sub-adult organisms. However, little is known about how (A) multiple stressors interact to affect these traits, (B) protective mechanisms can mitigate such damage and (C) anatomical structures of the brain and/or cognitive functions are differentially sensitive to deleterious effects of stressful environments. We addressed these issues by testing the effects of sub-adult heat shock (variably coupled with stress response-inducing heat pretreatment), larval density and early-adulthood sensory enrichment on external and brain anatomical features and olfactory learning in mature adult *Drosophila melanogaster*. A stress response-inducing heat pretreatment administered prior to daily heat shock of sub-adults partially mitigated heat-shock mushroom body phenotypes and, to a lesser degree, learning impairments. In thermally-benign conditions, wing area, leg length and the volumes of adult antennal lobes and optic lobes were inversely related to larval rearing density, while mushroom body and central complex volumes were less sensitive to rearing density. Likewise, adult learning ability was unaffected by larval rearing density. Daily heat stress during sub-adult development had no effect on wing area, leg length, optic lobe volume and central complex volume, but muted the rearing density-dependence of most features. Sensory enrichment during early adulthood did not mitigate mushroom body developmental damage caused by daily heat shock in sub-adult stages. These results suggest that, in various stressful rearing environments, the mushroom body's plasticity contributes to both its likelihood of damage and its developmental fidelity relative to other brain structures.

***47.2*** ROBERTSON, Jeanne M*; ROSENBLUM, Erica Bree; Univ. of Idaho, Moscow; *jmrobertson@uidaho.edu*

***Male aggression and territoriality in recently diverged populations of desert lizards***

Models of ecological speciation focus on the reproductive isolation of ecologically divergent populations. However, the diversification of male territorial behavior in incipient species is largely unexamined, despite that resource acquisition and defense is critical to male reproductive success. White Sands in southwestern New Mexico is a geologically young formation (~ 6000 yrs) of stark white sand dune surrounded by Chihuahuan desert habitat. Multiple species, including our focal taxon, the Western Fence Lizard (*Sceloporus undulatus*) exhibit cryptic (blanched) dorsal coloration that distinguishes it from the dark coloration of the surrounding desert scrub populations. Male fence lizards also show strong divergence in social signal coloration, suggesting a role for both natural and sexual selection in this system. The white sands lizards are thus an ideal system to investigate the divergence in intersexual competition as a cause or consequence of ecologically speciation. We examined male-male aggressive and territorial behavior to determine whether males of recently diverged populations (white sands versus desert scrub) can discriminate between local and non-local conspecifics and whether territorial males are more aggressive towards local males. We found that males in both populations can discriminate between intruder male phenotypes, but that the effect and direction of aggression differed between sites. As predicted, white sands males were more aggressive to local males while desert scrub males showed higher levels of aggression toward non-local males. We also found surprising shifts in the composite behavior of territorial males. This study underscores the significance of male-male interactions in the early stages of divergence.

***13.3*** ROBINSON, H.E.*; FINELLI, C.M.; BUSKEY, E.J.; University of California, Berkeley; *erobinson@berkeley.edu*

***Turbulence over a coral reef interferes with zooplankton escape behavior***

Bottom-dwelling marine animals rely on water motion to deliver planktonic prey. As currents and waves interact with the ocean floor, variation in the fluid environment can alter predator-prey interactions. Some zooplankton can avoid predation by detecting hydrodynamic cues that are formed as fish predators lunge and open their mouths. Calanoid copepods exhibit rapid escape jumps in response to the flow fields generated by suction feeding fish. In structurally complex marine environments such as coral reefs, flow passing over corals can increase turbulence. Turbulence may interfere with copepod avoidance behavior by masking hydrodynamic signals of their predators. We tested the ability of *Acartia tonsa* to detect and evade predation in laboratory flumes that produced both unidirectional and wavy flow conditions similar to those measured over coral reefs. Turbulent flow regimes over smooth vs. rough substrata were compared. A fixed siphon simulated a suction predator flow-field; copepod detection of the hydrodynamic stimuli was measured as the reaction distance from the siphon. Escape jumps were initiated closer to the siphon in faster currents and in rough turbulence, indicating copepods were less able to detect predators in these flow regimes. While the capture rates of non-evasive *Artemia* nauplii did not vary with flume conditions, adult copepods were captured significantly more with increases in current speeds, wave motion, and in rough flow. The effect of turbulence on escape behavior may account for increases in predation in hydrodynamically complex environments.

***82.4*** ROBINSON, D. M.*; MORRIS, M. R.; Ohio University; *dr647706@ohio.edu*

***Unraveling the complexities of variation in female mate preference for vertical bars***

Female preferences differ not only in response to changes in the environment, but also due to differences across females in the nature of these responses. Comparative, multivariate studies of wild-caught adult females can assess the potential for reaction norms to produce variation in female mate preference as they can elucidate how different female phenotypes respond to environmental differences. We used a multivariate analysis to examine variation in female preferences for vertical bars across five populations of *Xiphophorus cortezi* that vary in the frequency of males with bars. We tested female preferences for barred versus barless males using video animations of males as stimuli. All candidate models for variation in female preference included two aspects of the female's phenotype (bar state and size) as well as population. Based on knowledge about the genetics of vertical bars, the aggressive behavior of barred and barless males, as well as differences across populations, we hypothesize that both aspects of a female's phenotype (bar state and size) influences how they respond to more aggressive barless males, and at least for barred females, this depends on having had experience with both barred and barless males. These results suggest that to study the evolution of female preference for vertical bars one needs to consider the behavior as different reaction norms for barred and barless females.

***4.2*** ROGERS-LOWERY, CL; Catawba College; *clowery@catawba.edu*

***Effects of elevated atmospheric $CO_2$ on growth in newly-settled coral polyps***

As levels of atmospheric carbon dioxide increase due to anthropogenic causes, it is projected that the pH of the oceans will become more acidic. Lower pH decreases aragonite saturation of seawater and may, as a consequence, negatively impact the growth and survival of coral While much research has been dedicated to the impact of $CO_2$ levels on calcification and other physiological mechanisms of adult coral, little has dealt with early developmental stages. In the current study, newly-settled polyps of the coral *Favia fragum* were exposed to different levels of atmospheric $CO_2$ and growth was measured over 12 weeks. The average growth of coral in normal conditions (380 ppm $CO_2$) was 987.5±135.3% of initial polyp area, which was significantly greater than those reared under conditions of 600 and 1000 ppm $CO_2$ (408.8±81.3% and 248.9±44.6%, respectively). Other parameters of growth and physiological state, including protein content to skeletal weight ratio, calcium content, and ultrastructure of the skeleton, were compared between coral reared in normal and elevated atmospheric $CO_2$. The oceans deposit a very important amount of carbon through calcification in marine organisms. If calcification of cnidarians is lowered significantly, then it is possible that on a global scale much less carbon will be sequestered by the oceans. This could then lead decreased ability of the oceans to absorb the surplus carbon from the atmosphere, leading to accelerated climate change.

***35.3*** ROELKE, Corey E.*; GREENBAUM, Eli B; The University of Texas at Arlington, The University of Texas at El Paso; *croelke@uta.edu*

***The natural history, taxonomic status, and conservation biology of the endangered African treefrog, Leptopelis karissimbensis***

*Leptopelis karissimbensis* is a treefrog species endemic to the Albertine Rift of central Africa and is considered endangered by the IUCN. Some authors have considered the species conspecific with a morphologically similar species, *L. kivuensis*. Many authors have stated that the known range *L. karissimbensis* is restricted only to the Virunga Mountains. We present evidence that *L. karissimbensis* and *L. kivuensis* are distinct species and include a review of characters historically used to diagnose the two species. We provide new molecular, behavioral, and morphological characters that can be used to diagnose the two species. *Leptopelis karissimbensis* has a distinct advertisement call, unique defensive behavior, an amino acid deletion in a nuclear gene, and several morphological characters that serve to distinguish it from *L. kivuensis*. We also extend the known range of *L. karissimbensis* to the West and provide a review of the known distribution of the species. Based on observations that the species occurs over a much wider range than previously thought, we recommend that the IUCN downgrade the frog's endangered status so as not to overestimate the perceived rarity of the species.

***37.4*** ROGNSTAD, R L*; HILBISH, T J; Univ. of South Carolina, Columbia; *rhiannon@biol.sc.edu*

***Genetic recombination within Mytilus as evidence of past species distributions***

The *Mytilus edulis* (common blue mussel) complex is composed of three sister species (*M. edulis, M. galloprovincialis,* and *M. trossulus*) that are capable of interbreeding when they co-occur. Hybridization between these species has been extensively examined in many of the locations where they are sympatric. Studies of these and other hybrid zones provide information on the genetic mechanisms of speciation and evolution by describing patterns of recombination and selection. Interspecific variation in the gene encoding adhesive *Mytilus* foot protein-1 (mfp-1) has allowed the development of markers capable of distinguishing the three sister species. When used together, markers targeting the 5' and 3' ends of the mfp-1 coding sequence can be used to identify interspecies recombination within this large gene. Investigation of western European hybrid zones of *M. edulis* and *M. galloprovincialis* indicates interspecies recombination rates average about seven percent. Results also indicate significant variation in the number of recombinant alleles among size classes, with a greater frequency of recombinant alleles usually observed in smaller size classes. Comparison of recombinant allele frequency within the current hybrid zone with that of areas that were recently composed of hybrid populations reveals a significant reduction of recombinant alleles over time. Together these patterns suggest that natural selection occurs against recombinant alleles and that these genetic variants are being continuously regenerated within and spread from hybrid populations. Estimated selection coefficients based on these data predict hybrid zone movement similar to movement predicted based on changes in climatic variables.

***6.4*** RORICK, Mary/M.*; WAGNER, Gunter/P.; Yale University, New Haven, CT; *mary.rorick@yale.edu*

***Protein Modularity and Evolvability: Evolutionary Origins and Consequences***

It is well recognized that “modularity” is an important feature of living systems, though we lack concrete definitions for what this term means. Being able to quantify modularity, at least at one level of biological hierarchy, is essential for addressing questions about its evolutionary origins and implications. Here we develop an index for protein modularity that reflects how much of the protein’s tertiary structure is constrained by coevolving amino acids. A quantitative method for measuring protein modularity makes it possible to test whether there is natural variation in modularity, and whether it correlates with directional selection. If we find a correlation between modularity and directional selection at the protein level, we can conclude that biological modularity is the product of natural selection for evolvability. We test for this correlation in a dataset of orthologous genomic markers that have solved tertiary structures. For each protein in the dataset, we use a site model to obtain a proportion of sites under directional selection, p, and an associated ω for this category of sites. Our index for directional selection is p(ω-1). Our index for modularity is the P-value of the average distance between coevolving pairs of amino acids in the tertiary structure. Given that proteins are the fundamental building blocks of essentially all biological systems, addressing whether protein modularity evolves for the sake of protein evolvability is its own justification. However, to the extent that our indexes are grounded in formal definitions that are independent of the specific context within biological hierarchy, it may be possible to extrapolate from our findings to form hypotheses about modularity and evolutionary dynamics at other biological levels, such that of the whole organism.

***70.5*** ROS, I.G.*; BIEWENER, A.A.; Harvard U.; *ivo.ros@gmail.com*

***Detailed 3D Wing Kinematics during Low Speed Maneuvering in the Pigeon Columba livia.***

High power and precise control are two critical aspects of low speed maneuvering flight. Insight into the control of flight maneuvers requires understanding the mechanics and aerodynamics involved, which to date, has received little attention compared with steady forward flight and has not been based on high-resolution 3D kinematic analysis. To expand on the current understanding that redirection of the net aerodynamic force occurs as a consequence of bilateral asymmetries in both downstroke velocity and angular momentum of the two wings, detailed wing kinematics during 90 degree-level turns in rock pigeons were analyzed based on multiple camera views at 500 Hz. Four individuals were trained to perform the turning maneuver in a stereotypical fashion. In support of previous studies, peaks of roll and pitch accelerations occur early and late in the downstroke, whereas yaw torques are generated late in the upstroke and during the latter half of the down stroke. Timing asymmetries between the inside and outside wing beat cycles do not predict body torques. Roll accelerations into the turn correlate with a more vertical downstroke of the outside wing, while the inside wing is depressed along a more caudally swept trajectory. Surprisingly, the inside wing is extended roughly 10% more than the outside wing throughout downstrokes that roll the pigeon into the turn. The slight, but consistent baseline kinematic asymmetries will require stereotypical comparisons of a given wing acting as the inside versus outside wing to dissect the underlying neuromuscular mechanisms that produce those asymmetries. *NSF IOS-0744056*

***S11.5*** ROSA-MOLINAR, E.*; LAUDER, G. V.; University of Puerto Rico-Rio Piedras, San Juan, PR, Harvard University, Boston, MA; *ed@hpcf.upr.edu*

***Sexually dimorphic remodelling of Gambusia's anal fin, body plan, and spinal neural circuitry which facilitates rapid copulatory behavior***

For 24 years, our research on the Western Mosquitofish, *Gambusia affinis* (*Gambusia* hereafter) has refined and extended prior research on the species and elucidated a mechanism by which the sexually dimorphic modified anal fin, the gonopodium, of the male *Gambusia* is radically remodelled and anteriorly transposed. We assert the anterior transposition of the gonopodium aligns the urogenital pore with a permanent dorsal groove of the gonopodium and the alignment is necessary and sufficient for the transfer and deposition of spermatozeugmata within the female urogenital sinus. Three-dimensional kinematics confirm our assertion and extend Peden's (1975; Can. J. Zool. 53: 1290-1296) and others' observations of sexually dimorphic copulatory behavior. We confirm that male *Gambusia* circumducts the gonopodium without displaying precopulatory behaviors and show that circumduction is a complex movement in which abduction, extension, pronation, and adduction movements are combined in a very rapid sequence. Contrary to previous reports, the sexually dimorphic pectoral fin does not support the gonopodium during copulatory behavior. We elucidated the spinal neural circuitry involved in control of gonopodium circumduction by identifying distinct pools of ωGolgi-likeω labeled motor neurons innervating anal fin muscles and observing dye-coupling between motor neurons and interneurons. To better define the nature of the dye-coupling, we employed freeze-fracture replica immunogold labeling for connexin 35. Our results show the presence of connexin 35 immunopositive dendrodendritic gap junctions between motor neurons and between motor neurons and interneurons. Gap junctions' role may be to increase speed and to increase or decrease synchrony of neural activity of neuronal populations controlling the anal fin muscles. Research supported by NIH-NS30405.

***56.3*** ROSEN, O.*; MANOR, R.; WEIL, S.; LINIAL, A.; AFLALO, E.D.; SAGI, A.; Ben-Gurion University of the Negev; *ohadrosen1@gmail.com*

***A Sexual Shift Induced by an Androgenic Gland Insulin-Like Gene Silencing in Intersex Crayfish***

Male sexual differentiation in crustaceans is controlled by a unique male specific androgenic gland (AG). In the Australian red claw crayfish *Cherax quadricarinatus*, a phenomenon of sexual plasticity is exhibited in form of intersex individuals bearing both a fully active male reproductive system and masculine secondary sex characters along with a constantly arrested ovary. In the present study, the intersex model was used for the examination of changes caused by silencing of *Cq-IAG*, an insulin-like gene specifically expressed in the AG, through dsRNA injection. Upon the silencing of this single gene, intersex crayfish went through a wide array of sex-related alterations. The pleopods of injected individuals were transformed and exhibited characteristics associated with egg bearing and maternal care. The formerly spermatophore-filled sperm duct had emptied and the spermatogenic testis went through extensive apoptosis. Simultaneously, expression of the female specific vitellogenin gene was induced and a significant increase in the ovary size was highly evident. This observation is attributed to the accumulation of the yolk protein vitellin in the developing oocytes. In addition to the functional determination of *Cq-IAG* as the pivotal androgenic hormone encoding gene in the crayfish, the necessity of its product as an anti-apoptotic maintenance agent of the male gonad had been unequivocally elucidated. This study provides the first evidence that silencing of a single insulin-like gene can manipulate and transform a wide array of male-related phenotypes into female-unique characteristics.

***90.1*** ROSS, C.F.*; HERREL, A.; METZGER, K.A.; REED, D.A.; SCHAERLAEKEN, V.; GEORGI, J.; BADEN, A.L.; WOLFF, M.S.; University of Chicago, IL, Museum National d'Histoire Naturelle, France, Hofstra University, NJ, University of Antwerp, Belgium, Midwestern University, AZ, Stony Brook University, NY, New York University, NY; *rossc@uchicago.edu*

***Jaw kinematics in lepidosaurs and mammals and the evolution of amniote chewing.***

Mammals chew more rhythmically than lepidosaurs and show less variance in chew cycle durations. The research presented here evaluated possible reasons for this difference in relationship to variation in sensorimotor systems. Variance in the absolute and relative durations of the phases of the gape cycle was calculated from kinematic data gathered from a range of lepidosaurs and mammals. Bone strain data from the mandibular corpus were used to evaluate how lepidosaurs modulate bite force during chewing. Mammals exhibit less variance in overall gape cycle duration than in the durations of its constituent phases, suggesting trade-offs in variance among the phases of the gape cycle. Similar effects are much less pronounced in lepidosaurs. In addition, mammals show isometric changes in gape cycle temporal shape: the relative durations of the phases of the gape cycle change little with increasing cycle time. In contrast, in lepidosaurs the variance in total gape cycle duration is associated with increases in the proportion of the cycle made up by the slow open phase. *Tupinambis* resembles mammals in rate-modulating bite force. We hypothesize that in mammals the central nervous system includes a representation of the optimal chew cycle duration maintained using afferent feedback on the ongoing state of the chew cycle. The differences between lepidosaurs and mammals may not lie in the nature of the sensory information collected and its feedback to the feeding system during slow open, but rather the processing of that information by the CNS and its use for modulating other gape cycle phases.

***46.4*** ROSVALL, K.A.; Indiana University, Bloomington; *krosvall@indiana.edu*

***A novel cost of a sexually selected trait in females: more aggressive female tree swallows incubate less***

Among the most studied behavioral trade-offs is that between mating and parental effort, where individuals divide limited resources between attracting mates or repelling rivals on the one hand, and caring for offspring on the other. Historically, the two sexes were placed at opposite ends of this trade-off, with males investing primarily in mating effort and females investing primarily in parental effort. More recently, research shows that females also display exaggerated traits and behaviors that may be important for mating effort. Intrasexual aggression in female tree swallows (*Tachycineta bicolor*) is one such potentially sexually selected trait: more aggressive females are more likely to obtain a nesting cavity, a limited resource required for reproductive success. High levels of aggression may prove costly, however, if females trade-off aggressive and parental behaviors. Males and females in many species trade-off aggression and provisioning, although much less is known about the potential trade-off between aggression and incubation. Here, I treated female tree swallows with exogenous testosterone (T) to test whether females trade-off intrasexual aggression and incubation behavior. I used a behavioral bioassay to measure female aggressive response to a simulated same-sex intruder. I measured female incubation behavior using iButton data-loggers that record nest temperature from the perspective of an egg. T-implanted females were significantly more aggressive and incubated significantly less than control females. These results experimentally demonstrate that T at least partly mediates aggression in female tree swallows and that females trade-off aggressive and incubation behaviors. Results will be discussed in light of their implications for the evolution of intrasexual aggression in females.

***101.9*** ROTH, E.S.*; ZHUANG, K.; STAMPER, S.A.; FORTUNE, E.S.; COWAN, N.J.; Johns Hopkins University, Baltimore, MD; *eatai@jhu.edu*

***Linear Dynamical Models for Refuge Tracking Behaviors of the Weakly Electric Knifefish Eigenmannia virescens***

In numerous behaviors, animals modulate locomotor patterns to stabilize sensory images on receptor arrays. Many behaviors can be explained as a sensorimotor loop: sensing modulates motor action, the mechanical system generates forces on and filters external forcing from the environment, and these actions in turn generate reafferent sensory signals. In this work, we explore the applicability of linear dynamical models to "image stabilization" tasks, a broad class of sensorimotor behaviors in which animals modulate locomotor patterns to stabilize sensory images on receptor arrays. Despite the fact that many of the constituent sensory or mechanical subsystems are highly nonlinear, the closed-loop stabilization makes these behaviors particularly amenable to linear modeling. In this work, we observe the longitudinal tracking response of the weakly electric knifefish *Eigenmannia virescens*. These fish swim forward and backward using propulsion from an anal ribbon fin in response to motion of a computer-controlled moving refuge. Through an assay of perturbation experiments and control theoretic analyses, we identify that for a restricted yet still rich class of refuge trajectories, a linear dynamical model closely estimates actual tracking performance. We further observe regimes of stimuli which yield characteristically nonlinear responses and explore the implications of and hypotheses furnished by these results. Such data-constrained dynamical models provide parsimonious and quantitative task-level characterization of behavior. In conjunction with these task-level models and locomotor mechanics models (which might be derived from physical principles or fit empirically), system identification methods can be applied to infer the requisite neural processing for a given behavior.

***S4.1*** ROWE, N.P.; CNRS, Univ Montpellier, France; *nrowe@cirad.fr*

***How do climbing plants climb?***

Climbing plants have fascinated biologists since the pioneering works of Charles Darwin and his contemporaries. One of the most noticeable aspects of climbing plant diversity is the range of attachment organs that have evolved to initiate attachment and maintain mechanical contact with host supports. Climbing plants are common in tropical rain forest ecosystems where they show many kinds of attachment; these appear to be functionally linked to particular growth strategies and mechanical organisations of the stem and branch system. Many species exhibit a “search and attach” strategy in early development, requiring mechanical traits that combine (a) spanning gaps between hosts and (b) securing an attachment. These initial stages are generally followed by developmental mechanisms that increase flexibility and failure resistance of the mature climbing stems. Comparative studies indicate that these overall patterns vary widely and depend on the kind of attachment mechanism: for example, species that attach rapidly and securely via twining stems develop flexibility sooner than species that attach via hooks. Such differences can influence the exact mode of climbing and the kinds of habitat and host preference of different climbing species. Phylogenetic and developmental constraints profoundly influence how stiffness, attachment and flexibility are achieved in climbing plants. Highly divergent clades among dicots and monocots have evolved these mechanical prerequisites via different combinations of traits and developmental plans. An understanding of the mechanical traits and the evolutionary processes that have shaped them, offer the chance to understand the diversity and origins of some of the most spectacular and bizarre growth forms in the plant world.

***98.9*** ROWE , Michael F*; BAKKEN , George S ; RATLIFF, Joey ; LANGMAN , Vaughan ; Indiana State University, Terre Haute , Audubon Zoo, New Orleans , USDA/APHIS; *mrowe6@indstate.edu*

***Thermodynamics of Asian Elephant (Elephas maximus) Locomotion: The Functional Significance of Heat Storage and Pinna Vasodilatation***

Abstract The large body size of Asian elephants (*Elephas maximus*) presents a large surface for absorbing solar and thermal energy from the environment (external heat load), while their small surface area to mass ratio makes dissipation of metabolic heat (internal heat loads) challenging. During locomotion metabolic rate in Asian elephants can increase up to 4.5 times resulting in a rise in core body temperature (heat storage). Seasonal variations in environmental conditions may make dissipation of metabolic heat differentially challenging. While the pinna (ears) of elephants have been proposed as thermoregulatory organs no study has examined their significance to heat loss during locomotion. To quantify the thermal energy budget of Asian elephants during locomotion we measured rectal temperature (Tb) and performed thermal imaging before and after exercise in the winter, summer and fall of 2009 on two adult Asian elephants, ranging in mass from 3,447kg to 4,627kg, at the Audubon Zoo in New Orleans, Louisiana. The distance of exercise events were either 945m or 1614m. The change in Tb during these short and moderate distance walks ranged from 0.3 to 1.7 ˚C. Heat storage increased significantly ($P<0.05$) in the summer. Radiant heat loss from vasodilatation of the pinna also increased significantly ($P<0.05$) in the summer, however it accounted for only 2% of the total heat loss regardless of season. Due to their small surface area to mass ratio heat loss in exercising elephants occurs at slower rates than metabolic heat production, therefore the majority of heat generated by locomotion is stored.

***S4.3*** RUEGGEBERG, M.*; BURGERT, I.; FRATZL, P.; Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; *markus.rueggeberg@mpikg.mpg.de*

***Elucidating the mechanical principles of stem movements in heliotropism***

Heliotropism is the movement of plant organs such as leaves or flowers in order to track the sun which can be seen in a variety of plant species. Whereas receptors and sites of light perception have been identified, the underlying mechanisms of organ movement have been well characterised for the leaves only. At the basis of leaf petioles, a specialised region consisting of motor cells, the so called pulvinus, enables the movement through (reversible) changes of cell volume due to changes in turgor pressure. However, such motor cells have not been observed in flower stems and the underlying mechanism of floral heliotropism remains to be identified. The movement is of particular interest from a biomechanical perspective. The flowers stem represents an upright beam, which is fixed on one end, whereas the other end, the flower, tracks the sun over an angle of about 180°. Thus, torsion of the plant axis might be involved as well as differential growth and/or changes in turgor pressure, enabling this particular movement. In our study, we investigate the mechanism of floral heliotropism under laboratory conditions taking the alpine plant *Ranunculus alpestris* as model organism. We track the 3D-movement of the stem and the flower. By combining this with a detailed analysis of the stem, especially regarding cell dimensions and orientation, we want to distinguish between irreversible movements caused by (differential) growth and reversible movements caused by turgor changes. We further intend to identify whether bending or torsional movements are involved.

***81.1*** RUIZ, M.A.; Indiana University, Bloomington; *mayruiz@indiana.edu*

***Resource supplementation reduces trade-offs in male, but not female, sagebrush lizards***

The dietary resources available to organisms in their natural environment determine the energy available at a given time. This energy is essential for an organism to carry out the cellular processes required for survival and reproduction. We thus considered the effect of food availability on immune function and reproductive physiology in a field population of sagebrush lizards, *Sceloporus graciosus*. In a series of field studies, we manipulated diet (with supplemental feedings) of males (in 2008) and females (in 2009) in a natural population. Additionally, we increased testosterone (T) levels with a non-invasive dermal patch in male lizards. After a week of manipulation, we collected blood from the postorbital sinus for use in immune and hormone assays. We determined immune response by calculating the bacterial killing capability of collected plasma exposed to *E. coli* ex vivo. We determined reproductive investment by assessing reproductive hormone concentrations (T in males) through radioimmunoassay and by measuring morphological changes of female reproductive characteristics. We observed an interactive effect of food availability and T-patch on immune function in males, with food supplementation increasing immunity in T-patch lizards. Furthermore, males with supplemental food had higher circulating testosterone than controls. In females, food supplementation did not enhance immune function nor did it seem to have an immediate affect on female reproduction. Collectively, this study shows that the energetic state of the animal plays a role in modulating the interactions among immunity and reproduction and that the sexes differ in the distribution of these tradeoffs in sagebrush lizards and likely other species.

***39.2*** RUNDELL, Rebecca J.*; LEANDER, Brian S.; University of British Columbia; *rrundell@interchange.ubc.ca*

***Microeukaryotes and the masters of miniaturization: Diversification in marine sand***

Marine interstitial environments harbor an extraordinary diversity of coexisting microeukaryotic lineages collectively called “meiofauna.” The extensive geographic distribution and long geological history of interstitial environments suggest that knowledge of meiofaunal diversity is critical for understanding the early evolution of eukaryotic life. Meiofaunal animals such as acoels, gnathostomulids and nemerteans are poorly known, but provide important insights into fundamental patterns of macroevolution, such as the miniaturization of animal body plans, convergence and heterochrony (e.g., paedomorphosis). In this talk, we address the diversification of a few major groups of meiofaunal animals – especially acoels and nemerteans from the eastern Pacific Ocean – using molecular phylogenetic approaches, scanning electron microscopy and light microscopy.

***88.2*** RUSSELL, Anthony P.*; HIGHAM, Timothy E.; University of Calgary, Clemson University; *arussell@ucalgary.ca*
***Modulation and modularity : behavioral insights into secondary reduction and loss of the gekkotan adhesive system***
The subdigital adhesive pads of geckos consist of a hierarchy of structural components. The epidermally-derived setae are the ultimate agents of adhesion, but their action is dependent upon a suite of morphological components that control the pattern of application and release of the setae. Whether or not the adhesive system is deployed in any given situation is dependent upon sensory feedback relating to body orientation. In horizontal locomotion the digits are carried in a permanently hyperextended configuration, regardless of the challenges of traction that may prevail. Despite the many advantages that the adhesive system may confer, some lineages of geckos have secondarily reduced or lost it as a functional entity. The pattern of reduction or loss is suggestive that the adhesive apparatus is an integrated developmental and evolutionary module. The pattern of reduction and loss is typified by a distal shift and truncation of the apparatus, resulting in a diminution in the number of scansors involved, and ultimately a breakdown in the orderly arrangement of the setal fields. Ecological circumstance and behavioral control collectively correlate well with reduction and loss of this system. Examples from African geckos occupying diverse habitats and trending towards secondary terrestriality will be used to illustrate the morphological transformations that exemplify reduction and loss, and to explore how these changes lead to new patterns of adaptation and new configurations of the modular system.

***68.1*** RYAN, Joseph*; PANG, Kevin; HERRERA-GALEANO, Enrique; MORELAND, Travis; NGUYEN, Anh-Dao; NIH SEQUENCING CENTER, ; MULLIKIN, James; MARTINDALE, Mark; BAXEVANIS, Andreas; National Human Genome Research Institute, University of Hawaii, National Institutes of Health Sequencing Center; *jfryan@mail.nih.gov*
***The Genome of the Lobate Ctenophore, Mnemiopsis leidyi***
Genome sequencing of species from early-branching metazoan phyla such as Porifera, Placozoa, and Cnidaria have provided important insights into the evolution of multicellular animals, the relationship between genomic complexity and morphological complexity, and the molecular basis for the evolution of novel cell types such as epithelia, neurons, muscle, and stem cells. Until now, Ctenophora was the last non-bilaterian animal phyla without a sequenced genome. New sequencing technologies have made *de novo* genome sequencing affordable, but technological challenges still remain. Here we report the results of the sequencing, annotation, and initial analysis of the 200-megabase genome of the ctenophore *Mnemiopsis leidyi*. We produced 8,068,590 reads from seven rounds of 454 sequencing, along with 26,864,036 reads from one lane of Illumina transcriptome sequencing, yielding 50x sequencing coverage of the genome. Using the Phusion assembler, 161 megabases of genomic sequence was assembled into 10,106 scaffolds with an N50 scaffold length of 123 KB, the longest scaffold being 597 KB in length. We have compared important developmental and human disease-related gene families from *Mnemiopsis* with those found in other animal genomes. Our early findings suggest that *Mnemiopsis* possesses an impressive repertoire of genes involved in patterning, signaling, the immune system, neural development, and other key developmental pathways. Further analysis of the Mnemiopsis genome will continue to shed light on the mechanisms driving metazoan diversity and complexity.

***95.4*** RYAN, C.A*; DUDGEON, S.R.; California State University, Northridge; *carly.ryan.16@csun.edu*
***Measuring the heritability of plasticity in a colonial model hydroid, Hydractinia symbiolongicarpus***
The influence of environmental variation on the phenotypes of individuals has long been of interest to researchers. In species which demonstrate a high level of phenotypic plasticity, individuals have a mechanism to cope with living in a predictably unpredictable environment. The phenotypic changes wrought by this mechanism however have the potential to alter the fate of individual organisms, thus affecting allele frequencies, which can affect the downstream evolution of the species. However, it is largely unknown if the extent of plasticity itself is a heritable trait which is subject to selection. That selection can act on the shape of a reaction norm is an idea that has been postulated, but has rarely been tested by explicit experimentation. We have explicitly addressed this hypothesis in the colonial model system *Hydractinia symbiolongicarpus* using the concepts of clonal repeatability and quantitative genetics to ask the question: is the morphological plasticity exhibited by these encrusting hydroids in response to hypoxia in fact a quantifiable, heritable trait?

***25.4*** RYERSON, WG; University of Connecticut; *william.ryerson@uconn.edu*
***Jumping in the salamander Desmognathus ocoee***
Jumping in plethodontid salamanders has been noted anecdotally as a defense mechanism, but there is currently no description of how this movement is performed. Contrary to most terrestrial examples, where this behavior is powered by hind limb activity, these salamanders jump using body bending. I investigated the mechanics of jumping in the plethodontid salamander *D. ocoee* using high speed imaging at 1000 fps. Kinematic analyses of twenty individuals in an ontogenetic series (SVL 2.0 - 4.8 cm) showed jumping in these salamanders is performed by: (1) bending the body laterally, (2) rapidly straightening the body, (3) the individual becomes airborne. Durations, velocities and angles were measured for bending and straightening, only duration was measured for jumping. The duration of the three stages is less than half of a second (250 ± 77 ms). Initial bending of the body had a higher duration (135 ± 64 ms) than both straightening (43 ± 16 ms, $p < 0.001$) and jump duration (72 ± 19 ms, $p < 0.001$). None of the kinematic variables could be used to predict jump duration. In addition to quantifying the kinematics of jumping, I also investigated the effect on size on this behavior. Only duration of bending increased with SVL ($p = 0.03$). Although the axial musculature is primarily responsible for this behavior, the role of the limbs during jumping in these salamanders remains to be seen.

***S8.3*** SANCHEZ, Juan A.; Universidad de los Andes, BogotÃ¡, Colombia; *juansanc@uniandes.edu.co*
***Intragenomic ITS2 (rDNA) variation in octocorals: ancestral polymorphisms or footprints of reticulate evolution?***
Ribosomal DNA is supposed to evolve via concerted evolution resulting in the homogenization of its copies. However, variations within individuals have been reported in diverse eukaryotes. Regrettably, there is no proper way to evaluate if the IntraGenomic Variation (IGV) is the result of recent hybridization or incomplete lineage sorting. Here we tested, examining several groups of octocorals, if IGV has reticulate evolution signals. The ITS2 variation was assessed with DGGE, sequencing, secondary structure prediction, and phylogenetic approaches. Results were compared against mitochondrial phylogenies. Little IGV was found in deep-sea genera such as *Paragorgia* and *Corallium*, and shallow-water genera such as *Plexaurella* and *Leptogorgia*. In contrast, extensive IGV was detected in the deep-sea family Isididae and the shallow-water genera *Gorgonia*, *Pseudopterogorgia*, *Eunicea*, *Muricea* and *Pacifigorgia*. Phylogenetic analyses among the recovered intragenomic variants exhibited polyphyletic patterns. Most groups involving IGV exhibited mito-nuclear discordance. An interpretation of reticulate evolution is suggested for the origin of *Gorgonia mariae* (a brooder) as hybrid between *Pseudopterogorgia* (brooder) and *Gorgonia* (broadcast spawner) ancestors. Other cases, such as *Eunicea*, *Muricea* and *Pacifigorgia* with low divergence among species, suggest patterns related to recent burst-like adaptive radiations. Another approach is being tested to corroborate these results: Nucleolar Dominance, a potentially useful tool for assessing hybridization thanks to the epigenetics of rDNA transcription.

***S5.8*** SANCHEZ ALVARADO, A; Howard Hughes Medical School, University of Utah School of Medicine; *sanchez@neuro.utah.edu*
***Stem cells, regeneration and the developmental plasticity of planarians***
It is paradoxical that for many animals (including humans), the apparent anatomical stability of their adult bodies is maintained by constant change. Under normal physiological conditions, the functions of many organs depend on the continuous destruction and renewal of their cells. Equally remarkable is the fact that the adult tissues and organs of many organisms can be fully restored after amputation. In fact, it appears that metazoans have evolved a series of renewal and repair mechanisms to respond to both trauma and normal wear and tear. Moreover, these mechanisms are under tight regulatory control such that organismal form and function can be maintained throughout life. As important as repair and restoration of tissues are to the survival of multicellular organisms, we know little about how these processes are effected and regulated at the cellular and molecular levels. Here, I will discuss how the study of a simple metazoan, the planarian Schmidtea mediterranea, is beginning to shed light on the way adult animals regulate tissue homeostasis and the replacement of body parts lost to injury.

***91.2*** SANTAGATA, S.*; RESH, C.; HEJNOL, A.; PASSAMANECK, Y.; MARTINDALE, M.Q.; Long Island University, C.W. Post Campus, Kewalo Marine Laboratory, University of Hawaii, Kewalo Marine Laboratory, University of Hawaii; *scott_santagata@hotmail.com*
***Evolutionarily conserved expression of genes involved in the differentiation of anterior neural tissues within the larva of the articulate brachiopod, Terebratalia transversa.***
Evolutionarily conserved transcription factors are involved in the anterior-posterior patterning of the nervous system among divergent bilaterian phyla. Specifically, several genes such as *fez*, *otp*, and *NK2.1* are expressed in cells within the anterior and medial regions of the nervous system. We isolated and characterized the expression patterns of these genes and others found in neuronal cells within the embryos and larvae of the articulate brachiopod, *Terebratalia transversa*. Both *fez* and *otp* exhibit broad expression within the developing apical ganglion during the late stages of gastrulation. *Fez* maintains broad expression within the apical ganglion through late larval stages, however *otp* becomes restricted to a small subset of medially positioned neuronal cells in the apical ganglion and the mantle lobe at late larval stages. Similar to *otp*, *NK2.1* is expressed more broadly within anterior neuronal tissues during the latter stages of gastrulation and becomes restricted to a medial group of neuronal cells within the apical ganglion by the late larval stage. These results, coupled with immunohistochemical data on the distribution of neurotransmitters, support bilaterian-wide developmental conservation of anterior neurosecretory structures. Although some aspects of these expression patterns are shared among all bilaterians and influenced by functional constraints, the majority of our data are more consistent with expression patterns found among trochozoan larval forms than those of deuterostomes.

***90.7*** SANTANA, S.E.*; DUMONT, E.R.; DAVIS, J.L.; UMass Amherst; *ssantana@bio.umass.edu*
***Mechanisms of bite force production and their relationship with diet in Neotropical leaf-nosed bats***
In terms of cranial morphology and diet, Neotropical leaf-nosed bats (family Phyllostomidae) are one of the most diverse groups of mammals. This morphological diversity translates into variation in biting performance (bite force), which corresponds with some aspects of their dietary ecology. However, relatively little is known about the morphological determinants of bite force production among phyllostomids, and whether these determinants vary among dietary groups. Here we investigate morphological predictors of bite force across 25 species of phyllostomids that are commonly described as insectivores, frugivores, nectarivores, omnivores, and sanguivores. We built a 3D static bite force model based on cranial and muscle data from individual specimens whose bite force was measured in the field. We used the model to predict bite force during canine and molar biting, and to investigate variation among dietary groups. The predicted bite forces were significantly correlated with our in vivo bite force data, although $r^2$ values were relatively low. Based on the relative contribution of the cranial muscles to the total moment about the temporomandibular joint (TMJ), species fall into groups that appear to reflect dietary hardness. The temporalis is the main contributor to rotation about the TMJ in all the bats we studied, but its relative contribution is highest within the group composed of durophagous frugivores and carnivores. In contrast, the medial pterygoid makes a greater relative contribution to rotation about the TMJ in bats that specialize in liquid diets (nectarivores and sanguivores). Our results suggest that variation in the morphology of phyllostomid skulls reflects mechanical specializations to variation in the physical properties of their diets.

***83.3*** SANTHANAKRISHNAN, Arvind*; DOLLINGER, Makani; MILLER, Laura; UNC Chapel Hill; *asant0@email.unc.edu*
***Characterization of the Fluid Motion Generated by Upside-Down Jellyfish Cassiopea***
The fluid flow produced by bell pulsation in oblate medusan swimmers such as the moon jellyfish (*Aurelia*) has been examined in recent studies to understand the biomechanics of feeding via unsteady propulsion (see Dabiri *et al.*, J. Exp. Biol., 2005). The upside-down jellyfish (*Cassiopea*) differs from the commonly observed swimming forms of scyphomedusae in that it is naturally found adhered to the muddy bottoms of shallow ocean waters in regions saturated with sunlight. While they tend to momentarily swim when significantly disturbed, these organisms prefer to otherwise attach their bell surface to the sand floor and direct their feeding appendages to the free surface in an 'upside-down' orientation. Filter feeding and prey capture are accomplished in these primarily non-swimming medusae by pulsatile contractions of the bell. The flow generated by the unsteady bell pulsations of these animals is examined herein using a combination of digital particle image velocimetry (DPIV) and videography measurements conducted in laboratory aquaria. The phase-averaged flow field closely resembles a blowing jet centered about the body, with fluid entrainment occurring near the bell surface. Reversed flow regions are identified during both the contraction and relaxation phases of pulsing. The effect of changing bell diameter on the jet characteristics as well as the production of flow structures is investigated. A qualitative comparison of the flow field between these organisms and swimming medusae will be presented.

***39.1*** SANTINI, F.*; ALFARO, M.E.; Univ. of California, Los Angeles; *santini@eeb.ucla.edu*
***Origin ad evolution of the coral reef fish fauna***
Coral reefs occupy less than 2% of marine surface, yet about 40% of the approximately 170000 marine fish species live predominantly or exclusively on coral reefs. Earlier studies of tetraodontiform fishes (puffers, box- and triggerfish) showed that reef-associated fish clades are significantly more diverse than non reef clades, suggesting that coral reefs have increased fish diversification rates. Here we test whether reef-association has driven diversification in other fish clades as well using time-calibrated phylogenies from 28 reef-associated clades. Analysis of diversification rates for 42 groups based upon method of moments estimates (Magallon and Sanderson, 2001) , indicates that reef clades have higher diversification rates than teleost fish as a whole. However we find that most named reef clades are not significantly more diverse than percomorphs. We also apply recently developed comparative methods to test for exceptionally rapid or slow diversification events within reef families and across time periods.

***S6.8*** SAPIR, Nir*; NATHAN, Ran; WIKELSKI, Martin; AVISSAR, Roni; The Hebrew University, Israel, Max Planck Institute for Ornithology and Konstanz University, Germany, University of Miami, USA; *nir.sapir@mail.huji.ac.il*
***The effect of weather on migrating bee-eaters studied by radio-telemetry and numeric atmospheric model***
Despite being the subject of comprehensive basic and applied research, current understanding of the response of migrating birds to environmental factors is still hampered by our capacity to discern key interactions of migrating birds with their environment at appropriate small and short scales over which a bird senses, and responds to, environmental variation. To overcome this major limitation, we employed radio-telemetry systems and numeric atmospheric modeling to study the migration of the European Bee-eater (*Merops apiaster*) over Southern Israel. The Regional Atmospheric Modeling System (RAMS) was applied to simulate the meteorological conditions encountered by the birds at 0.25 km and 1 min resolution. We found that bird take-off from stopover sites was associated with temperature peak at the between-day scale, and occurred during increasing temperature trend at the within-day scale. Moreover, soaring birds took-off at significantly higher temperatures compared to flapping birds. During cross-country migration, flight-mode was found primarily to depend on the atmosphere's turbulence kinetic energy (TKE), and temperature. Soaring was executed under high TKE and temperature, and weak tailwind assistance, while flapping took place under extremely low TKE and temperature, and headwind conditions. Bird airspeed during flapping was higher than during soaring, but the corresponding ground speeds were similar due to the effect of tailwind assistance. Bird heart-rate during soaring was found to be substantially lower compared to flapping, explaining the propensity of bee-eaters to migrate by soaring. We suggest that application of numeric atmospheric modeling may help scrutinize the response of migrating birds to their environment.

***95.3*** SARANATHAN, V.*; PRUM, R. O.; Department of Ecology and Evolutionary Biology, Peabody Museum of Natural History, and Center for Research on Interface Structures and Phenomena (CRISP), Yale University, New Haven, CT; *Vinodkumar.Saranathan@yale.edu*
***Evolutionary Photonics Of Avian Amorphous Color-Producing Nanostructures***
Non-iridescent structural colors in feather barbs form an important aspect of the avian phenotype and are frequently used in sexual and social communication. They are produced by quasi-ordered/amorphous photonic (color-producing) nanostructures of beta-keratin and air. In order to understand their biological function and evolution, however, we need to physically characterize organismal structural color production using a precise 3D knowledge of the nanostructure. However, current techniques like SEM/TEM do not provide 3D data. We used Small Angle X-ray Scattering (SAXS) to characterize the spatial organization of avian barb photonic nanostructures. We collected SAXS data from ~210 distinct structurally colored plumage patches belonging to ~150 avian species at the Advanced Photon Source, Argonne National Labs. We use single light scattering theory to predict the optical reflectance directly from the SAXS structural information, which are not only congruent with reflectance measurements, but offer substantial improvements over 2D-Fourier analysis of TEMs. Phylogenetic analysis suggests that barb structural colors have indpendently evolved at least 40 times across the avian phylogeny. Using SAXS, we are also reliably able to distinguish between the two classes of barb nanostructures–spheres and channels. We discuss these results in light of the putative self-assembly of these avian barb nanostructures through phase separation kinetics of beta-keratin from the cellular cytoplasm.

***2.0*** SATTERLIE, R A; University of North Carolina Wilmington; *satterlier@uncw.edu*
***Nervous System "Centralization" in Jellyfish***
Three of the four cnidarian classes have life cycles that include medusoid members. Jellyfish of these three classes have both common and unique features of nervous system organization. Both within-class and between-class comparisons of nervous system form and function suggest that despite their radial symmetry, themes of "centralization" include compression of nerve nets to form more specific and directed conducting pathways, in the form of nerve rings that contain multiple, parallel conducting systems. Furthermore, as seen in cubomedusae, there is restriction of conducting pathways and formation of dedicated, direction pathways within marginal neural/sensoty structures, called rhopalia, The rhopalia have a neural organization that is very similar to that seen in the ganglia of bilateral invertebrates.

***S1.7*** SAUKA-SPENGLER, T; Caltech; *spengler@caltech.edu*
***Sympathoadrenal lineage in lampreys***
The neural crest is a multipotent stem cell-like population that forms a plethora of derivatives, including neurons and glia of the peripheral nervous system, craniofacial skeleton and melanocytes. Data compiled from vertebrate model organisms has led us to propose a multi-module GRN that underlies neural crest formation (NC GRN). We have used a basal vertebrate, the lamprey, to test, for the first time, the validity of the proposed NC GRN in a single vertebrate. Our results show that the majority of regulatory modules responsible for early steps in neural crest ontogeny are in place in the most basal vertebrate, and thus were fixed early in vertebrate evolution. This includes regulatory mechanisms responsible for specification of bona fide neural crest specification and control of their migration. While many neural crest derived cell types and structures also are conserved, lampreys lack several crest derivatives, most notably jaws and sympathetic nervous system. Here, we asked whether the genes that regulate differentiation of the sympathoadrenal and other autonomic lineages in higher vertebrates were present or absent in lamprey to gain insight into the molecular basis and evolutionary history of this lineage. The results suggest that evolution of the vertebrate autonomic nervous system may have involved cooption of genes present in other embryonic structures such as the notochord.

***34.1*** SAWICKI, G. S.*; ROBERTS, T. J.; Univ. North Carolina at Chapel Hill and NC State University, Brown University; *greg_sawicki@ncsu.edu*
***Muscle-tendon architecture shapes conditions for economical force production***
During cyclic movements (e.g. running, walking), muscle fibers at distal joints save metabolic energy by producing force nearly isometrically, avoiding costly mechanical work. Series elastic structures (e.g. tendon and aponeurosis) within the muscle-tendon unit are crucial for economical force production because they can stretch, storing strain energy while limiting the length changes applied directly to the muscle fibers. The goal of this study was to determine how muscle-tendon architecture (i.e. free tendon length) influences the conditions required to maintain fibers isometric during cyclic force production. We used an optimally tuned real-time feedback controller to drive frog plantaris muscle-tendon through the length change pattern that minimized plantaris fiber length change (as monitored from implanted sonomicrometry crystals). To study the effects of architecture, the feedback protocol was performed with the muscle-tendon unit clamped at (1) the distal free tendon (DFT) and (2) the distal aponeurosis (DA). In both DFT and DA conditions, the muscle-tendon unit length change trajectory required for isometric force production was highly asymmetric, displaying rapid lengthening followed by much slower shortening. The rate of muscle-tendon stretch required to keep fibers isometric was greater in the DFT versus DA condition. However, in both cases, the muscle-tendon stretch rate exceeded the maximum shortening velocity of the fibers. These results indicate that much of the compliance in a muscle-tendon unit may arise from the aponeurosis and not the free-tendon. As a consequence, even in muscle-tendons with relatively short free-tendons, extremely high rates of stretch may be required to maintain isometric force production.

***40.2*** SCHMITZ, Lars*; MOTANI, Ryosuke; University of California, Davis; *lschmitz@ucdavis.edu*
***Inference of diel activity pattern suggests complex temporal resource and habitat partitioning among Mesozoic archosaurs***
Diel activity pattern (DAP) is an important behavioral characteristic of vertebrates that influences niche partitioning and resource use. Despite the complexity observed in the extant biosphere, our knowledge of vertebrate DAPs in the Mesozoic has been sparse. We remedied this problem with a threefold approach that is based on physiologic optics and eyeball morphology. First, we established that osteological features are correlated with optically relevant eyeball soft-tissue structures. These structure-function relationships are evident in both avians and squamates. Second, we demonstrated that groups of different DAP among extant terrestrial amniotes can be delineated with discriminant analysis of both eyeball soft-tissue and osteological dimensions. Third, we used discriminant analysis to infer the diel activity pattern of 33 fossil archosaurs, including *Euparkeria*, *Proterosuchus*, nine pterosaur, and 22 dinosaur (including four avians) species. Our analysis revealed that a variety of DAPs existed among Mesozoic archosaurs, including diurnal, nocturnal, and cathemeral or crepuscular patterns. The previous assumption of a dichotomous split of temporal habitat and resource use among terrestrial amniotes in the Mesozoic, with archosaurs being diurnal and mammals being nocturnal, needs to be re-evaluated. While quantitative inferences of the DAP of Mesozoic mammals are not available yet, our results suggest that many Mesozoic archosaurs were active both day and night. The results provide the first concrete evidence that the complex partitioning of temporal habitat and resources already existed in the Mesozoic.

***S9.5*** SCHNEIDER, Stephan Q; Iowa State University; *sqs@iastate.edu*

***Symmetry makers and symmetry breakers: the transition of a spiral cellular arrangement to bilateral symmetry in early embryos of Platynereis dumerilii***

Embryonic development shapes the size of subsequent morphological features e.g. of larvae and/or adults by specifiying areas and/or progenitor cells of different size and fates. Spiralian embryos accomplish these by highly stereotypic and invariant asymmetric cell divisions. In *Platynereis* embryos each embryonic cell can be already identified by its size and position within the embryo. Here we report the cell lineages of the four animal-pole daughter cells from an eight cell stage embryo, the micromeres 1a, 1b, 1c, and 1d until the ~ 200 cell stage. We define the stereotyped sister cell asymmetries (as observed by different cell sizes, cell cycle times, and beta-catenin activation patterns) in each cell division cycle within this period. The patterns of spindle orientation are tightly regulated on the right and left side to generate invariant embryonic symmetries as well as asymmetries. Bilateral symmetrical patterns of progenitor cells arise within most of the cell lineages e.g. that form pairs of eyes and brains. However, symmetries get sometimes broken to generate asymmetric single embryonic progenitors that may form the apical organ and the dorsal midline. Our analyses demonstrate how modules of sister cell asymmetries form animal-vegetal, dorsal-ventral, and left and right global embryonic axes. The identification of cell lineage relationships of each cell of the ~200 cell stage embryo enabled us to identify each cell that expresses certain developmental regulators including the homeodomain protein Pdum Distal-less defining novel potentially ancestral roles for this transcription factor in dorsal-ventral axis formation.

***47.6*** SCHRANDT, M.N.*; HARDY, K.M.; JOHNSON, K.M.; LEMA, S.C.; Univ. of North Carolina, Wilmington; *mns6093@uncw.edu*

***Ecological correlates of intraspecific behavioral variation in the bicolor damselfish (Stegastes partitus): Interacting influences of physical and social conditions***

Environmental conditions are known to affect animal behavior, yet few studies have explored how physical and social conditions interact to shape intraspecific behavioral variation in the wild, especially for marine taxa. We used the bicolor damselfish (*Stegastes partitus*) as a model to examine the relationship between spatial variation in coral reef habitat and fish behavior. Bicolor damselfish are a coral reef fish exhibiting high site fidelity, but are found in a wide range of reef microhabitats. Habitat assessments and behavioral observations were conducted across habitats ranging from dead coral rubble to live reef structure at three coral reefs in Curaçao with the goal of identifying environmental correlates to damselfish behavior. The density of bicolor damselfish increased in accordance with more shelter holes in the benthos, declining rugosity, and reduced substrate coral cover. In all microhabitats, large (>40 mm SL) and small (<40 mm SL) bicolor damselfish differed in behavior with large fish showing elevated aggression and courtship, and more frequent use of substrate shelters. Large damselfish also became more aggressive across the transition from reef to rubble habitats, corresponding to an increase in the number of small damselfish. Given this behavioral variation, we are now exploring whether habitat-associated intraspecific behavioral variation in this species relates to reactivity of the HPA axis to stress. Understanding how local habitat variation shapes the behavior and stress physiology of bicolor damselfish will provide a better understanding of how reef fish are affected by, and may respond to, perturbations to reef structure and its associated community.

***BERN.1*** SCHRECK, C.B.; Oregon State University; *carl.schreck@oregonstate.edu*

***Haruspication: Why Is The Endocrine System So Similar and Why Is It So Dissimilar Amongst Fishes?***

The endocrine system of teleost fishes is remarkably stereotypic. However, this “fact” is contradicted by another, that there is a large amount of variation in the endocrinology between individuals, species and higher taxa. That fish go through a “typical” corticosteroid stress response as well established is an example of the former contention. That some stressors cause a corticosteroid stress response while others do not or that the same stressor can result if a quite different corticosteroid stress response between two healthy individuals of the same species, are examples of the latter assertion. In this paper I attempt to explain these apparent discrepancies using examples from the endocrinology of stress, development and reproduction. My sense is that they result from a lack of clarity concerning the taxonomy and systematics of our study animals, a paucity of knowledge concerning life history variation, and use of study animals that are inbred or have undergone domestication selection. Many endocrine processes are non-linear, in fact they can be bimodal; such hormetic responses can confound interpretation. Further, my perception is that these problems are compounded by the imprecision in our science; we often do not differentiate between theory and fact. This leads to conclusions that, tongue in cheek, are basically haruspication, something that Howard Bern recognized and shared with us as rapporteur of a meeting many years ago.

***60.3*** SCHUTZ, H*; KRIEGER, J.D.; GURALNICK, R.P.; GARLAND, T. Jr.; Univ. of California, Riverside, The Natural History Museum, Univ. of Colorado, Boulder; *heidisc@ucr.edu*

***Pelvic Sexual Dimorphism in the Carnivora: A Phylogenetic Approach***

In many mammalian groups, the pelves of females are differently shaped and are relatively and absolutely larger than those of males, regardless of dimorphism in body size. This pattern of dimorphism is the opposite of that found in body size and craniodental features. Thus, pelvic dimorphism is potentially driven by evolutionary processes different than those affecting body size and other structures. The pelvis serves three biomechanical roles in mammals: weight-bearing, reproduction, and locomotion. Weight-bearing affects pelvic shape due to the stress that body mass places on the limbs. Reproduction affects pelvic shape by requiring an ample aperture for the passage of offspring, and the relationship between maternal size or maternal pelvic geometry and offspring size have been linked to indicators of female pelvic size and shape. Locomotion affects pelvic shape through requirements for limb orientation and muscle attachment, and pelvic shape varies considerably with locomotor mode, even within the same species where locomotor differences can be very subtle. This study employed a comparative phylogenetic approach to examine variation in the magnitude of pelvic size and shape dimorphism in relation to the independent variables of mating system, relative offspring size, and locomotor mode. Pelvic shape and size dimorphism varied with all variables in a complex mosaic of interactions. Mating system had a greater effect on size than on shape dimorphism, and locomotor mode had an effect on both size and shape dimorphism. Of the two offspring size ratios, the ratio of offspring mass to female pelvic size had a different effect on shape and size dimorphism than the ratio of offspring mass to female mass.

***53.2*** SCHWARTZ, M.L.*; NORENBURG, J.L.; University of Puget Sound, Smithsonian Institution; *mschwartz@pugetsound.edu*

***Comparative morphology and evolution of pilidiophoran larvae (Nemertea)***

Pilidiophoran life-history has been characterized as possessing indirect development via a planktotrophic larva, the pilidium. Although so-called direct development has also been recorded, only six instances are currently known. This dichotomy in developmental mode is not clear-cut. In pilidiophorans so-called direct development displays a variety of pilidial features, including the adult anlage typical of pilidia, an apical plate, and reduced pilidial lobes. Hence, we refer to it as non-feeding larval development. We present the first extensive and well-supported phylogeny for Pilidiophora and demonstrate that these non-feeding larvae are in fact derived with respect to feeding pilidia, and that they have evolved at least three times. One species pair, *Lineus viridis* and *Lineus ruber*, exhibits simple encapsulated, lecithotrophic development in the former, and larval cannibalism in the latter. Encapsulated development among other invertebrates occupying similar high-energy, littoral, rocky shores has been suggested as an adaptation to minimize dispersal and desiccation. The other examples of non-feeding pilidiophorans are sublittoral, and the adaptive significance of encapsulated development or brooding among other sublittoral invertebrates is more controversial. One obvious attribute these pilidiophorans have in common is unpredictable, patchy habitat, which under one hypothesis would favor minimizing dispersal. The relatively few examples among pilidiophorans contribute data but are insufficient for independent tests of competing hypotheses. However, our discovery of three unrelated forms of non-feeding pilidiophoran larvae call into question the accepted expectation that these forms are rare. Although we know pilidia can be abundant and diverse in the plankton, we know the actual developmental mode for only about 30 of the approximately 450 known species of pilidiophorans.

***74.2*** SEARLE, CL*; BELDEN, LK; BLAUSTEIN , AR; Oregon State University, Virginia Tech; *searlec@onid.orst.edu*

***The effects of stress hormones on infection by a fungal pathogen, Batrachochytrium dendrobatidis, in larval amphibians***

Pathogens are important components of ecological communities and can have large influences on species population dynamics. The fungal pathogen, *Batrachochytrium dendrobatidis* (Bd), has been implicated in amphibian population declines throughout the world. Recent emergence and spread of Bd infection could be due to a number of factors, including increased susceptibility of hosts after they are exposed to environmental stressors. For example, environmental stressors can increase circulating levels of stress hormones which may result in immunosuppression and increased susceptibility to pathogens. We exposed amphibian larvae of three species to exogenous corticosterone, the main glucocorticosteroid stress hormone in amphibians, and subsequently exposed them to Bd. We compared growth, mortality and Bd infection levels among treatments and species. This study may have important implications for how environmental stressors could act to influence susceptibility to pathogens in amphibians.

***S4.7*** SEIDEL, R.*; THIELEN, M.; SCHMITT, C.; BÜHRIG-POLACZEK, A.; FLECK, C.; SPECK, T.; Plant Biomechanics Group, Botanical Garden, University of Freiburg, Germany , Plant Biomechanics Group, Botanical Garden, University of Freiburg, Germany, Foundry-Institute of the RWTH Aachen, Germany , Materials Engineering, Berlin Institute of Technology, Germany

***Functional Morphology and Biomechanics of Fruit Walls and Nut Shells: Concept Generators for Innovative Biomechanic Materials***

The fruit walls of nuts and drupes are of special interest for the development of impact and puncture resistant materials. Their walls are hierarchically organized on at least five levels, the integral, macroscopic, microscopic, ultra structural and biochemical level. In addition to high hardness and toughness of the fruit wall of nuts and drupes with highly lignified endocarp the structural composition of some drupes, e.g. *Cocos nucifera* and the drupe related *Citrus*, indicates potential for shock absorption, an important function regarding the protection of the fragile kernel at free fall from heights of 10 meters or more. By detailed investigation of the Macadamia nut with its tough endocarp, *Citrus maxima*, possessing a large spongy mesocarp and *Cocos nucifera*, having a combination of fibrous mesocarp and tough endocarp, it becomes evident that those structures will provide excellent role models for impact and puncture resistant materials. Conducting high speed camera controlled free fall experiments of *Citrus maxima* from six metres height and comparing the potential energy of the fruits before and after impact (n=13) shows that a high proportion of the energy, possibly up to 90%, is dissipated by the fruit wall and pulp. Understanding the principles of how combining structure and material in biological tissues yields a fully functional protection layer will allow us to construct new lightweight materials of high impact and puncture resistance with a combination of high energy dissipation, benign failure and recovery from large deformations.

***90.11*** SELF, CJ; University of Washington, Seattle; *cjself@u.washington.edu*

***Tooth Root Surface Area as an Indicator of Bite Force***

The tooth root provides attachment area for the periodontal ligament and an increase in root area may be advantageous for subsisting on harder food or having a larger bite force. The goal of this study was to determine if root surface area can act as a potential surrogate for bite force. Frugivory that does not involve seed processing is thought to be less challenging than insect crushing. If insects require more force to process, the relative tooth root surface area should be larger in insectivorous species when compared to fruigivores. Two frugivorous (*Carollia perspicillata* and *Chiroderma vollosum*) and two insectivorous bat species (*Phyllostomus discolor* and *Macrotus californicus*) were chosen for their potential force disparity during food processing. This study utilized 9 micron CT scans to allow accurate 3D measurement of tooth root surface areas. Surface areas from the mandibular cheek tooth row were measured for five specimens of each species. Mandible length was used to control for body size. The combined tooth root surface area of all teeth studied was not significantly different between the dietary groups, however the distribution varied. Insectivorous species had a larger relative tooth root surface area at the first molar (M1). Frugivores had larger root surface areas for the first and second premolars (P1 and P2). Root surface area varied along the tooth row, peaking at the M1 for insectivores and at P1 for Frugivores. Insectivorous species did exhibit the overall largest root surface area for the M1, but not at any other location. It is possible that the M1 is the primary processing location for these insectivores, while the frugivores produce the highest bite force near P1 and P2. Overall, these results indicate that tooth root surface area may be a reliable indicator of bite force, and could represent a record of habitually encountered oral forces.

***16.3*** SEMON, Shelby N*; ROBIN, Francois; SHERRARD, Kristin; MUNRO, Edwin; Univ. of Washington, Seattle, MGCB, Univ. of Chicago, The Center for Cellular Dynamics; *snsemon@u.washington.edu*

***Neural Tube Closure: Zipper Propagation in Ascidian Embryos***

Ascidians are a member of the chordate phylum and as such they undergo many of the same developmental processes that other chordates undergo. The difference is that Ascidians have a much smaller number of cells and larger cell size to embryo size ratio making them an ideal system in which to study the fundamental processes involved in neural tube closure. Focusing on the cellular processes involved in neural tube closure, we used confocal microscopes for fixed and time lapse imaging with fluorescent probes to carefully observe the cellular behaviors of control embryos. We found that neural tube closure proceeds unidirectionally from posterior to anterior in a behavior we call zippering. This behavior involves three main processes: cell crawling, adhesion and contraction. Focusing on the role of contractility, we found that there is a mechanically continuous actin purse string that has myosin localized in an area of high contractility in the boundary cells closest to the zipper. Using Y-27632, a drug that inhibits RhoKinase-activated myosin to inhibit contractility at different stages during zipper closure, we found that when Y-27632 was added near the beginning of the zippering process, zippering did not proceed and when added late in the zippering process, the zipper broke and the interior structures of the embryo extended out of the anterior half. However, invagination of the floor cells of the neural plate occurred normally in Y-27632 treated embryos. We conclude that contractility is essential for zipper initiation and propagation but not a driving force in the invagination that proceeds the zippering process.

***1.2*** SERAFINI, L.*; TOMANEK, L.; Cal Poly, SLO; *lserafin@calpoly.edu*

***Comparative Proteomics: The Response of the Ascidian Congeners Ciona intestinalis and C. savignyi to Acute Temperature Stress***

*Ciona intestinalis* and *C. savignyi* are congeneric tunicates that are commonly found along the Pacific coast of North America. In order to compare the thermal stress response between these two sister species, we studied global changes in protein expression in response to heat stress using proteomics. The ascidians' phylogenetic position as urochordates, along with their sequenced genomes, make *C. intestinalis* and *C. savignyi* model organisms for proteomics research. To observe the effect of heat shock, animals of both species were exposed to either a 22˚C, 25˚C, or 28˚C temperature treatment for 6 hours, and then allowed to recover at 13˚C for 16 hours. Two-dimensional gel electrophoresis was employed to separate proteins and create protein expression profiles. We found that 32% of the total protein spots detected for *C. intestinalis* and 24% of those detected for *C. savignyi* underwent significant changes in their expression across treatment groups. In order to further characterize the thermal stress response, we used MALDI TOF/TOF mass spectrometry to identify proteins of interest and had a 90% success rate. After comparing the identified proteins across species, we were able to determine that different proteins showed changes in their expression across treatments. This suggests that the thermal stress response differs between these two species. For *C. savignyi*, the thermal stress response consisted of variations in the expression of cytoskeletal proteins; while *C. intestinalis* had a more complex response consisting of changes in a wide-range of proteins including chaperones, transport proteins, and metabolic proteins. These interspecific differences in the thermal stress response suggest possible biochemical differences that may lead to variation in thermal tolerance.

***45.11*** SEWALL, K.B.*; CARO, S.P.; SOCKMAN, K.W.; Univ. of North Carolina, Chapel Hill; *ksewall@email.unc.edu*

***Quality of the song environment affects monoaminergic activity in the forebrain of male Lincoln's sparrows***

Male songbirds often establish territories and attract mates by singing, and some song features reflect the singer's quality or condition because they are costly to learn or produce. The condition of competitors and hence the quality of the song environment can change with ecological conditions, and in a recent study we showed that male Lincoln's sparrows (*Melospiza lincolnii*) modulate their own singing effort in response to the quality of the song environment. Socially-induced shifts of singing effort could be mediated by neuromodulatory effects of monamines including norepinephrine, dopamine and serotonin in brain regions that control signal perception and regulate song output. To evaluate this possibility, we exposed male Lincoln's sparrows to chronic playback of songs that were either "high" or "low" quality, depending on the songs' length and complexity and the performance of trills within them. We then used high pressure liquid chromatography to quantify levels of monoamines and their metabolites in two forebrain auditory processing regions, the caudomedial nidopallium and caudomedial mesopallium, and in the song control regions HVC, Area X and robust nucleus of the arcopallium (RA). We found that males exposed to the high quality song environment, who sang more, had lower levels of dopamine metabolite in HVC and lower levels of serotonin and its metabolite in RA, even when we statistically controlled for differences in singing effort. Thus, exposure to high quality song and subsequent shifts in singing effort may be mediated in part by dopamingergic and serotonergic activity in nuclei of the song motor control pathway.

***S6.9*** SHAMOUN-BARANES, J.*; BOUTEN, W.; VAN LOON, E.; Univeristy of Amsterdam; *shamoun@uva.nl*

***Integrating measurements and models to study the influence of weather on migration***

Atmospheric dynamics play an important role in migration, influencing among other things the onset of migration, migration duration, migratory routes, stop-over decisions, flight speeds en-route and the cost of migration. However, measuring the influence of weather on different aspects of migration is particularly challenging and generally restricted in space, time and species. Furthermore, meteorological and ornithological data are generally not available at the same temporal or spatial scale. Different data sources have been used to study the impact of weather on migration, for example, radar, visual observations, radio and satellite telemetry, each with their own strengths and weaknesses. In an attempt to quantify the effect of meteorological conditions at different scales on various aspects of migration, we present a series of studies integrating physical or statistical models with field measurements. We show examples from soaring migrants, waders and nocturnal passerine migrants and different data sources to constrain and test our models. Finally we discuss the importance of considering the variability in meteorological conditions along a migratory trajectory, between seasons and between years.

***S9.3*** SHANKLAND, M.*; SCHMERER, M.W.; NULL, R.W.; U. of Texas at Austin; *hastypig@mail.utexas.edu*

***Paxβ: a lophotrochozoan gene family implicated in spiral cleavage***

The Paxβ gene family is restricted to the bilaterian superphylum Lophotrochozoa. A conserved intron:exon organization suggests that the ancestral Paxβ arose by duplication and divergence of a Pax2/5/8 gene. This founding gene duplication appears to have occurred near the base of the lophotrochozoan radiation, prior to the separation of platyhelminths, molluscs, annelids, nemerteans, and brachiopods. Spiral cleavage is also unique to the lophotrochozoan clade. Functional studies in the leech *Helobdella* indicate that *Hau-Paxβ1* regulates a critical step in spiral cleavage, raising the possibility that the Paxβ family may have been involved in the evolution of this cleavage program. During normal spiralian development the ectodermal and mesodermal blastomeres of the D quadrant undergo symmetric cleavages that presage the bilateral symmetry of the adult body plan. But these symmetric divisions follow a series of asymmetric spiral cleavages that lead to the production of micromeres. Interfering with *Paxβ1* in the *Helobdella* embryo prevents this developmental transition: i.e. the ectodermal and mesodermal blastomeres continue to cleave at the appropriate time, but rather than adopting bilateral symmetry they produce additional micromeres of alternating chirality. Genetic and pharmacological data suggest that maternal Hau-Paxβ1 protein is acting as a transcriptional activator during these developmental events. We hypothesize that Hau-Paxβ1 is activating the expression of one or more zygotic gene products, which are responsible in turn for repositioning the mitotic spindle to the median plane at the symmetric divisions that terminate spiral cleavage. Ongoing studies are directed at identifying these putative Hau-Paxβ1 target genes.

***98.11*** SHELDON, Kimberly S.*; TEWKSBURY, Joshua J.; University of Washington, Seattle; *ksheldon@u.washington.edu*

***If you can't stand the heat: how CTmax drives thermal breadth in beetles across latitude***

Despite nearly a century of work on physiological response of organisms to temperature, we still do not know the exact nature of the relationship between environmental temperatures and physiological variability. Yet, knowledge of the impacts of temperature on physiology has become increasingly crucial as global warming threatens species around the world. Using dung (Scarabaeinae) and burying (Silphidae) beetles, we found that beetles living in areas with greater temperature variation had greater breadth of tolerance, consistent with previous research. Contrary to other findings, however, CTmax varied consistently across latitude, while CTmin did not always change. Here we present our results on critical thermal limits along with an analysis of temperature variables potentially driving thermal tolerance in beetles.

***105.2*** SHERO, M.R.*; LESTYK, K.C.; ANDREWS, R.D.; BURNS, J.M.; St. Mary's College of Maryland, University of Alaska, Anchorage, Alaska SeaLife Center; *mrshero@smcm.edu*

***Development of oxygen stores and muscle in Northern fur seals (Callorhinus ursinus): limits on juvenile foraging ability?***

Northern fur seal (*Callorhinus ursinus*) population numbers have been declining, perhaps due to limited foraging ability of juveniles. Since a marine mammal's proficiency at exploiting prey resources in a hypoxic environment is based on the ability to store large amounts of oxygen ($O_2$) and to utilize these reserves efficiently, this study was designed to determine if juvenile Northern fur seals (NFS) had lower blood, muscle, and total body $O_2$ stores than adults. Pups (<1 month old) were found to have calculated aerobic dive limits ~40% those of adult females primarily due to lower blood and, to a much greater extent, muscle $O_2$ stores. Development of the *Pectoralis* (*Pec*) and *Longissimus dorsi* (*LD*) muscles was further examined by determining their myosin heavy chain (MHC) composition and enzyme activities. In all animals, the oxidative MHC I and IIA fibers were dominant, but adult muscles contained significantly more (*Pec*: ~150%; *LD*:~350%) fast-twitch oxidative-glycolytic MHC IID/X protein than pup muscles. This suggests that adults have greater ability to generate muscle power rapidly and/or under anaerobic conditions. Pup muscles also had lower aerobic and anaerobic ATP production potential, as indicated by lower metabolically-scaled citrate synthase, β-hydroxyacyl CoA dehydrogenase, and lactate dehydrogenase activity (all *P* values <0.001). In combination, these findings support the hypothesis that juveniles are biochemically and physiologically limited in their diving capabilities relative to adults. This may contribute to lower first year survival.

***S1.6*** SHERWOOD, Nancy/M*; ROCH, Graeme/J; TELLO, Javier/A; University of Victoria; *nsherwoo@uvic.ca*

***Genomics of Amphioxus and Tunicates: Tracing the Evolution of the Endocrine System***

The sequencing of the genomes for amphioxus and tunicates has allowed us to examine the foundation of the endocrine system in species that evolved at the transition between invertebrates and vertebrates. In regard to reproduction, the neuroendocrine system in these early chordates is vertebrate-like, but the pituitary and gonadal endocrine hormones and receptors are clearly lacking a number of vertebrate components. In tunicates (*Ciona intestinalis* and *C. savignyi*), six gonadotropin-releasing hormones (GnRH) and four receptors were cloned. The six GnRH peptides selectively activated recombinant forms of their receptors and in vivo spawning. In amphioxus (*Brachiostoma floridae*), four GnRH receptors were cloned and expressed in COS7 cells; their pattern of response provides evidence that both invertebrate-type and vertebrate-type GnRH receptors exist in amphioxus. In contrast, functioning neuroendocrine systems in basal chordates do not appear to activate specific pituitary hormones, as neither FSH nor LH hormones/receptors are identified in the amphioxus or tunicate genomes. Rather it is likely that the GnRH peptides act directly on the gonads. Only amphioxus and not *Ciona* has the necessary enzymes for biosynthesis of sex steroids. Also, both chordate groups have a small number of nuclear receptors but only amphioxus has steroid-type nuclear receptors. Outside of reproduction, the insulin-IGF family and receptors, essential for growth, development and metabolism, are present in both amphioxus and tunicates along with other hormones including the osmoregulatory hormone stanniocalcin. The endocrine components are homologous to those in vertebrates and reveal the foundation of the chordate endocrine system before the genomic duplications in early vertebrates.

***S2.9*** SHI, Yun; LIU, YuHong; JERNIGAN, Amanda L; BHATTACHARYA, Arunabh; BUFFENSTEIN, Rochelle; AUSTAD, Steven N; VAN REMMEN, Holly *; University of Texas Health Science Center, San Antonio; *VANREMMEN@UTHSCSA.EDU*

***Skeletal muscle mitochondrial metabolism in three rodent species with disparate longevity***

The oxidative stress hypothesis of aging predicts that long lived species might produce less reactive oxygen species (ROS), exhibit superior antioxidant defenses, and/or have low amount or slowed rate of oxidative damage accumulation. In this study we measured skeletal muscle mitochondrial metabolism in three rodent species with disparate longevities, the common laboratory mouse (Mus musculus, 4 years), the white-footed mouse (Peromyscus leucopus, 8 years) and the naked mole rat (Heterocephalus glaber, 30 years), to test the hypothesis that longer-lived species have lower ROS generation and more efficient ATP production. Compared to mitochondria isolated from M. musculus skeletal tissue from the two long-lived species generated lower levels of ROS [H2O2 and/or superoxide] and mitochondria from H. glaber show a reduced inactivation of aconitase activity. Surprisingly ATP production rate is lower in the species with intermediate longevity despite increased ATP synthase activity. Separation of mitochondrial oxidative phosphorylation complexes by blue native gels with subsequent in-gel enzymatic activity assays shows that both P. leucopus and H. glaber have reduced activity of Complex I compared with M. musculus, while Complex IV activity is reduced in H. glaber but increased in P. leucopus. Lower ROS generation and increased potential for ATP synthesis through elevated ATP synthase are consistent with increased longevity in P. leucopus and H. glaber. However, future studies will be conducted to determine whether these changes are specific to skeletal muscle mitochondria or similar in different tissues in each species. In addition, we will expand the comparison to include other species of similar body size and basal metabolic rate.

***10.4*** SHILLINGTON, Cara; Eastern Michigan University; *cshilling@emich.edu*

***Feeding metabolics and prey capture in newly emerged tarantula spiderings (Theraphosa leblondi).***

For most animals, an integral portion of their energy budget is associated with foraging and the metabolic response that accompanies digestion and food assimilation (=specific dynamic action (SDA)). Previous studies have shown that the magnitude and duration of SDA is influenced by many factors including meal size and composition as well as various environmental factors and body size of the predator. In this study, I examined the SDAs of naïve predators feeding for the first time. Model animals for this study were tarantula spiders (*Theraphosa leblondi*) that had just emerged from their eggsac. I measured resting metabolic rates (RMRs) over three successive molts as well as SDAs after their first feeding and again after their next molt. Spiderlings were divided into three groups that received prey that varied in proportion to tarantula body mass (Group 1: 5-15%, Group 2: 25-35%, Group 3: 45-55%). In addition, I compared prey capture times over successive feedings trials to determine the role of experience in hunting success. Few differences were found between the two higher feeding groups in either metabolic rates or body mass. However, Group 1 had significantly lower body mass after their second molt post-emergence and had lower RMRs and thus a higher scope. Among all three groups, prey capture times were faster at their second feeding compared to their first feeding.

***48.5*** SHUTTARI, N*; JACOBS, M.W.; Boston University, Woods Hole Oceanographic Institution ; *nidas@bu.edu*

***Variation in Behavior of Larval Lobsters as a Function of Population, Parentage, and Development Time***

Variation in Behavior of Larval Lobsters as a Function of Population, Parentage, and Development Time Shuttari N and M.W. Jacobs Woods Hole Oceanographic Institution Boston University nidas@bu.edu Offspring of the lobster *Homarus americanus* hatch as swimming larvae and grow through three molt stages in the plankton. At the fourth molt, the larvae metamorphose into a postlarval settlement stage and swim down to the benthos. We studied substrate selection behavior over time during this critical stage as a function of age from metamorphosis, age from hatching, population of origin, and maternal parentage. Settlement behavior was tested in a large mesocosm where postlarvae were offered a choice of sand, small rocks, large rocks, or artificial PVC shelters. We measured behavior of individual postlarvae during timed 5 minute trials, and also released groups of labeled postlarvae into the mesocosm for overnight settlement trials. We found that settling behavior varied strongly as a function of age from metamorphosis. In overnight mesocosm experiments, the proportion of postlarvae found crawling in the open decreased throughout the settlement period, while the proportion found sheltering in large rocks or PVC shelters increased. We expected the proportion found swimming to be inversely proportional to the proportion found sheltering, but interestingly swimming behavior peaked in the middle of the settlement period. These results suggest that attraction to the bottom during settlement is decoupled from sheltering behavior. Settlement behavior was similar overall between parents and populations, but preliminary analyses suggest that Rhode Island postlarvae increase sheltering behavior earlier than Georges Bank postlarvae, suggesting that variation in settlement behavior is influenced by both genetics and environment.

***95.2*** SIGWART, JD; Queen's University Belfast; *j.sigwart@qub.ac.uk*

***How do chitons see their world? A new sensory organ in basal molluscs (Polyplacophora: Lepidopleurida)***

Polyplacophoran molluscs (chitons) are “primitive” animals that have a simple nerve system of non-ganglionised longitudinal nerve cords and no cephalised sense organs. Two sensory structures in the pallial cavity have previously been described in the early-diverging chiton order Lepidopleurida. The examination of these structures seems historically to have been motivated primarily by a quest for an osphradium homolog, which is not convincingly present in lepidopleuran chitons. Recent work has described the three-dimensional anatomy of a new additional sensory organ in basal living chitons, referred to as the “Schwabe organ” after the discoverer. Anatomical examination has included semi-thin sectioning and three dimensional computer reconstruction of the anterior nervous system as well as TEM imaging of the fine structure. This sense organ is macroscopic and clearly visible on the external epithelium in living animals, yet has never been reported in 150 years of anatomical literature. As this structure has only been found in the basal clade of chitons, future work will focus on developmental work and identifying potential homologous structures in the putative sister taxa to this clade. More detailed assessment of available morphological characters is needed to uncover usable morphological synapomorpies to define clades. Sensory structures, which clearly have a significant relationship on how an organism interacts with its environment, may be especially useful in this context. The datasets currently available already provide interesting insights into the analytical power of traditional morphology, as well as some knowledge about the early evolution and radiation of this group.

***78.6*** SIKES, J.M.*; BELY, A.E.; Univ. of Illinois, Urbana-Champaign, Univ. of Maryland, College Park; *jsikes@illinois.edu*

***Evolution of diverse asexual reproduction strategies and reversal of the primary body axis in Convolutriloba acoels***

Acoels in the genus *Convolutriloba* are unusual among bilaterians in that morphologically similar species have evolved dramatically different modes of asexual reproduction that radically modify the primary body axis, including examples of transverse fission, longitudinal fission, and reversed polarity budding. We conducted parallel regeneration trials on *Convolutriloba* species to elucidate the regenerative capacities that may have allowed for the evolution of such different asexual reproduction strategies. Our data suggest that the *Convolutriloba* ancestor possessed a rich regeneration toolkit that may have allowed for extreme diversification of asexual reproduction in the group. We further investigated bud formation and axial properties of the parent-bud boundary in *C. retrogemma*, a species that reproduces by a remarkable process in which buds form with a body axis orientation exactly opposite that of the parent. Studies of axial patterning gene expression, cell proliferation, musculature organization, and regenerative potential indicate that manifestations of axial polarity of the bud develop only gradually after bud initiation and reveal a swath of tissue at the boundary between parent and bud that appears to remain completely unpolarized. Tissue excised entirely from within this boundary zone fails to regenerate or acquire any evidence of axial polarity, a phenotype identical to animals in which GSK-3 is pharmacologically inhibited, suggesting Wnt/β-catenin or Hedgehog signaling may mediate the establishment of this unpolarized boundary zone. The formation of unpolarized tissue may provide a buffer between opposing polarity cues and be a general mechanism by which budding animals establish and maintain linked body axes.

***79.2*** SILVERTHORN, D.U.; Univ. of Texas, Austin; *silverthorn@mail.utexas.edu*

***The "Scientific Foundations for Future Physicians" Report: Opportunity and Challenge***

In 2007 the Association of American Medical Colleges (AAMC) and Howard Hughes Medical Institute convened the Scientific Foundations for Future Physicians Committee (SFFP). The committee, composed of basic and clinical scientists and undergraduate scientist-educators, was charged with "recommend[ing] specific [scientific] competencies . . . fundamental to medicine that all medical students should demonstrate," and "identify[ing] scientific competencies that learners should demonstrate before entry into medical school [with] emphasis . . . on defined knowledge, scientific concepts and skills rather than specific courses or disciplines." The committee report, published June 2009, begins with overarching principles that span all of the scientific disciplines, followed by scientific competencies and associated learning objectives for medical and entering medical (i.e. undergraduate) students. The first two entering medical competencies are quantitative skills and process of science skills, followed by more traditional content-based competencies. The report ends with a discussion of how innovative and interdisciplinary college courses might allow students to achieve these competencies in place of the traditional pre-med coursework. The SFFP report debuts as AAMC begins revision of the MCAT, the National Board of Medical Examiners revises the USMLE, and the College Board revises the AP Biology curriculum. Coordinating recommendations from these diverse groups will provide undergraduate faculty with curriculum opportunities and challenges in the years to come.

***40.3*** SLATER, G.J.; PRICE, S.A.*; SANTINI, F.; ALFARO, M.E.; University of California, Los Angeles, University of California, Davis; *gslater@ucla.edu*

***Are extant cetaceans the product of an adaptive radation?***

The transition from land to the sea represents a major shift in adaptive zone for cetaceans but it is not known whether the patterns of body size disparity and species richness in modern cetaceans reflect an initially rapid radiation into this habitat or whether more recent geologic and paleoclimatic factors are better explanations for their biodiversity. We constructed a molecular timescale for the evolution of extant cetaceans and used it to investigate diversification rates and patterns of body size evolution. Cetaceans did not undergo an early pulse of lineage diversification, as expected in an adaptively-radiating clade. However, a series of morphological analyses show that body size evolution does bear the signature of adaptive diversification. Body size has a strong influence on feeding behavior in cetaceans and early phylogenetic partitioning of niche space seems to be responsible for the current distribution of feeding behaviors. The evolution of extant cetaceans was adaptive, but not an adaptive radiation.

***54.4*** SMITH, Jeramiah J.*; AMEMIYA, Chris T.; Benaroya Research Institute; *jsmith@benaroyaresearch.org*

***Tight Regulation of Large-Scale Genome Rearrangements: the Sea Lamprey (Petromyzon marinus)***

Our recent computational and empirical studies have revealed developmentally-regulated and large-scale genome reorganizations in a definitively vertebrate genome (the sea lamprey - *Petromyzon marinus*: a jawless vertebrate). Several lines of evidence demonstrate that the lamprey undergoes a dramatic remodeling of its genome, resulting in the elimination of hundreds of millions of base pairs (~20% of the genome) from many somatic cell lineages during embryonic development. Embryological studies reveal that many of these rearrangements take place early in development, resulting in a situation wherein an individual's "germline" and "somatic" cell lineages differ substantially in gene content. Computational and array CGH (comparative genomic hybridization) studies reveal that several distinct genomic regions are altered during this process and have identified specific rearrangement breakpoints. Genomic regions that are removed via programmed rearrangements include genes that are transcribed in adult and juvenile testes or during early embryonic development. Some of these somatically-deleted genes have homologs that are known to contribute to genome stability or the specification of reproductive tissues. Notably, ostensibly similar rearrangements have also been observed in hagfish - suggesting that this dynamic genome biology can be traced to a point very near the common ancestor of all vertebrates. Understanding the mechanisms by which lamprey regulates such extensive remodeling of its genome will provide invaluable insight into factors that can promote stability and change in vertebrate genomes, and the consequences of reorganization in the context of "normal" vertebrate development and cell biology.

***5.3*** SMITH, A. M.*; MENGES, M.; Ithaca College; *asmith@ithaca.edu*
***Cross-linking in slug glue: gelled plaster of Paris?***
The defensive glue of the slug *Arion subfuscus* sets rapidly into a sticky, elastic mass. There appear to be several cross-linking mechanisms, but the initial gelation may occur through complex coacervation involving sulfate and calcium-binding polymers. In this mechanism, electrostatic forces bring together charged polymers creating locally high concentrations. These may cross-link to create a reticular network. Calcium and sulfate are particularly interesting, as their interaction causes setting in plaster of Paris. Slug glue was shown to contain a strikingly high concentration of calcium (40 mM) as measured by atomic absorption spectrometry and energy dispersive SEM. It also contains a comparable amount of sulfate (40-50 mM) as measured by a colorimetric assay and SEM. The sulfate is likely bound to polysaccharides, while several of the proteins bind strongly to metals. The sulfate would create a high negative charge density, which would be neutralized by the calcium leading to coacervation, drawing metal-binding proteins and sulfated polysaccharides together. Several assays were developed to determine if any proteins in the glue bound to sulfate in this way. These assays identified a 15 kDa protein that was known to be unique to the glue and has been shown to stiffen gels. This protein precipitated with sulfated sugars, but only in the presence of metals. Furthermore, it bound to sulfate groups in column chromatography when metals were present. Chelating the metals often blocked this binding. Thus, there is a specific metal-based interaction between the primary cross-linking protein and sulfate groups. The glue is not soluble in acid, however, and the calcium is not tightly bound to the glue, suggesting that a strong solubility-based interaction, as seen in plaster, does not occur.

***38.3*** SMITH, LC*; MENDONCA, MT; Auburn University; *chessmith@gmail.com*
***Effects of capture and restraint stress on neutrophil/lymphocyte ratio in big brown bats.***
As part of a broader study on the effects of anthropogenic stressors on neutrophil/lymphocyte (N/L) ratios in bats, we examined the changes in N/L ratio due to the acute stress of capture and blood sampling in big brown bats (*Eptesicus fuscus*). In mammals, N/L ratio has been shown to increase in response to acute and chronic stressors, and this seems to be mediated by glucocorticoid (GC) hormones, which rise within minutes after exposure to a stressor. However, this stress-induced increase in N/L ratio reportedly takes longer to develop (at least 45 to 60 minutes) and persists longer than the GC response. It has been suggested that N/L ratios may be useful as indicators of chronic stress, but the timeline for the observed change has not been well documented. There is very little information in bats on immune responses in relation to stress exposure. To test this relationship, we bled wild bats within 3 min of their capture, and then held them in containers and re-bled them 60 min later. A small amount of blood was used to make blood smears for leukocyte counts, and we used the remaining plasma to measure GC levels. Preliminary results indicate that N/L ratios did significantly increase within an hour of capture and bleeding ($p = 0.005$, paired t-test). The relationship between this increase in N/L ratios and GC levels as well as response of N/L ratios to metyropone, a GC antagonist, will be discussed.

***89.2*** SOCHA, J.J.*; COX, L.; LEE, W.K.; MEANS, M.; TOLLEY, J.; Virginia Tech, Argonne National Laboratory, Bucknell University; *jjsocha@vt.edu*
***Under pressure: the biomechanical mechanism of rhythmic tracheal compression in carabid beetles***
Although diffusion is considered to be the dominant mechanism of respiration in insects, many species are known to exhibit active ventilation. Rhythmic tracheal compression (RTC) is one such form of ventilation, in which parts of the tracheal system collapse and reinflate multiple times per minute, with each compression resulting in movement of air out of the body. These compressions have been characterized using x-ray imaging; however, the morphological mechanism of RTC is unknown. From preliminary x-ray video data, we have identified a rhythmic dorsoventral abdominal contraction that co-occurs with tracheal collapse in the carabid beetles *Platynus decentis* and *Pterostichus stygicus*. In combination with the generally synchronous nature of tracheal compressions throughout the body, this suggests that RTC is caused by a global pressure change, whereby an increase in internal hemolymph pressure effects tracheal tube collapse. To explore this hypothesis, we take an integrative approach. Changes in hemolymph pressure were measured with fiber-optic probes inserted into the beetle's thoracic hemocoel, while abdominal body movements and $CO_2$ release patterns were recorded concurrently. To confirm that RTC co-occurs with rhythmic changes in pressure, we repeated these measurements under synchrotron x-ray imaging to directly visualize tube collapse in real time. Lastly, we dissected tracheae from the beetles and conducted *in vitro* pressure tests to determine thresholds of collapse in individual tracheal tubes. In general, tube collapse occurred at lower pressures than those observed in the living beetles. These data strongly support a global hemolymph pressure change mechanism of RTC in carabid beetles. Research supported by NSF 0938047, VT ICTAS, and the Jeffress Memorial Trust.

***61.5*** SOCKMAN, K.W.; Univ. of North Carolina, Chapel Hill; *kws@unc.edu*
***Maternally-induced developmental conditions predict the shape of a songbird's bill, a sexually and naturally selected trait***
The bill is an adult songbird's most important tool, but the underlying sources of the between-individual variation in this trait on which both natural and sexual selection act are largely unknown. Due to the possibility that the massive change in bill morphology between the nestling and adult life stages is limited by developmental plasticity and to the often strong individual differences in selective forces that characterize the nestling period of development, I predicted that adult bill shape reflects nestling bill shape and that variation between nestlings arises due to hatching order and the seasonal timing of development. Using Lincoln's sparrows (*Melospiza lincolnii*), I measured individuals as free-living nestlings and later as free-living or as laboratory-housed adults for a metric of bill shape (height/width) that is associated with an adult Lincoln's sparrow's performance of vocal, sexual signals. I found that bill shape during the nestling stage positively correlated with that during the adult stage for both free-living and laboratory-housed adults. I also found that nestling bill shape declined with hatching order and that the bill shape of both nestlings and laboratory-housed adults declined with the individual's seasonal timing of development. These findings suggest that maternally induced developmental conditions may influence the value of a sexually and naturally selected trait. Nestlings may vary in bill shape either for adaptive (e.g., wider bills may be more favored among later-hatching offspring as a means of competing for food with older brood mates) or non-adaptive (bill shape may reflect differences in developmental constraints, such as nutritional deprivation) reasons, and such variation may explain the persistence of suboptimal bill shapes among adult songbirds in the presence of strong stabilizing or directional selection.

***4.3*** SOFAER, H.R.*; SILLETT, T.S.; GHALAMBOR, C.K.; Colorado State University, Smithsonian Migratory Bird Center; *helen@lamar.colostate.edu*

***Offspring growth and functional performance in Orange-crowed Warblers: a comparison between populations that differ in life-history strategies***

The evolution of parental investment strategies is expected to depend on parental residual reproductive value as well as on the relationship between parental care and offspring fitness. However, life history theory has been poorly integrated into the study of the growth and developmental rates of species whose offspring are entirely dependent on parental care. In passerine birds, few studies have related parental investment with offspring growth rates, or asked how this relationship may vary between populations with different life history strategies. In addition, although nestling mass has been positively correlated with future fitness, studies have not related mass to functional performance in fledglings. Here, we compare the nestling feeding and growth rates in two populations of Orange-crowned Warblers (*Vermivora celata*) that differ in their life history strategies, and ask how parental behavior and offspring mass may affect offspring mobility. We use a novel method to measure offspring functional performance, by quantifying the distance nestlings and fledglings can jump from a perch. Our results show a positive correlation between jumping distance and offspring mass, providing the first data linking mass to performance in passerine fledglings. Interestingly, our data also show that although per-nestling provisioning rates are higher in the population with the slower life history, nestlings in the population with the faster life-history strategy grow more quickly. These results support the hypothesis that there may be a trade-off between offspring quality and quantity within a single passerine species, and suggest that there may be costs to rapid growth even within altricial birds.

***104.5*** SOKOLOVA, I.M.*; IVANINA, A.; LIEB, N.; KUROCHKIN , I.; BENIASH, E.; University of North Carolina at Charlotte, Charlotte, NC, University of Pittsburgh, Pittsburgh, PA, University of Pittsburgh, Pittsburgh, PA; *isokolov@uncc.edu*

***Elevated atmospheric carbon dioxide levels affect metabolism and shell formation in oysters Crassostrea virginica (Gmelin)***

Ocean acidification due to global rise in $CO_2$ can afflict marine organisms negatively impacting ecosystem health. $CaCO_3$-producing marine species such as mollusks can be especially vulnerable to such changes, since elevated $CO_2$ levels and lower pH lead to a decrease of the degree of saturation of calcium carbonate potentially affecting biomineralization. We determined the effects of elevated $CO_2$ levels on biomineralization and metabolic physiology of an intertidal mollusk, eastern oyster *Crassostrea virginica* using atmospheric and $CO_2$-enriched air (5000 ppm $CO_2$) corresponding to the current conditions and a IPCC projection for the year 2300, respectively. Elevated $CO_2$ levels in sea water negatively affected physiology, rates of shell deposition and mechanical properties of the shells of oysters. High $CO_2$ levels led to elevated juvenile mortality and inhibited shell and soft body growth in oysters. Furthermore, the increase in $CO_2$ levels resulted in elevated standard metabolic rates in juveniles due to the higher energy cost of homeostasis. The hypercapnic conditions also led to changes in the ultrastructure and mechanical properties of shells, and an upregulation of carbonic anhydrase gene expression in mantle tissue of oysters indicating that elevated $CO_2$ levels have negative effects on the biomineralization process. These data strongly suggest that the rise in carbon dioxide can impact the physiology and biomineralization in marine calcifiers such as oysters threatening the survival of this species and leading to profound ecological and economic impacts. Supported by NSF, North Carolina Sea Grant and UNC Charlotte.

***98.4*** SOUTHWOOD, A.L.*; HARDEN, L.A.; University of North Carolina Wilmington; *southwooda@uncw.edu*

***Temperature effects on metabolic enzyme activity in diamondback terrapins (Malaclemys terrapin)***

The diamondback terrapin (*Malaclemys terrapin*) spans a geographic range that stretches along the East and Gulf coasts of the United States from Massachusetts to Texas. It is the only estuarine species of turtle, and inhabits shallow, brackish waters of coastal marshes and creeks. In North Carolina, terrapins are most active from March through October and spend the winter months buried shallowly in the muddy substrate of the intertidal zone. Terrapins in this region experience air temperatures of 19.1 – 36.2&degC during the summer and -5.5 – 24.6&degC during the winter. Water temperatures vary from 24.6 – 32.6&degC during the summer and 8.7 – 17.2&degC during the winter. Temperature has profound effects on metabolism and physiology of reptiles, and thermal conditions likely play an important role in the timing of seasonal behaviors of terrapins. We investigated the effects of temperature on activity of lactate dehydrogenase (LDH), pyruvate kinase (PK), citrate synthase (CS), and cytochrome c oxidase(CCO) in muscle tissue collected from terrapins during the summer and winter. Assays were conducted at 10, 20, 30, and 40&degC. Within the temperature range of 10 – 30&degC, Q10 values varied between 1.3 and 1.8 for all enzymes. Q10 values for the anaerobic enzymes (LDH and PK) were higher (2.9 – 5.6) when assayed between 30 – 40&degC. There was no significant effect of season on activity of anaerobic enzymes, but there was a significant effect of season on activity of aerobic enzymes (CS and CCO), with winter activity lower than summer activity when assayed at the same temperature. Results are interpreted in light of terrapin ecology and habitat utilization.

***S1.9*** SOWER, STACIA A.*; KOSUGI, TAKAYOSHI; AQUILINA-BECK, ALLISAN; FREAMAT, MIHAEL; University of New Hampshire, Durham, University of New Hampshire Durham; *sasower@cisunix.unh.edu*

***Origins of the Neuroendocrine System in a Basal Vertebrate, the Sea Lamprey***

The hypothalamic-pituitary (HP) system is considered to be a vertebrate innovation and seminal event that emerged prior to or during the differentiation of the ancestral agnathans and led to the neuroendocrine control of many complex functions including growth, reproduction, osmoregulation, stress and metabolism (Sower et al., 2009). In spite of the very diverse patterns of life cycles and reproductive strategies and behaviors, this endocrine system is remarkably conserved throughout the gnathostome lineages. For neuroendocrine studies, the availability of the genome has been critical for identification of ligands and receptors. We will report on some of our latest findings from the lamprey genome that includes the identification of lamprey (l) GnRH-II, two novel GnRH receptors (lGnRHR-2 and GnRHR-3, and two glycoprotein hormone receptors, (lGpHR-I, gonadal-like and lGpHR-II, thyrotropic-like) as well as functional studies on the GnRH and glycoprotein hormone receptors. From our data we propose a model in that the neuroendocrine control of reproduction and thyroid functions in an Agnathan, the sea lamprey, exhibits an overlapping, simplified organization represented by one and possibly two glycoprotein hormones putatively interacting with two glycoprotein receptors, a gonadotropin-like receptor and a thyroid stimulating hormone-like receptor. This paradigm can serve as a model for analysis of the evolutionary mechanisms leading to emergence of the highly specialized Gnathostome endocrine axes. Supported by NSF IBN-0421923, IOS-0849569, NH AES Hatch 332 and NIH 5R21RR024477-02 to SAS.

***68.3*** SPARKMAN, A.M.*; PALACIOS, M.G.; BRONIKOWSKI, A.M.; Iowa State University; *asparkma@iastate.edu*
***Life history and immune defense in two garter snake ecotypes I - A field study***
Life-history theorists have long observed that fast growth and high reproduction tend to be associated with short lifespan, suggesting that greater investment in such traits may trade off with self-maintenance. The immune system plays an integral role in self-maintenance, by defending organisms from pathogens which may reduce survivorship. Recent ecoimmunological theory predicts that fast-living organisms should rely more heavily on constitutive innate immunity than slow-living organisms, given that these defenses tend to be cheaper to develop, become functionally mature earlier during ontogeny, and act more rapidly and generally against pathogens than acquired defenses. We conducted the first study to test this hypothesis in an ectothermic vertebrate using replicate populations of two life-history ecotypes of the garter snake, *Thamnophis elegans*, one fast-living and one slow-living. We tested for differences in three aspects of constitutive innate immunity—natural antibodies, complement-mediated lysis, and bactericidal competence—between fast-living and slow-living ecotypes. As predicted, free-ranging snakes from the fast-living ecotype had significantly higher levels of all three measures of immunity than the slow-living ecotype. This difference may reflect an immunological trade-off in life-history strategy, differences in resource availability between the two ecotypes, or both. Ecotype differences were not explained by parasite loads measured. Finally, both ecotypes also exhibited a positive relationship between innate immunity and age/body size in the field, with fast-living snakes showing faster rates of increase in innate immunity with age in association with faster growth rates.

***S2.3*** SPEAKMAN, John; University of Aberdeen ; *j.speakman@abdn.ac.uk*
***The heat dissipation limitation theory and the evolution of life histories***
The traditional view of energy in life history evolution is that energy is a limited environmental resource. Animals are therefore forced to allocate this limited resource selectively between processes that ensure survival, and those that enable reproduction. The evolutionary solution to this problem is presumed to depend on the extrinsic risks of mortality. Low extrinsic risks of mortality favour strategies of longevity assurance, and reduced reproduction, while high extrinsic mortality risks promote increased investment in reproduction at the expense of longevity assurance. A key factor driving the variation in extrinsic mortality is body size. This evolutionary framework is suggested to lead to the familiar relationships between fecundity and body size and longevity and body size. The heat dissipation limit (HDL) theory provides a different conceptual perspective on the evolution of life histories in relation to body size. I suggest that rather than being limited, energy supplies in the environment are often unlimited, and that animals instead are constrained in their ability to expend energy by their maximal capacity to dissipate heat generated as a by product of their metabolism. This novel theoretical framework leads to a new interpretation of the evolution of life histories. In particular, the convergence of the theoretical maximal heat dissipation capacity with the basal metabolic rate constrains the ability of animals to invest in reproduction as they get larger. I suggest that this is the primary reason why fecundity declines as animal size increases. Because large animals are constrained by their heat dissipation capacity to have low reproductive rates, only those large animals living in habitats with low extrinsic mortality could evolve longevity assurance mechanisms to survive long enough to have viable populations: leading to the familiar patterns of life history trade-offs and their links to extrinsic mortality rates.

***26.4*** SPEISER, D.I.*; LOEW, E.R.; JOHNSEN, S.; Duke University, Cornell University; *dis4@duke.edu*
***Spectral sensitivity of the concave mirror eyes of scallops: The influence of habitat and longitudinal chromatic aberration***
Scallops have unique eyes that use a concave spherical mirror to form images by reflection. Scallop eyes also contain a lens and two retinas, one proximal and one distal. Molecular evidence suggests that each retina expresses a different visual pigment, but it is not known if these pigments differ in their spectral sensitivity. We used microspectrophotometry (MSP) to measure the absorption spectra of photoreceptors from both of the retinas of the shallow-dwelling bay scallop *Argopecten irradians* and the deeper-dwelling sea scallop *Placopecten magellenicus*. Photoreceptors from the *P. magellenicus* proximal retina had an average wavelength of maximum light absorption ($\lambda_{max}$) of 488 ± 1 nm (mean ± *SE*; $N = 20$), while photoreceptors from the distal retina had a $\lambda_{max}$ of 513 ± 3 nm ($N = 26$). In comparison, the proximal and distal photoreceptors of A. irradians had a $\lambda_{max}$ of 506 ± 1 nm ($N = 21$) and 535 ± 3 nm ($N = 14$), respectively. Inter-specific variation in spectral sensitivity suggests that environment may influence the evolution of scallop visual pigments. The shorter wavelength visual pigments in *P. magellenicus* are consistent with the bluer water where this scallop lives, while the longer wavelength pigments of *A. irradians* match the greener water of this species' habitat. Intra-specific differences in spectral sensitivity may be influenced by longitudinal chromatic aberration (LCA), a problem commonly produced by biological lenses and one which animals have solved in a variety of ways. In the scallop eye, it appears that longer and shorter wavelengths fall, respectively, on the distal and proximal retinas, a pattern consistent with the spectral sensitivities of the two retinas and one which may serve to minimize the effects of LCA in the scallop eye.

***52.6*** SPERLING, Erik A.*; ROBINSON, Jeffrey M.; PISANI, Davide; PETERSON, Kevin J.; Yale University, Dartmouth College, The National University of Ireland, Maynooth; *erik.sperling@yale.edu*
***Where's the Glass? Biomarkers, Molecular Clocks and microRNAs suggest a 200 Million Year Missing Precambrian Fossil Record of Siliceous Sponge Spicules***
The earliest evidence for animal life comes from the fossil record of 24-isopropylcholestane, a sterane found in Cryogenian deposits, and whose precursors are found in modern demosponges, but not choanoflagellates, calcisponges, hexactinellids or eumetazoans. However, many modern demosponges are also characterized by the presence of siliceous spicules, and there are no convincing fossil spicules until the Lower Cambrian. This temporal disparity highlights a problem with our understanding of the Precambrian fossil record – either these supposed demosponge-specific biomarkers were derived from the sterols of some other organism and are simply retained in modern demosponges, or there is a significant gap in the demosponge spicule fossil record. To resolve this issue, we must establish the phylogenetic placement of another sponge group, the hexactinellids, whose spicules are thought to be homologous to the spicules of demosponges, and who also make their first appearance near the Precambrian/Cambrian boundary. Using two independent data sets – traditional molecular phylogenetic analyses and the presence or absence of specific microRNA genes – we show that demosponges are monophyletic, and that hexactinellids are the sister group of demosponges. Thus, spicules must have evolved before the last common ancestor of all living demosponges. A molecular divergence estimate places the origin of this last common ancestor well within the Cryogenian, consistent with the biomarker record, and strongly suggests that there was a massive failure to preserve siliceous spicules during the Precambrian.

***55.4*** SPONBERG, S.*; DANIEL, T.L.; Univ. of Washington; *bergs@u.washington.edu*

***Phase modulation and control of flight power muscles during visually-induced turning responses in the hawkmoth, Manduca sexta***

The established perspective of flight control in insects holds that their remarkable maneuverability arises from neural modulation of relatively small steering muscles acting in concert with the regular, clock-like activation of larger power muscles. While in asynchronous fliers, phase modulation of the main power muscles is unlikely, synchronous fliers, like the hawkmoth, *Manduca sexta*, could have control capability in these muscles. To test the capacity for such control, we hypothesized that the main power muscles of M. sexta flight are bilaterally phase locked, with modulation of wing motions and aerodynamic forces arising from the action of the steering muscles. We recorded from the bilateral pair of dorso-ventral muscles (DVMs) in adults using bipolar tungsten electrodes. We used an oscillating vertical grating pattern to visually stimulate tethered moths, which induced strong, sustained yaw maneuvers. We found significantly larger variance in the phase of the two muscles during induced turning responses than during steady flight with a static visual stimulus. During maneuvers, changes in relative timing ranged over more than 20% of wing beat period; a very significant effect since even subtle phase shifts in these muscles can lead to large changes in muscle work output. Moreover, in some trials the phase of activation between the bilateral DVM pair closely tracked the phase of a 1 Hz sinusoidal visual stimulus. We reject the hypothesis that power muscles necessarily operate in phase, demonstrating that the DVMs can be asymmetrically modulated via a visual sensorimotor feedback loop. Our results support the emerging view that phase modulation of neuromuscular activity encodes significant information for locomotor control of insects.

***19.5*** SPRAGUE, J. C.*; WOODS, H. A.; The University of Montana; *jonathan1.sprague@umontana.edu*

***Buried Alive: The Physiological Ecology of Manduca sexta Pupal Chambers***

Many organisms mold the physical material of their environments to their own benefit, and these changes can have far reaching ecological and physiological effects (i.e., bird nests, beaver dams, ant colonies, and fossorial burrows). For instance, near Portal, Arizona, in the dry heat of the Chihuahuan and Sonoran Deserts, the sphingid moth *Manduca sexta* pupates for ~ 18 days, 3 to 11 cm below ground in carefully constructed chambers roughly twice the volume of their pupal case. These chambers are not cheap: larvae may spend over 6 hours wandering the desert floor to find suitable burrowing sites. They then spend several days and use up to 30% of their body mass in water weight to create and coat the chamber walls. But two benefits to pupating underground are immediately apparent. First, exposure to certain predators (wasps, ants, birds) is reduced. Second, while temperatures on the surface of the soil can reach 60°C (hot enough to fry an egg), a mere 6 cm down it's a balmy and consistent 25-35°C. But why a costly, thick-walled chamber? Why not just dig down and pupate? We explore two possible functions of these chambers: (1) That the thick walls of the chamber retain water vapor and prevent desiccation in dry desert soil and (2) that chambers facilitate gas exchange to and from the pupa by creating a large soil-air interface.

***76.5*** SRYGLEY, R.B.*; LORCH, P.D.; USDA-Agricultural Research Service, Kent State University, Ohio; *robert.srygley@ars.usda.gov*

***Nutritional effects on migration and immunity: Mormon crickets in Nevada contrast sharply with a band in Utah***

Mormon crickets (*Anabrus simplex*) form large migratory bands that march over rangeland in the western U.S. in search of nutrients. Immune defense is particularly relevant to survival in migratory bands, but little is known about the role of nutrition in insect immunity. We hypothesized that immune defenses are compromised in Mormon cricket bands due to nutrient limitations. To determine general constituents lacking in their diet, we presented captive members of the band with both protein rich and carbohydrate rich diets. Members of a migratory band in Utah preferred the protein diet, indicating a protein deficiency, whereas members of the Nevada band preferred the carbohydrate diet and showed little interest in proteins. These two kinds of nutrient deficiency were associated with different kinds of immunodeficiency. In the protein-deficient band, a protein diet enhanced phenoloxidase (PO) activity, an enzyme involved in wound healing and fighting foreign invasion. PO activity was unaffected by the dietary treatments in the carbohydrate-deficient band. In the carbohydrate-deficient band, feeding on carbohydrates enhanced the crickets' ability to encapsulate foreign particles and lyse bacteria, whereas these abilities were unaffected by the dietary treatments in the protein-deficient band. The difference in components of the immune system that are enhanced by the contrasting dietary constituents suggests that PO activity requires protein whereas encapsulation and antibacterial activity require carbohydrate. Thus there may not be a common currency for the generalized immunity of insects. In the general framework of ecological nutrition, insects may require a balanced diet to maximize defense against invasion.

***32.6*** STAAB, KL*; FERRY-GRAHAM, LA; HERNANDEZ, LP; George Washington University, Moss Landing Marine Labs; *kstaab@gwmail.gwu.edu*

***Morphological and Kinematic Variation in Upper Jaw Protrusion in Cypriniform Fishes***

Cypriniformes is a diverse clade of freshwater fishes that likely owes some of its success to the novel feeding mechanism employed by members of the group. Cypriniform fishes effect premaxillary protrusion via a kinethmoid, a sesamoid ossification that is a synapomorphy for the order. The kinethmoid is entirely suspended by ligaments to the premaxillae, maxillae, palatines, and neurocranium. While the ligamentous attachments are relatively conserved among species, there is variation in kinethmoid shape. Cypriniforms are trophically diverse with most species feeding on secondary producers such as macrocrustaceans and insects. Many members are benthic feeders, while others can switch between pelagic and benthic modes depending on food availability. Our previous work has suggested that morphological variation in kinethmoid shape is likely correlated with ecological niche. Here we performed kinematic analyses on five cypriniform species with varying kinethmoid shape. Our initial hypothesis was that *Carassius auratus* and *Catostomus insignis*, species with elongate kinethmoids that feed on benthos would have slower protrusion speeds than *Danio rerio* and *Devario aequipinnatus*, which feed on insects and possess shorter kinethmoids. Our results tell a more complex story. *C. auratus* and *C. insignis* both fall into the faster protrusion category and this may be due to the architecture of the adductor mandibulae. Determination of where these species fall on the ram-suction spectrum revealed that *Gila robusta* and *C. auratus* are more suction-dominated feeders than the others. These data suggest that kinethmoid-mediated premaxillary protrusion in benthic cypriniforms is a versatile mechanism, allowing for searching through benthos as well as effective capture of elusive prey.

***83.6*** STAAF, Danna J.*; DENNY, Mark W.; GILLY, William F.; Hopkins Marine Station of Stanford University; *joyshul@stanford.edu*

***Aperture size effects in paralarval squid swimming***

The recent range expansion of the Humboldt squid *Dosidicus gigas* has spurred studies on its swimming abilities and metabolic demands. These have generally focused on adults, which can be caught by jigs and tagged. The mobility of paralarvae is also an important factor in dispersal, but these smaller life stages are more difficult to find and impossible to study using the same techniques as for adults. We report here on the swimming behavior of paralarval squid, both from artificially fertilized eggs and from the first (and only) egg mass ever found in the wild. Standard and high-speed videos of the paralarvae were used to quantify swimming speed and mechanics. We found that *D. gigas* hatchlings employ multiple jet propulsive gaits to cover a range of speeds, and they may partially control their speed by altering the size of the jet aperture. We compare these findings to results from a computer model of squid swimming to test the hypothesis that aperture size is responsible for swimming speed in paralarval *D. gigas*.

***17.4*** STAHL, A.L.*; OLSON, W.M.; University of Northern Iowa; *aarons@uni.edu*

***A timecourse study in embryonic development of African dwarf frogs Hymenochirus boettgeri exposed to atrazine***

Stahl, Aaron A timecourse study in embryonic development of African dwarf frogs *Hymenochirus boettgeri* exposed to atrazine Atrazine is one of the most commonly used broad-leaf herbicides in the world. It functions by binding to a protein in photosystem II and inhibits electron transport. Previous studies have indicated that vertebrates exposed to atrazine display consequences such as behavioral changes, endocrine disruption, and delayed development. The focus of this study is to determine the effect of atrazine on embryonic developmental rate of the African dwarf frog. It has been proposed that development can be slowed due to decreased cyclin levels caused by exposure to atrazine. Cyclin levels must reach a threshold to progress the cell through mitosis. The first study focused on embryonic development from fertilization to 72 hours after hatching. In this experiment eggs were collected immediately after fertilization. Half of the eggs were exposed to three different quantities of atrazine: 10 ppb, 5 ppb, and 1 ppb. Eggs not exposed to atrazine were used as a control. Specimens were analyzed for morphological abnormalities and changes in developmental rate; some were also stained for the analysis of neuromuscular junctions. The second study examined $G_1$ cyclin levels. Cellular synchronization was achieved by amputating the right hindlimb of tadpoles at stages 52 to 54. The limb was allowed to regenerate over a period of 14 to 20 days in the three different quantities of atrazine and a control. After the regeneration period morphological features of the organism and the limb bud were analyzed. The regenerated limb buds were amputated and homogenized to extract nuclear proteins. Extractions were used in a sandwich ELISA for quantification of the $G_1$ cyclins. Preliminary results will be presented.

***19.3*** STAHLSCHMIDT, Z.R.*; DENARDO, D.F.; Arizona State Univ., Tempe; *zs@asu.edu*

***Parental behavior in pythons is dependent on both the hydric and thermal dynamics of the nest***

Parental behavior is instrumental to the success of a diverse array of taxa, and female-only nest attendance is particularly widespread. Python egg-brooding behavior is an intriguing example of female-only nest attendance because it significantly influences several variables critical to embryonic development, namely embryonic predation, hydration, respiration, and temperature. During brooding, females predominately adopt a tightly coiled posture that reduces the exchange of heat, water vapor, $O_2$, and $CO_2$ between the nest and clutch environment which benefits water balance at the cost of embryonic respiration. To determine the plasticity of this important behavior, we manipulated nest temperature and humidity while monitoring nest-clutch thermal, hydric, and respiratory relationships to test the hypothesis that female Children's pythons (*Antaresia childreni*) modify their egg-brooding behavior due to an interaction between environmental thermal and hydric conditions. During moderate and high nest humidity treatments (23 and 32 g/m$^3$ $H_2O$, respectively), females spent more time coiling tightly when the nest was cooling than when it was warming which benefited clutch temperature. However, brooding females in low humidity nest environments (13 g/m$^3$ $H_2O$) showed a high frequency of tight coiling even when the nest was warming; thus, nest temperature and humidity had an interactive effect on egg-brooding behavior in support of our hypothesis. Our results also suggest that certain egg-brooding behaviors (i.e., postural adjustments) are more energetically costly to females than other behaviors (i.e., tight coiling). To conclude, we provide empirical support for the significance of python egg-brooding behavior which provides insight into the significance of female-only nest attendance, in general.

***6.3*** STANHOPE, B. A.*; BERENDZEN, P. B.; University of Northern Iowa; *bstan@uni.edu*

***Evolution of genome size in tetraploid suckers (Catostomidae: Cypriniformes)***

Genome size varies among organisms and is often correlated with developmental rate and morphology. It has long been observed that a larger genome size will positively correlate with elongated development periods and larger body size, whereas smaller genomes will be paired with shortened lifespan and specialization of physical features. Catostomidae is a family of freshwater fishes known as suckers. Catostomids descended from a single tetraploid ancestor and its members present a wide variety of body types and maturation periods. Preliminary studies of the Catostomidae have indicated loss of duplicate gene expression. The objective of this study is to determine if a correlation exists between genome content, phylogeny, and biological characteristics. This investigation utilizes single-strand conformational polymorphism (SSCP) analysis of several nuclear genes and feulgen image densitometry for analysis of genome size based on DNA content within red blood cells. SSCP will determine the number of copies of genes in various species of catostomids to determine if duplicate copies are lost or are no longer functional. Results of the SSCP analyses will be used to construct a gene tree to determine the evolution of each gene. Preliminary analyses of the DNA content data suggest that there is a general positive association between genome size and longevity, age of maturation, egg diameter, and body length. The strongest correlation exists between genome size and egg diameter, which is consistent with previous studies of other fishes. Genome size data will be mapped on a phylogeny to test for evolutionary trends.

***8.1*** STAYTON, C. Tristan; Bucknell University; *tstayton@bucknell.edu*
***The influence of mechanics on morphological disparity in the evolution of emydid turtle shell shape***
Turtle shells exhibit great morphological diversity in terms of both shape and size. However, previous studies have demonstrated that certain clades of turtles show greater per-taxon variation in shell shape than similar, related clades. One possible explanation for these differences in disparity involves the different functions that the turtle shell performs in different clades. Turtle shell shape undoubtedly influences how well shells perform certain functions (force resistance, moving through fluids, heat exchange, etc...), but few studies exist that quantify this relationship. Here I use geometric morphometrics to quantify shell shape and Finite Element (FE) methods to model the mechanical performance of emydid turtle shells in resisting physical loads and reducing drag. FE models of turtle shells were loaded at points on both the carapace and plastron, and stresses that developed as a result of that loading were quantified and compared between models. As previous studies have found, aquatic turtles generally possessed flatter shells that those found in terrestrial species. Flatter shells usually developed higher stresses for a given load, although in many aquatic species stresses were not exceptionally high. However, flatter shells also showed lower frontal and total wetted areas, implying less drag during swimming. Moreover, the Deirochelyinae, an entirely aquatic clade of emydid turtles, showed less per-taxon morphological disparity than its more ecologically diverse sister clade, the Emydinae. Aquatic emydids, needing to optimize both force resistance and drag reduction, are limited to a narrow range of shell morphologies, while terrestrial species, not requiring low-drag shells, show more disparity in shell shape. However, compromises in shell strength due to shape may be offset by evolutionary changes in shell size.

***S5.10*** STEELE, Rob; University of California, Irvine; *resteele@uci.edu*
***Exploring Hydra regeneration and budding with genomics, transgenics, and chemical genetics***
Hydra was first described in 1702 by van Leeuwenhoek, who noted the presence of buds on the animal. In 1744, Trembley published his memoirs, in which he described Hydra's ability to reproduce asexually by budding and its remarkable ability to regenerate. Efforts to understand the molecules and mechanisms underlying budding and regeneration in Hydra can now be pursued using the recently completed Hydra genome sequence and the ability to make stably transgenic animals. We have generated transgenic Hydra with altered expression of genes encoding proteins in the insulin and hippo signaling pathways. These animals show alterations in budding rates. Using a chemical genetic screen, we have identified small molecules that affect regeneration.

***12.3*** STEFFEN, J.E.*; APPEL, A.G.; Auburn University; *steffje@auburn.edu*
***The energetic costs of different components of the social display in male Brown Anoles.***
Male Anoline social displays are dynamic and typically consist of several different components (e.g., head nods, dewlap extension, and two and four legged push-ups), which appear to be physically costly. Studying the energetics of these different display components may allow us to define the limits of sexual selection by designating which display components are significantly energetically expensive, and which may then act as a form of fitness cost. To investigate the energetic expense of these display components, we quantified oxygen consumption (VO2) of displaying male Brown Anoles. We placed focal adult males in transparent respirometry chambers that were 5 cm away from a size-matched male and a female (both in separate, transparent plastic boxes). We performed Flow-through respirometry on the focal male to determine male oxygen consumption while engaged in social displays. We used an event recorder program to count the number and duration of all display components, and we obtained oxygen consumption values for each display component that occurred. Multiple regression of display VO2 against real-time sums of the display component O2 consumption rates revealed that push up and head nod frequency were the only components to explain a significant variation in display VO2. These results imply that components of display behavior such as dewlap extensions and head nods are relatively energetically inexpensive, whereas 2 and 4-legged push-ups are more costly. These findings may have implications for understanding which components of the Anoline display are under significant sexual selection.

***S7.1*** STEINBERG, D.K.*; SCHOFIELD, O.M.E.; FRASER, W.R.; STAMMERJOHN, S.E.; MARTINSON, D.G.; DONEY, S.C.; MONTES-HUGO, M.; DUCKLOW, H.W.; Virginia Institute of Marine Science, Gloucester Point, Virginia , Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, New Jersey, Polar Oceans Research Group, Sheridan, Montana , University of California, Santa Cruz, Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York , Woods Hole Oceanographic Institution, Woods Hole, Massachusetts , Marine Biological Laboratory, Woods Hole, Massachusetts ; *debbies@vims.edu*
***The Changing Ecosystem of the West Antarctic Peninsula***
The West Antarctic Peninsula (WAP) is one of the most rapidly warming regions on Earth. The Palmer, Antarctica Long-Term Ecological Research (PAL LTER) Program is investigating marine ecosystem response to this climate change along the peninsula's marine continental shelf and marginal sea ice zone. Regional warming and sea ice decline in the northern part of the study area are already leading to changes from the base of the foodweb to its apex. Changes in the mean standing stocks of phytoplankton and rates of primary production in response to sea ice decline are complex: phytoplankton have declined by 89% in the north and increased by 66% in the south as a result of differential changes in vertical mixing and exposure to sunlight resulting from reductions in sea ice cover and duration. Changes in distribution and relative abundance of zooplankton taxa such as krill and salps could lead to changes in biogeochemical cycling and export of carbon from surface waters. Moving further up the foodweb, Adélie penguins have declined locally by over 70% and are being replaced by sub-Antarctic congeners. We are now attempting to understand the mechanisms of ecosystem response to rapid climate change by conducting detailed, ship-based process studies addressing trophic linkages and biogeochemical dynamics.

***3.6*** STEINMETZ, Sarah M*; MALADEN, Ryan D; DING, Yang; GOLDMAN, Daniel I; Bioengineering Program, Georgia Tech, School of Physics, Georgia Tech, School of Physics, Georgia Tech; *ssteinmetz3@gatech.edu*

***Muscle activation during surface and subsurface locomotion in sandfish (Scincus scincus)***

A recent study (Maladen et. al, Science, 2009) found that sandfish swim in sand using a traveling wave body undulation without limb use and that kinematics are independent of volume fraction (φ) due to identical scaling of thrust and drag forces, which double between loose (low φ) and close (high φ) sand packings. Additionally, our numerical model of the sandfish indicates that a traveling wave muscle activation pattern is required to achieve the observed kinematics. Consequently, we hypothesize that animal muscle activation varies with varying φ . We test our hypothesis by combining high speed x-ray and visible light imaging with synchronized electromyography (EMG) of sandfish back (epaxial) muscle during surface and subsurface motion. While running on the surface, body oscillation was not observed and simultaneous EMG recordings revealed only a low intensity activation level. During burial, the animal executes a stereotypical entry, gradually ceasing limb use while increasing body undulation amplitude, and the EMG signal increases from zero to a fixed intensity level for periods of activation. During sand swimming the EMG signal reveals a uniphasic rostrocaudal traveling wave of muscle activation similar to our numerical model. However, in contradiction to our hypothesis both the activation duration and intensity are independent of φ ($P > 0.05$). Potential explanations of this surprising result include (1) muscle activation onset changes relative to the phase of the kinematic wave, and (2) the sand immediately surrounding the animal and in which it swims evolves to the same critical packing state independent of the initial preparation.

***57.5*** STEWART, W.J.*; BREUER, K.S.; MCHENRY, M.J.; Univ. of California, Irvine, Brown University; *wstewart@uci.edu*

***Lateral line sensing depends on the volume of the swim bladder in larval fish***

The ability to detect the water flow generated by a predator could be essential to the survival of a larval fish. However, it is not well understood what flow stimuli a larval fish detects before triggering an escape response. Mathematical modeling suggests that the density of a larva's body is a major factor in determining the flow of water relative to the body that may be detected by the lateral line system. The goal of the present study was to evaluate how this relative flow varies in the early development of larval zebrafish (*Danio rerio*), when the density of the body changes as the swim bladder inflates. We developed a novel approach for measuring the tissue density of anesthetized larvae (3-6 days post fertilization (dpf)) from measurements of terminal velocity in solutions of varying density. Over the course of growth, tissue density decreased from 1.06 g $mL^{-1}$ to 1.0045 g $mL^{-1}$. We considered the implications of these changes on relative flow using an analytical model of a larva in the pressure field generated by a suction-feeding predator. Our results suggest that the flow velocity generated by a predator is substantially reduced (>98%) with respect to the frame of reference of the larva's body (the larva moves with the surrounding fluid). The relative velocity that may be detected by the lateral line system is 8-times greater in hatchlings than mature larvae (5-6 dpf) because of the greater density generated by not having an inflated swim bladder. Therefore, flow stimuli are greatly attenuated by the motion of a larva's body and that this signal is reduced further with the inflation of the swim bladder. These results suggest that lateral line function may change dramatically over the life history of a fish due to the scaling of flow stimuli relative to the size and mass of the body.

***41.3*** STOLTEY, T*; SHILLINGTON, C; Eastern Michigan University; *tstoltey@gmail.com*

***Metabolic Rates and Movements of Male Tarantulas During the Breeding Season***

Tarantulas (Araneae: Theraphosidae) exhibit sexual dimorphism in their resting metabolic rate (RMR). The significantly higher RMRs observed in sexually mature males may be an adaptive strategy to support increased energetic demands imposed by mate searching. In this study, we investigated how intra-sexual differences in male RMR may affect their locomotory activity and behavior during the breeding season. Over a 2-year period, we radio-tagged males, measured their movements, and periodically recorded their metabolic rates in an open-flow respirometery system over the course of the breeding season. Differences found in search speed, search area size, and movement patterns were not sufficiently explained by the small amount of intrasexual variation exhibited in RMR. Individuals were capable of searching areas up to 29 hectares and moved up to 365 m/day. In addition, metabolic rate measured over a 24-hr period showed no circadian periodicity and remained constant over the season. Lastly, the body condition of new captures stayed constant throughout the season, corroborating observations of males feeding and drinking.

***24.3*** STREBY, Henry/M*; ANDERSEN, David/E; Minnesota Cooperative Fish and Wildlife Research Unit; *streb006@umn.edu*

***When is Success not Success? When it's Songbird Nesting Success***

Estimates of nesting success have long been used as a proxy for reproductive success in songbird populations. These estimates have been used to monitor populations across multiple temporal and spatial scales, index habitat quality, and model source-sink population dynamics. Despite a growing body of evidence that the post-fledging period is a time of high mortality for many songbird species, this period is usually unstudied and often included in population models as an ambiguous constant. During 2007 and 2008 we studied reproductive success of a population of Ovenbirds in the Chippewa National Forest in north-central Minnesota. We monitored 234 active Ovenbird nests and tracked 110 fledglings from successful nests using radio telemetry. Although nesting success was twice as high in 2008 as in 2007, the opposite was true for post-fledging survival, resulting in nearly identical estimates of full season reproductive success. Our results suggest that survival may be highly variable during the dependent post-fledging period, which has implications for using nesting success as a proxy for reproductive success in a variety of contexts.

***89.3*** STROTHER, J.A.*; WEGNER, N.C.; GRAHAM, J.B.; Univ. of California, Irvine, Scripps Institution of Oceanography; *strother@uci.edu*

***The mechanics of ventilation in a scombrid fish***

Many scombrid fishes are capable of achieving remarkably fast swimming speeds, which they are often able to maintain during long distance migrations. The elevated metabolic rate required for such activity is believed to be supported by a number of specializations in the gill morphology of these species. Increases in the respiratory surface area and decreases in the diffusional barrier thickness result in elevated diffusion capacities. Simultaneously, fusions that join adjacent filaments or secondary lamellae are thought to reinforce the gills to prevent deflection in the ventilatory flow stream. To examine the functional consequences of these differences in gill morphology, the flow around the gills of a scombrid fish was measured using particle image velocity (PIV) and the bending stiffness of the gills was measured using three-point bending. The freshly-excised gill arches of a bonito (*Sarda chiliensis*) were placed in a closely fitting flow-through chamber, and the flow rate through the chamber was varied. PIV was used to measure the velocity of water along the trailing edge of the primary lamellae, from which several measures of respiratory efficiency were calculated. The bending stiffness of the gills was measured using a modified three-point bending fixture, with the deflection parallel to the ventilatory flow and the bending moment parallel to the gill arch. We found that, with the observed flow rates, non-respiratory shunting and flow heterogeneity remained low. However, as the flow rates increased these effects began to compromise respiratory performance. It is possible that such effects impose functional constraints on the rate of ventilation and the morphology of the gills in scombrid fishes.

***45.5*** SUNADA, Hiroshi; SAKAKIBARA, Manabu*; Tokai University; *manabu@tokai.ac.jp*

***The shadow response of RPeD11, in Lymnaea***

Stress, especially that elicited by ecologically relevant stressors (e.g. Predator detection) enhances long-term memory (LTM) formation in the pond snail, *Lymnaea stagnalis*. In addition, predator detection elicits a suite of so-called vigilance behaviors one of which is a heightened response to a shadow (i.e. Often the complete withdrawal of the snail into its shell). The shadow withdrawal response is mediated by so-called dermal photoreceptors located primarily on the foot, mantle cavity, and skin around the pneumostome area. Here we asked whether we could obtain a neural correlate of the heightened withdrawal response elicited by a shadow following predator detection. We measured the electrophysiological properties of 'Right Pedal Dorsal 11 (RPeD11)', an interneuron that plays a major role in withdrawal behavior of the animal. In naive semi-intact preparations (i.e. snails not exposed to predator scent) the shadow stimulus elicits a small depolarization in RPeD11 which is mediated by dermal photoreceptors making a mono-synaptic connection to RPeD11. In stressed snails (i.e. exposed to predator scent) there are a number of significant changes in the intrinsic membrane properties of RPeD11 compared to naive preparations. RPeD11 is significantly more depolarized (~8mV) and the input resistance is significantly greater. Moreover in these 'stressed' preparations the response to the shadow stimulus is of a significantly longer duration leading to an increased RPeD11 response.

***85.5*** SUNDAY, Jennifer M.*; CRIM, Ryan; HARLEY, Chris D.G.; HART, Michael W.; Simon Fraser University, University of British Columbia; *sunday@sfu.ca*

***Potential to adapt? Heritability of larval growth in an acidified ocean***

Under future atmospheric $CO_2$ projections and the associated decrease of oceanic pH, the vulnerability marine organisms, particularly at their larval stages, has come under concern. Laboratory studies show that growth and development of calcifying larvae are negatively affected by increased partial pressures of $CO_2$ in seawater, but there is individual variability in the response. A key parameter for trait evolution is the extent to which this variability is heritable, allowing for a more efficient response to selection. Using a full factorial mating design, we estimated the heritability of growth response under elevated $CO_2$ conditions in larvae of the Northeast Pacific sea urchin, *Strongylocentrotus franciscanus*, and mussel, *Mytilus trossulus*.

***83.4*** SUTHERLAND, K. R.*; MADIN, L. P.; MIT/WHOI Joint Program in Oceanography, Woods Hole Oceanographic Institution; *krakow@whoi.edu*

***Form, function and flow in the plankton: Jet wake structure and swimming performance of pelagic tunicates***

Salps are barrel-shaped marine invertebrates that swim by jet propulsion. Morphological variations among species and life-cycle stages are accompanied by differences in swimming mode. The goal of this investigation was to compare propulsive jet wakes and swimming performance variables among morphologically distinct salp species (*Pegea confoederata, Weelia (Salpa) cylindrica, Cyclosalpa affinis*) and relate swimming patterns to ecological function. Using a combination of in situ dye visualization and particle image velocimetry (PIV) measurements, we described properties of the jet wake and swimming performance variables including thrust, drag and propulsive efficiency. Locomotion by all species investigated was achieved via vortex ring propulsion. We found that the slow-swimming *P. confoederata* produced the highest weight-specific thrust (T= 53 N $kg^{-1}$) and swam with the highest whole-cycle propulsive efficiency ($\eta_{wc}$= 55%). The fast-swimming *W. cylindrica* had the most streamlined body shape but produced an intermediate weight-specific thrust (T= 30 N $kg^{-1}$) and swam with an intermediate whole-cycle propulsive efficiency ($\eta_{wc}$= 52%). Weak swimming performance variables in the slow-swimming *C. affinis*, including the lowest weight-specific thrust (T= 25 N $kg^{-1}$) and lowest whole-cycle propulsive efficiency ($\eta_{wc}$= 52%), may be compensated by low energetic requirements. Swimming performance variables will be considered in the context of ecological roles and evolutionary relationships.

***100.3*** SUZUKI, Takao*; KURATANI, Shigeru; RIKEN CDB, Japan; *tsuzuki@cdb.riken.jp*

***Evolutionary reorganization of moth wing patterns towards a 'dead leaf' resemblance***

How an enormous organismal diversity and complexity could have evolved is a fundamental question of design principles of living organisms. As seen in vertebrate head skeleton evolution, the diversity of moth wing pattern can be generated by the inherited morphological parts. To avoid predators, it is probable that these parts are organized sufficiently to perform a requsite function. However, it has never been referred to how the pattern parts are integrated. Here, we reported the morphological design and evolutionary emergence of moth wing pattern mimicking a dead leaf.

As a model organism, we picked up a noctuid moth, *Oraesia excavata*, whose forewings have all the appearances of a detailed resemblance to a leafy pattern with one main and left-/right-sided leaf veins. By employing morphometrics, we found that the leafy pattern established a precise and modular organization: a lower variation against generic diffrences and the synchronizedly covariation concordant with leaf-vein features. To satisfy ecological requirements, these characteristics are likely to improve a camouflage strategy for an effective resemblance in a wild life. Furthermore, we found that when the leafy pattern evolved, a degree of integration within the pattern bands were restructured by changing the covariational structure. In addition, we investigated another noctuid moth, *Thyas juno*, which represents a different camouflage strategy. We found that unlike *O. excavata*, *T. juno* wing pattern posses a high degree of independency and almost no correlation among the pattern bands. It appears that more complex pattern evolved, more frequently the covariational structure was reorganized. Thus, the complex pattern was generated by an extremely flexible developmental system that allows successive changes of the pattern bands free from mutual constraints.

***50.5*** SVENDSEN, JC*; TUDORACHE, C; JORDAN, AD; STEFFENSEN, JF; AARESTRUP, K; DOMENICI, P; Technical University of Denmark, University of Antwerp, University of Copenhagen, University of Copenhagen, International Marine Centre Localita Sa Mardini; *jos@aqua.dtu.dk*

***Partition of aerobic and anaerobic swimming costs related to gait transitions in a labriform fish***

Striped surf perch *Embiotoca lateralis* swim using the pectoral fins at low to moderate speeds, while the caudal fin is assisting at high swimming speeds. The gait transition from pectoral fin propulsion to pectoral and caudal fin propulsion occurs at a distinct threshold speed termed $U_{p\text{-}c}$. The objective of this study was to quantify aerobic and anaerobic swimming costs at speeds below and above the $U_{p\text{-}c}$ in *E. lateralis* using swimming respirometry and video recordings to test the hypothesis that the gait transition leads to anaerobic metabolism. In this species, 1.4 body lengths per second (bl $s^{-1}$) is below the $U_{p\text{-}c}$, whereas both 1.9 and 2.3 bl $s^{-1}$ are above the $U_{p\text{-}c}$. Exercise oxygen consumption ($MO_2$) while the fish were swimming at these speeds was determined. The presence and magnitude of excessive post exercise oxygen consumption (EPOC) was evaluated after the three swimming speeds. There was no evidence of EPOC after swimming 1.4 and 1.9 bl $s^{-1}$ indicating that the gait transition from pectoral oscillation to axial undulation is not a threshold for anaerobic metabolism. In contrast, swimming at 2.3 bl $s^{-1}$ resulted in EPOC being 51.7 mg O2 $kg^{-1}$ suggesting that anaerobic metabolism added about 34% to the exercise $MO_2$. *E. lateralis* switched to an unsteady burst and flap gait at 2.3 bl $s^{-1}$. Burst activity correlated linearly and positively with the magnitude of the resulting EPOC. Collectively, these data suggest that steady axial propulsion does not lead to EPOC whereas transition to burst assisted swimming above $U_{p\text{-}c}$ is associated with anaerobic metabolism in this labriform fish.

***7.3*** SWEENEY, A.M.*; HOLT, A.L.; MASON, E.; MORSE, D.E.; University of California, Santa Barbara; *sweeney@lifesci.ucsb.edu*

***Deep-sea silver: photonics and biochemistry of semi-coherent broadband reflectors on squid eyes***

The eyes of most species of squid are covered in a silver layer which exhibits unusual cell biology, biochemistry, optical properties and visual ecology. This layer comprises a semi-coherent photonic reflector with unique angle- and polarization-independent reflectivity, making these tissues a model for a self-assembled wavelength-independent dielectric mirror. The optical material is composed of layered spindle-shaped cells providing high refractive index regions, and an expanded extracellular glycocalyx providing low refractive index regions. The optically homogeneous infill of the spindle-shaped cells is composed of a mixture of reflectin protein and a novel protein characterized by its high hydrophobic amino acid content. Interesting variations in the optical geometry and composition of this silver layer correspondingly change with the visual ecology of deep-sea squid species and have implications for underwater camouflage. The discovery of a second optically active protein in these reflective cells initiates our exploration of the organizing principles of self-assembly of soft photonic structures in organisms.

***96.3*** SWIDERSKI, D.L.*; ZELDITCH, M.L.; Univ of Michigan, Ann Arbor; *dlswider@umich.edu*

***Isometric scaling of lever arm lengths in squirrel jaws leaves jaw shape free to meet diverse functional demands***

Allometric scaling appears to be a nearly universal feature of morphological diversity, with the conspicuous exception of the mammalian mandible. Some theoretical analyses suggest mandibular lever arm lengths should be isometric relative to each other, which some empirical studies confirm. Our analysis of 23 New World tree squirrel species likewise found that most lever arm lengths were isometric relative to each other, but were negatively allometric relative to jaw size. Despite these correlations, most jaw shape diversity was uncorrelated with jaw size differences. To determine whether this pattern is particular to one group of fairly homogeneous and recently radiated species, we also evaluated jaw morphology in chipmunks and ground squirrels. In these more diverse terrestrial species, relative jaw lengths were as tightly constrained as in tree squirrels, but unlike the tree squirrel pattern, some lengths exhibited strong positive allometry relative to jaw size. The terrestrial squirrels were also similar to tree squirrels in that overall jaw shape was much more diverse than indicated by these length correlations, and that shape differences were largely independent of size differences. Thus both groups appear to be under strong constraints to maintain lever arm ratios (mechanical advantages) across broad size ranges, but many different jaw shapes can meet those constraints, allowing great flexibility to meet other demands such as optimizing gape size or resistance to deformation. The contrast between the uniformity of tree squirrels and the diversity of terrestrial squirrels reflects the relative diversity of those other demands on jaw form and function.

***14.5*** TAFT, Natalia K.; University of Chicago; *taft.nk@gmail.com*

***Exploring the adaptive significance of morphological specializations of the pectoral fins among benthic scorpaeniform fishes***

Several groups of fishes use the pectoral fins for routine substrate contact and exhibit morphological specializations that have been hypothesized to be adaptive for a benthic lifestyle. Here I examine the relationship between pectoral fin morphology and a benthic lifestyle among the primarily benthic scorpaeniform fishes (sensu Smith and Wheeler, 2004). Evidence of correlated evolution between specializations of the pectoral fins and a benthic habitat can provide support for the hypothesis that these features are adaptive for bottom-dwelling. I examined pectoral fin morphology among 23 species from 15 scorpaeniform families. I identified three discrete characters of the pectoral fins that are associated with a benthic lifestyle: 1) an asymmetrical fin membrane among ventral fin rays, 2) the presence of fin rays that are unbranched distally and 3) the presence of ventral pectoral fin rays that are free of fin membrane. I tested for correlations between each of these characters and a benthic lifestyle using Pagel's test of correlated evolution. Asymmetry of the fin membrane among ventral fin rays is marginally correlated with a benthic lifestyle. The presence of unbranched fin rays is not correlated with a benthic lifestyle in this group. Free pectoral fin rays are rare among the species I examined and not correlated with a benthic lifestyle. However, free pectoral fin rays are present only in benthic species. Each of the morphological specializations I examined evolved independently more than once among benthic scorpaeniform clades suggesting that these characters are adaptive for bottom-dwelling. Scorpaeniform fishes are very speciose; these results provide a jumping-off point for future analyses of pectoral fin morphology of the group as a whole as well as within individual clades.

***105.4*** TATE, K*; SWART, J; EME, J; CONLON, JM; CROSSLEY II, DA; U N Dakota, U. Cal, Irvine, United Arab Emirates Univ; *kevin.tate@und.edu*

***Effects of Dehydration on Cardiovascular Development in Alligator mississippiensis***

Dehydration can have a significant impact on reptilian development. Embryos of the American alligator (*Alligator mississippiensis*), may be particularly susceptible to dehydration during drought episodes due to the nesting strategies. The potential for dehydration is exacerbated by the permeability of Alligator eggs. Our previous work demonstrates that periods of acute dehydration result in an irreversible loss of egg water; however, its impact on function needs further characterization. Therefore we subjected alligator eggs to acute drying events (20% total egg mass loss) during the first two-thirds of incubation to achieve two goals: understand the impact on cardiovascular (CV) development and determine the haematological response to these events. Blood volume (BV) and haematological parameters were determined at 70% & 90% of development. Further, the CV response to the vasoactive peptide Angiotensin II (Ang II) was used to assess the impact on CV function. BV estimations indicate that dehydrated embryos maintained BV, despite a significant decrease in embryo and egg mass. Ion composition ($K^+$, $Cl^-$, $Na^+$) of the blood and hematocrit, as well as heart, and kidney mass increased in dehydrated embryos, compared to controls. Dehydrated embryos also showed a relative bradycardia and hypertension. However the hypertensive response to Ang II in control and dehydrated embryos appeared similar. The data indicate that dehydrated embryos maintain BV while allowing ionic concentrations to rise, responses which are coupled to an increased heart and kidney mass suggesting an increase in functional capacity for these organs. Project was supported by a NSF career award to D.A.C IBN# IOS-0845741

***7.4*** TAYLOR, JS*; BREDEN, F; CHURCHER, AM; LAVER, CR; OWENS, GL; WARD, MN; WINDSOR, DJ; University of Victoria, Simon Fraser University; *taylorjs@uvic.ca*

***Gene duplication and divergence in live-bearer opsin genes***

Fish show an astonishing degree of opsin gene duplication and divergence, and the livebearers have proven to be no exception to the rule. Guppies *Poecilia retculata* (family Poeciliidae) possess ten visual opsins, all of which are expressed, albeit to varying degrees. Guppy males are very colourful and as part of our efforts to test the hypothesis that opsin gene duplication and divergence plays a role in colour-based sexual selection in this species, we have used southern-blotting, PCR, and DNA sequencing to characterize the opsin gene repertoires from other poeciliids and from two species (the one-sided livebearer and the four-eyed fish) in the sister group Anablepidae. These surveys show that retrotransposition, tandem duplication, gene conversion and key-site amino acid substitutions have all lead to the remarkable opsin gene number and sequence diversity found among species in these lineages.

***84.4*** TAYLOR, Jennifer R. A.*; PATEK, Sheila N.; Univ. of California, Berkeley, Univ. of Massachusetts, Amherst; *jrataylor@berkeley.edu*

***Biological punching bags: impact analysis of a mantis shrimp telson***

Collisions are prolific in nature and can impart significant impact forces on organisms. Our understanding of how biological structures respond to impact forces is limited, partly because most studies on material properties are conducted under static or quasi-static loading conditions. Here we perform an impact analysis on one of nature's remarkable punching bags: the mantis shrimp telson. During ritualized fighting, mantis shrimp (Crustacea, Stomatopoda) repeatedly strike each other with their raptorial appendage, delivering extremely fast and powerful blows to the telson of the opponent. Hence, the telson may respond differently to impact than other body regions, e.g. the abdomen. To test this, we performed ball drop tests on 16 *Neogonodactylus wennerae* that ranged from 0.47 to 4.6 g body mass. Small steel balls were dropped onto the telson and abdomen and recorded using high speed videography. Velocities were calculated from the video frames and used to determine the coefficient of restitution (COR), an index of elasticity (lower values mean less elasticity). The telson COR (0.56) was significantly lower than the abdomen COR (0.66), meaning that the telson absorbs 10% more impact energy than the abdomen. The telson COR was negatively correlated with body mass, while the abdomen COR showed no correlation. There was no difference in the COR for males and females. These results show variation in the impact response of morphologically different body structures. The telson, much like a punching bag, withstands and absorbs the impact of repeated blows, but the mechanism of energy absorption has yet to be explored. The impact response of the telson may be an integral component of assessment during ritualized fighting, and thus important in the evolution of telson morphology.

***64.4*** TøTTRUP, Anders P.*; RAINIO, Kalle; COPPACK, Timothy; LEHIKOINEN, Esa; RAHBEK, Carsten; THORUP, Kasper; Center for Macroecology, Evolution and Climate, Department of Biology, University of Copenhagen, Section of Ecology, University of Turku, Institute of Avian Research, Vogelwarte Helgoland, Germany, Zoological Museum, University of Copenhagen; *aptottrup@bio.ku.dk*

***Evaluating environmental predictors of climate-induced phenological changes in migratory birds***

No doubt global climate is changing rapidly and we expect such changes to affect timing of seasonal events. In migratory birds, we have already seen large changes in timing of migration and breeding. However, few studies have evaluated at which scale environmental conditions are important and which climatic factors are best predictors of recent shifts in timing of seasonal events. Our aim is to assess three commonly used proxies of climate conditions (spring vegetation “greenness” (NDVI), locale spring temperature and regional climatic index: North Atlantic Oscillation (NAO)) as predictors of avian migration as well as the impact on different population subset and species with different migratory strategies. We analysed phenological patterns of the entire spring migration period in 12 passerine species drawing on long-term data collected at three ringing sites. Locale temperature is the best predictor of phenology but gave the highest explanatory power in combination with NAO. Early migrants are more affected by climate variation compared to individuals on later passage indica¬ting that climate change affects subsets of migratory populations differentially. Species wintering closer to the breeding areas were affected more than species travelling longer distances and this pattern was strongest for the earliest population subsets. As climate scenarios predict further global warming, under¬stan¬ding which mechanisms and on what scale they work is crucial for future protection of migratory organisms.

***S10.3*** THOMSEN, M/S; National Environmental Research Institution, Denmark; *mads.solgaard.thomsen@gmail.com*

***Habitat cascades – a conceptual overview and estuarine examples***

Habitat formers, like trees, saltmarshes, coral reefs and seagrasses, have direct positive effects on many closely associated organisms. Recent studies have also highlighted the importance of indirect positive effects of certain habitat formers, for example, trees and saltmarshes can provide habitat for nest epiphytes and mussels, respectively, which again provide habitat for small mobile invertebrates. I will provide a conceptual overview over these ‘indirect habitat/facilitation cascades’, and show new data on understudied estuarine analogues from Europe, North America, Australia and New Zealand. The estuarine cascades are unique by being characterized by small primary habitat formers (polychaetes, bivalves, gastropods) that provide attachment space for larger secondary habitat formers (various seaweed species) that again provide space, food and shelter for small mobile invertebrates. Data will be shown for cascades that are represented by both native and introduced primary and secondary habitat providers. Finally, based on estuarine examples, I will discuss cascading effects on biodiversity and ecosystem processes and outline current research gaps.

***S6.6*** THORUP, Kasper; University of Copenhagen; *kthorup@snm.ku.dk*

***Understanding the migratory orientation program in birds: extending laboratory studies to studying free-flying migrants in a natural setting***

For many years, orientation in migratory birds has primarily been studied in the lab. Though a lab-based setting enables easy manipulation of the environment, the lab-based findings must be investigated in the wild in free-flying birds to fully be able to understand how birds orient on migration. Despite the difficulties associated with following free-flying birds over long distances, a number of possibilities currently exist for tracking the sometimes even global journeys undertaken by migrating birds. Birds fitted with radio transmitters can either be located from the ground or from aircraft (conventional tracking), or from space. Alternatively, positional information obtained by onboard equipment (e.g. GPS units) can be transmitted to receivers in space. Use of these tracking methods has provided a wealth of information on migratory behaviors that are otherwise very difficult to study. Here, we will focus on the progress in understanding components of the migration system that has been achieved and can be expected in the future from tracking free-flying migrants in the wild. Such methods have been successfully applied to study orientation cue use in raptors (satellite telemetry) and thrushes (conventional), where the findings in the natural setting may not always be as expected from cage experiments. Furthermore, these methods have finally allowed for extension of the paradigmatic displacement experiments performed by Perdeck in 1958 on the short-distance, social migrant, the starling, to long-distance migrating storks and long-distance, non-socially migrating passerines providing new insights to nature of the migratory orientation system that enables experienced birds to navigate and guide inexperienced, young birds to their species-specific winter grounds.

***32.8*** TKINT, T.*; VERHEYEN, E.; ADRIAENS, D.; Evolutionary Morphology of Vertebrates, Ghent University, Ghent, Belgium , Royal Belgian Institute of Natural History, Brussels, Belgium; *Tim.tkint@Ugent.be*

***The implications of mouthbrooding on feeding performance of two closely related cichlid species***

The cichlids of the East African lakes are known for their rapid speciation and extensive morphological diversity. Most of that diversity is located in the head region and can be related to their trophic ecology. The heads of fishes are, however, so densely packed with structures performing different functions, that it can be expected that some of these functions may not be optimally exerted, especially when several functions are performed by the same apparatus. The oral apparatus, for example, not only plays a role in feeding and breathing, but also serves to incubate the eggs in many cichlid species. The aim of this study is to better understand the implications of mouth-brooding on the morphology and performance of the feeding apparatus, because we expect a trade-off between direct fitness (reproductive success) and indirect fitness (feeding performance). We also hypothesized that these implications depend on the dominant mode of feeding (suction vs biting), so we studied this trade-off for two species of maternal mouthbrooding cichlids: a ‘suction feeding’ *Haplochromis piceatus* and a ‘biting’ *H. sauvagei*. Comparing males, where the constraint of mouthbrooding is absent, to females may allow us to unravel this trade-off. A geometric morphometric analysis of external morphology showed clear interspecific and intersex differences. Functional characterization revealed that some aspects of feeding performance (e.g. theoretical bite force) do indeed show a trade-off with mouth-brooding capacity.

***70.4*** TOBALSKE, B.W.*; ROS, I.G.; HEDRICK, T.L.; WARRICK, D.R.; BIEWENER, A.A.; Univ. of Montana, Harvard Univ., Univ. of North Carolina, Chapel Hill, Oregon State Univ.; *bret.tobalske@mso.umt.edu*

***3D Skeletal Kinematics During Hovering in Hummingbirds***

The ability to sustain hovering in hummingbirds is attributed in part to their highly-derived wing morphology and use of an aerodynamically-active upstroke with supination of the wing. Aerodynamic measurements suggest that the upstroke produces less force than the downstroke, a consequence of wing twist perhaps due to constraints upon supination at the shoulder. Prior kinematic studies suggest that the wing is held “rigid” during the wingbeat cycle, without flexion and extension at the elbow and wrist. To better understand wing function, we measured 3D skeletal and external kinematics during hovering in ruby-throated hummingbirds (*Archilocus colubris*, N = 4, 3.3 g). We used a pair of fluoroscopes in combination with light cameras sampling at 1000 Hz. We observed significant flexion and extension, pronation and supination at each joint in the wing. Consistent with an early hypothesis from anatomical study, the majority of the movement of the leading edge of the wing could be accounted for by humeral rotation (45%), elevation and sweep (22%). Long axis rotations of 75, 15 and 90 degrees were observed for the humerus, forearm and wrist, respectively. During downstroke, the wing featured relatively little axial twist, and rotations originated predominantly from the humerus and antebrachium. During upstroke, supination increased with distance along the wing and mostly originated from rotation distal to the wrist. Axial twist in the external wing segment from the elbow to the wrist closely matched twist in the antebrachium, but we are unable at present to resolve how much twist beyond the wrist originated from the skeleton or the feathers. Periodicity in kinematic-chain residuals indicated feather bending occurs either due to inertial or aerodynamic loads. NSF Grants: IOS-0923606 & IOS-0744056

***24.6*** TOBIN, E.D.*; GRUNBAUM, D; CATTOLICO, R.A.; School of Oceanography, Univ. of Washington, Depart. of Biology. Univ. of Washington; *etobin@u.washington.edu*

***Cell motility, life stage transitions and cyst distribution of the harmful alga, Heterosigma akashiwo***

In many harmful algal blooming (HAB) species, transitions between a vegetative, motile phase in the water column and a dormant, non-motile cyst phase in the sediments regulate the timing and location of bloom events. Many HAB species use motility during vegetative growth to control depth and locate favorable parts of their environment. We hypothesized that HAB species have distinct swimming behaviors during pelagic-benthic transitions, and that these behaviors facilitate deposition of cysts in shallow locations where survival and re-emergence are likely. We used video-based tracking to quantify cell swimming behaviors of *H. akashiwo*, a harmful marine flagellate, during the transition into resting cells. Cells were induced into the resting stage by subjecting them to low temperature (10°C) and darkness for 14 days. Our tracking methods provide detailed characteristics of individual cell swimming behaviors, including directionality, total speed, mean vertical and horizontal velocities, and oscillatory speed, which we used to assess physiological state and changes in motility during pelagic-benthic transition. Cells exhibited distinct swimming characteristics during transition, which can be used to determine timing and location of cyst formation. We did not observe downward swimming or active habitat selection. A simple 2D estuary model suggests that swimming during pelagic-benthic transition does not alter contact rates with shallow sediments compared to passive sinking, and that passive transport by turbulent mixing may be the primary determinant of accumulation in sediments, and consequently, potential for future HABs.

***S11.6*** TOKIć, Grgur*; YUE, Dick K.P.; Massachusetts Institute of Technology; *yue@mit.edu*

***From optimized swimming performance to optimal body shapes***

We address the question of whether the body geometry and motion characteristic of fish can be deduced directly from mechanical and hydrodynamical considerations. The mechanics and fluid mechanics of fish swimming has been widely studied in recent years, from experimental as well as from the computational standpoint. Hydrodynamical studies have generally focused on the analysis of flow structures around the fish body and the implications those might have on swimming performance. Other studies have as their objective modeling of the fish body and motion from structural/mechanical aspects. Dynamical studies have also been made to model the motion of the fish for given neural activations of the muscles. In these studies, however, the body shape and/or the motion are generally always prescribed. Our interest is in the inverse problem, namely whether the consideration of some notion of optimality in terms of the hydrodynamics, structural mechanics and muscular behavior may lead to specific "optimal" body shapes and swimming characteristics. Of significant obvious interest, of course, is whether such mechanically deduced shapes and characteristics are indeed observable in nature; and in some sense, therefore, not to answer how fish swim, but to possibly answer why they look and swim the way they do. To answer this question, we build an integrated model for fish swimming and combine the model with select performance objectives to find optimal "designs" in terms of morphological parameters relevant for locomotion. Our results show that the body shapes and motions obtained, as a consequence of optimization based on the swimming performance, in many cases offer strong resemblance to those of undulatory swimming organisms observed in nature.

***1.3*** TOMANEK, L.*; ZUZOW, M.; California Polytechnic State Univ.; *ltomanek@calpoly.edu*

***The proteomic response of Mytilus galloprovincialis and M. trossulus to acute temperature stress***

The Mediterranean blue mussel species *Mytilus galloprovincialis* has invaded southern California at the beginning of the last century and has since replaced the native *M. trossulus* from its southern range. Previous work has shown that *M. galloprovincialis* is the more heat tolerant of the congeners and has suggested that differences in temperature tolerance and increasing temperatures due to climate change drive the range expansion. By comparing the proteomic response of the two congeners in response to heat stress we were aiming to better understand the molecular underpinnings of differences in temperature tolerance and to discover indicators of the metabolic costs of heat stress. After acclimation to 11ºC for four weeks we incubated whole mussels gradually to 24ºC, 28ºC and 32ºC for 1 h. Mussels were brought back to 11ºC to recover for 24 h. Using two-dimensional gel electrophoresis and tandem mass spectrometry, we separated the proteins of gill tissue and analyzed the resulting gel images to quantify and identify proteins that changed significantly with heat stress. Of the more than 500 protein spots we detected, 28% changed expression in *M. trossulus* but only 14% in *M. galloprovincialis*. Several heat shock protein 70 (Hsp70) and small Hsp isoforms were induced at a lower temperature in the more heat sensitive *M. trossulus*. Changes in a number of metabolic enzymes suggest that gill cells are requiring an increasing amount of reducing equivalents in form of NADH with heat stress, most likely due to the generation of reactive oxygen species. However, the thermal limits of expression of oxidative stress proteins are lower in the heat sensitive *M. trossulus* in comparison to *M. galloprovincialis*, possibly setting the thermal limits to acute heat stress in these two congeners.

***12.4*** TOOMEY, M.B.*; BUTLER, M.W.; MCGRAW, K.J.; Arizona State University; *matthew.toomey@asu.edu*

***Long-term immune system activation depletes carotenoids from retina of house finches (Carpodacus mexicanus)***

The costs of developing, maintaining, and activating the immune system have been cited as an important force shaping life history evolution and maintaining the honesty of sexually selected signals. Immune activation requires energy, nutrients, and time that might otherwise be devoted to other life-history components like reproduction. Carotenoid pigments in animals provide a unique opportunity to track the costs of immune activation, because they are dietarily derived, modulate the immune system, and are used in sexually selected signals of quality. In several bird species, carotenoid supplementation enhances health, and immune activation depletes carotenoid levels in circulation and colorful ornaments. Carotenoids also accumulate in the retinas of birds, where they tune spectral sensitivity and provide photoprotection. If carotenoid accumulation in the retina follows the patterns of other tissues, then immune activation may deplete retinal levels impacting visual health and function. To test this hypothesis, we challenged molting wild-caught captive house finches (*Carpodacus mexicanus*) with weekly injections of lipopolysaccharide and phytohaemagglutinin over an eight-week period. Immunostimulated adult males and females produced significant antibody responses and molted slower than uninjected control birds. After eight weeks, immune-challenged birds had significantly lower levels of two major retinal carotenoid types (galloxanthin and zeaxanthin), but there were no significant differences in the plasma or liver carotenoid levels between the treatment groups. These results indicate that immune activation depletes retinal carotenoids, which may compromise visual health and performance representing an additional cost of immune activation.

***35.2*** TRACY, CR*; FORISTER, M; HAGERTY, B; SANDMEIER, F; SIMANDLE, E; NOLES, P; BECK, M; FISHER, R; University of Nevada Reno, Paul Smiths University, USGS Western Region; *dtracy@biodiversity.unr.edu*

***Phylogeny and phylogeography of western toads in the western Great Basin***

Western toads (Anaxyrus boreas group) are diverse and remarkably understudied, and in the Great Basin, Western Toads often have been isolated for many thousands of years. We used morphology and DNA markers to study toad populations in Nevada, southeastern Oregon, and California. Our analyses indicate that several isolated populations in central Nevada should be recognized as new species. A new population of A. exsul was discovered in the White Mountains of Nevada. A. canorus in the Sierra Nevada Mountains are clearly polyphyletic. The status of A. nelsoni as a species separate from A. halophilus is obscure. However, populations of Western Toads in discontinuous habitats (e.g., springs and isolated stretches of rivers) in the Great Basin are nearly all very highly differentiated, and many should be treated minimally distinct population segments for the purpose of conservation, and most are incipient species by some definitions of species.

***66.3*** TRAYLOR-KNOWLES, N.*; REITZEL, A.M.; FINNERTY, J. R. ; Boston University, Woods Hole Oceanographic Institute; *ntk17@Bu.edu*

***Identification and expression of genes for sex determination in the starlet sea anemone, Nematostella vectensis***

Sex determination in some animals is patterned by differential expression of transcription factors from the two gene families, DM-domain family and the Sox family. Throughout bilaterians the DM-domain genes, including doublesex in *Drosophila melanogaster*, Mab-3 from *Caenorhabditis elegans* and DMRT in vertebrates, are primarily involved in differentiation of male-specific characters. Sry, a member of the Sox family, is a critical gene for male specification in mammals. Genetic mechanisms for sex determination in early diverging animals (e.g., cnidarians, sponges) are unknown. Elucidating these molecular pathways will provide the necessary information for ascertaining conserved aspects of sex determination throughout animals and when these mechanisms likely evolved. Previously, a single DM domain containing gene was found in *Acropora millepora*, but the role of these transcripts in sex determination could not be elucidated due to the hermaphroditic nature of this coral.We have utilized the emerging model cnidarian *Nematostella vectensis* to identify and study expression of candidate genes involved in sex determination. Through a combination of similarity searches of the *Nematostella* genome and phylogenetic methods, we identified 6 distinct DM domain containing genes and one Sry-like gene. We characterized differential expression patterns of *Nematostella* DM-containing and the Sry-like genes using quantitative PCR and in situ hybridization. Our results show that due to the separate sex nature of *Nematostella* and the presence of these genes, this cnidarian will serve as a valuable model in understanding the evolution of sex determination.

***12.1*** TSAI, H.P.*; OWERKOWICZ, T.; SANCHEZ, L.; FELBINGER, K.; ANDRADE, F.; BLANK, J.M.; EME, J.; GWALTHNEY, J.; HICKS, J.W.; Univ. of California, Irvine; *hptsai@uci.edu*

***Exhaustive terrestrial and aquatic exercise does not affect periosteal deposition, structural properties or mineral content in limb bones of the American alligator***

Effects of exercise on skeletal growth and remodelling have been studied in a variety of mammals and birds, but exercise effects on bone microstructure in reptiles have received scant attention. We investigated the effects of long-term exercise on a motorized treadmill or in a flume on limb bones of the American alligator (Alligator mississippiensis). This allowed us to separate biomechanic and metabolic effects of exercise on bone - whereas terrestrial exercise increases both limb bone loading and metabolic rate, aquatic exercise increases only the latter. Juvenile female alligators were run or swum to exhaustion every other day for 17 months, and received fluorescent dye injections to determine bone deposition rates. We found no significant differences in whole bone morphology and cortical bone deposition rates in the alligator humeral or femoral midshaft, regardless of exercise regimen. Similarly, we found no effects of either exercise regimen on trabecular bone tissue density, number or thickness in the distal femur. In addition, bone mineral content was similar across exercise groups. Altogether, this suggests that long-term exercise has no discernible effect on bone microstructure in alligators. These results stand in contrast to studies on endothermic vertebrates. The disparity could be due to metabolic differences between ectothermic and endothermic vertebrates. An alternative explanation is that alligator limb bones are subjected to insufficient strain levels or load cycles during exercise bouts, which may account for lack of bone tissue response to exercise in alligators. Funded by the NSF IOB 04445680 to JWH.

***S5.9*** TSENG, A*; LEVIN, M; Tufts University; *aisun.tseng@tufts.edu*

***Bioelectric Events and Vertebrate Appendage Regeneration***

It has long been known that bioelectrical events play a causal role in vertebrate appendage regeneration. However, the underlying mechanisms have only recently begun to be revealed using the anuran frog, *Xenopus laevis*. *Xenopus* is able to regenerate its tail during development. The tail is a complex organ containing multiple cell types including muscle, nerve, spinal cord, and vasculature. After tail amputation, wound healing occurs by epithelial cell migration and is normally completed by 6 hours post amputation (hpa). By 24 hpa, a swelling called the regeneration bud is observed at the injury site and contains progenitors cells. Notably, amputated tails will regenerate fully with 7 days. A critical early event required for the initiation of tail regeneration is the activity of the proton pump, V-ATPase, which is expressed by 6 hpa (Adams et. al, 2007). A second ion transporter, a voltage-gated sodium channel (Nav1.2), is also required for the initiation of regeneration. Nav1.2 expression is dependent upon V-ATPase activity. In turn, Nav1.2 regulates the expression of genes (including Notch and Msx1) that drive regenerative outgrowth and patterning. Moreover, the regenerative process appears to directly respond to changes in the physiological state of the regeneration bud (i.e. changes in intracellular ion concentrations), and can bypass the requirement for ion channel activity. In fact, the pharmacological induction of a brief, transient sodium current into the regeneration bud after tail amputation is sufficient to restore full regeneration of the tail during the refractory period (an endogenous developmental period when regeneration is blocked). Thus modulation of ion transport is a key mechanism for controlling regeneration, and suggests that regulation of ion flows could represent an exciting new approach to tissue repair in mammals.

***9.4*** TURNER, KR*; SEBENS, KP; Univ. of Washington; *krturner@u.washington.edu*

***Indirect effects of marine protected areas on early community development in the San Juan Islands, WA***

Marine protected areas (MPAs) can be effective tools to aid the recovery of harvested species, but can also influence non-targeted species. In areas where top predators are protected, other species may decrease or increase in abundance due to direct and indirect interactions. To determine the effects of protected predatory fishes on the recruitment of sessile invertebrates, we affixed settlement plates to gently sloping solid bedrock substrate at approximately 21 m depth at two MPAs in the San Juan Islands, WA, known to have increased predator (lingcod, *Ophiodon elongatus*, and copper rockfish, *Sebastes caurinus*) abundance, and at two non-protected locations. Predation pressure was manipulated using four treatments: large-mesh cages, small-mesh cages, no cage, and a cage control. These treatments were designed to quantify the influence of different predator size classes on recruiting organisms, and how these effects change in MPAs. The plates were collected after 11 months, and non-metric multidimensional scaling was used to compare recruit communities. Location had the largest effect on community structure, an effect dominated by the abundance and identity of encrusting bryozoans. This clustering may be due to location-specific differences in the benthic community, as larvae of these bryozoans settle within hours of release. However, cage type may explain differences in communities within some of the locations, resulting in differential consumption of foliose red algae on caged and uncaged plates. These results are discussed in the context of trophic webs in the San Juan Islands, how these webs may be affected by MPAs, and our plans for the extension of this research.

***S11.7*** TYTELL, E.D.*; BORAZJANI, I.; LAUDER, G.V.; SOTIROPOULOS, F.; University of Maryland, College Park, St. Anthony Falls Laboratory, University of Minnesota, Harvard University; *tytell@umd.edu*

***Separating the effects of swimming mode and body shape in undulatory swimming***

Fish body shape and swimming mode are generally correlated. Slender-bodied fishes such as eels, lampreys, and many sharks tend to swim in the anguilliform mode, in which most of the body undulates at high amplitude. Fishes with broad tails and a narrow caudal peduncle, in contrast, tend to swim in the carangiform mode, in which only the tail undulates at high amplitude. Such fishes also tend to have different wake structures. Carangiform swimmers generally produce two staggered vortices per tail beat and a strong downstream jet, while anguilliform swimmers produce two pairs of vortices per tail beat and relatively little downstream flow. Are these differences a result of the swimming modes or the body shapes, or both? We present experimental results from a robotic flapping fin, along with data from swimming eels (anguilliform), bluegill sunfish (carangiform), and rainbow trout (subcarangiform), which indicate that the kinematic differences are small, and show strongly three-dimensional flow. Mackerel and lamprey swimming was also simulated computationally with realistic body shapes and both swimming modes: the normal carangiform mackerel and anguilliform lamprey, then an anguilliform mackerel and carangiform lamprey. Both experimental and computational results indicate that anguilliform swimmers are more efficient at lower swimming speeds, while carangiform swimmers are more efficient at high speed. Simulated wakes depended strongly on Strouhal number, but were largely unaffected by body shape or swimming mode. The differences between computational and experimental results may lie in a subtle interaction of Strouhal and Reynolds number, and potentially in the effect of body flexibility.

***87.6*** UPTON, K. R.*; RILEY, L.G.; California State Univ., Fresno; *kelliupton@csufresno.edu*

***Neuroendocrine Regulation of Decreased Food Intake During Acute Stress in the Tilapia, Oreochromis mossambicus***

Food intake results from a set of complex neuroendocrine signals that integrate external stimuli with the internal milieu of the animal. Ghrelin – a novel gut hormone – is known to stimulate appetite whose actions are mediated by neuropeptide Y (NPY) in the hypothalamus. Further, the ghrelin receptor (growth hormone secretagogue receptor: GHS-R) has been shown to be located on NPY-containing neurons. In several teleosts species, a decrease in food intake following an acute stress has been observed. However, the neuroendocrine mechanism controlling the reduction in food intake during stress has yet to be determined. This study was designed to investigate the effect of an acute stress on food intake and brain expression of NPY, ghrelin and GHS-R in the tilapia (*Oreochromis mossambicus*). After a 30 min crowding and handling stress, fish were fed for 1 h after which time food intake was determined. An acute stress significantly reduced food intake when compared to control fish. In a second group of animals, tissue samples were collected immediately following the stressor. Hypothalamic mRNA levels of NPY and ghrelin were significantly reduced, while GHS-R mRNA levels were significantly elevated. Conversely, in the telencephalon-preoptic area NPY, ghrelin and GHS-R mRNA levels were significantly elevated. The results indicate that decreased food intake following an acute stress is mediated by suppressed mRNA levels of NPY and ghrelin in the hypothalamus. Further, our findings suggest that ghrelin and NPY are differentially regulated in different regions of the brain during stress suggesting that these hormones exhibit multiple regulatory functions related to overall metabolism. This work was supported by the National Science Foundation (IOS-0639771) awarded to LGR.

***76.6*** URANO, Akihisa; Hokkaido Uiversity, Sapporo, Japan; *aurano@sci.hokudai.ac.jp*
***Neuroendocrine bases of spawning migration in chum salmon***
Chum salmon of Japanese stock spend several years to grow and mature in the summer Bering Sea and the winter Gulf of Alaska, and then home their natal rivers over thousands of kilometers for spawning. Since the control of such migratory behavior includes neural and endocrine, or neuroendocrine mechanisms, we tried to accumulate confirmable evidence along two working hypothesis: 1) dual controls by neuroendocrine neurons of the nervous and endocrine systems are crucial, and 2) transition from regulation of growth to that of reproduction is involved in the onset of homing. Information on the latter is particularly important to realize "when, where and how salmon initiate homing or spawning migration". Since transcription of genes was considered to precede physiological events, we focused to determine the exact amounts of hormonal mRNAs and assessed the changes in magnitudes of gene expression. Liquid nitrogen-frozen brain and pituitary samples of oceanic fish were repeatedly collected through several research cruises. In terms of the first working hypothesis, anatomical and physiological evidence showed importance of the GnRH neuronal system. GnRH neurons multiply project to various brain loci and the neurohypophysis, indicating dual controls of the nervous and endocrine systems. In terms of the second working hypothesis, IGF-I is considered to initiate gonadal development in the winter Gulf of Alaska. Since expression of GnRH gene was also high in fish which started sexual maturation, interaction of the brain GnRH system and the somatic IGF-I system may be important for the control of homing migration.

***66.5*** URTON, J.R.*; BRUNER, A.M.; MCCANN, S.R.; BALCELLS, R.; PEICHEL, C.L.; Fred Hutchinson Cancer Research Center; *cpeichel@fhcrc.org*
***The Evolution of Sex Determination in Stickleback Fishes***
Sex determination is critical to an individual's fitness. But, the initial sex determination signal and sex chromosomes can vary between closely related species. To understand this evolutionary process, it is important to study closely related species with different sex chromosomes and sex determination signals. In the stickleback family (Gasterosteidae), at least five sex chromosome systems have evolved in the last 35 million years. It is possible that each stickleback species has evolved a different sex determination gene. Alternatively, all sticklebacks could share the same sex determination gene, which has been transposed to different sex chromosomes. To address these possibilities, we must identify the sex determination gene in each species. We are starting our search in the threespine stickleback (*Gasterosteus aculeatus*), which has an XX-XY sex chromosome system and numerous genetic and genomic tools available. Our past genetic mapping approaches to find the threespine stickleback sex determination gene have not proved feasible. Thus, we are using a Solexa/RNA-Seq approach to identify transcripts present at the earliest stage of male gonadal differentiation. We will identify X and Y chromosome genes that are expressed during this developmental period and screen candidate genes using a transgenic assay to see if expression in female (XX) embryos causes male phenotypic development. Once we identify the threespine stickleback sex determination gene, we can see if this gene is present in other stickleback species, and ultimately gain insight into the evolution of sex determination pathways in this family.

***51.4*** VALENCAK, TG*; RUF, T; University of Veterinary Medicine Vienna; *teresa.valencak@vetmeduni.ac.at*
***Dietary n-3 and n-6 polyunsaturated fatty acid supplementation alters heart phospholipid composition but does not affect lifespan***
Smaller mammals such as mice possess tissues containing more polyunsaturated fatty acids (PUFAs) while at the same time living shorter lives. These relationships have been combined in the 'membrane pacemaker hypothesis of aging', a recent extension of the widely accepted 'oxidative stress' hypothesis of aging. It suggests that membrane PUFA content might determine an animal's lifespan. PUFAs in general, and certain long chain PUFAs in particular, are very prone to lipid peroxidation, which brings about a high rate of reactive oxygen species (ROS) production. We hypothesized that dietary supplementation of either n-3 or n-6 PUFAs might affect i) heart phospholipid composition and ii) lifespan of the animals because of the altered membrane composition and the thereby affected lipid peroxidation processes. Therefore, we kept 40 female laboratory mice from the C57BL/6 strain on three different diets (n-3 PUFA rich, n-6 PUFA rich, control) and assessed body weights, lifespan and heart phospholipid composition after the animals had died. We found that while heart phospholipid composition clearly differed between feeding groups, no influence on lifespan was detected. When relating certain fatty acid classes to the longevity of the mice however, we observed that the content of monounsaturated fatty acids was positively linked to lifespan. In other words, the eldest mice had the highest content of monounsaturated fatty acids in their heart phospholipids. We conclude that our dietary intervention, the addition of either n-3 or n-6 PUFAs did not affect lifespan of the animals. However, membrane phospholipid content of monounsaturated fatty acids was clearly related to longevity of the mice. Thus, further studies are needed to assess the role of monosaturated fatty acids on lifespan.

***84.5*** VAN DER MEIJDEN, A.*; SOUSA, P.; HARRIS, D.J.; CIBIO, University of Porto; *frog@arievandermeijden.nl*
***A comparative look at the defensive complex of scorpions.***
The two key features of the time-tested body plan of scorpions are the pinchers (chelae), and the stinger (telson). Scorpion chelae and telson functionally overlap in defense and subjugation of prey, and therefore provide an excellent but mostly unexplored system for the study of functional trade-offs. We present an exploratory analysis of the variation in the morphology and performance of these two systems. The chelae are multifunctional structures serving in prey capture, defense, courtship and mating, burrowing, climbing and serve as a platform for many sensory organs. In a broad sampling over several families, pinch force is highly correlated with chela height, similar to findings in crabs, whereas the aspect ratio of chela height to length even better explains the observed differences in pinch force. The shape of chelae across the scorpionidae is further explored in this light. The metasoma ("tail", actually a continuation of the body) carries the telson. High variability in metasoma shape and size is well known within the scorpionidae, in some cases related to specialized aspects of their behavior and biology. We provide the first data on the performance of the metasoma in defensive venom delivery.

***81.6*** VAN DYKE, J/U*; BEAUPRE, S/J; PLUMMER, M/V; University of Arkansas, Harding University; *juvandy@uark.edu*
***Examination of Residual Yolk Utilization in Hatchling Smooth Softshell Turtles, Apalone mutica***
Sufficient postnatal provisioning is presumed critical for survival before neonate animals successfully forage. While parents do not feed offspring in most lineages, nearly all lecithotrophic vertebrates retain a residual portion of yolk which was not used during embryogenesis. Hypothesized uses of residual yolk are diverse and include postnatal development, catabolic fuel for nest emergence, and nutritional sustenance for maintenance, activity, or hibernation. However, few studies have tested hypothetical uses of residual yolk and our understanding of consequences of different uses remains limited. We investigated the ability of unfed hatchling Smooth Softshell Turtles (*Apalone mutica*) to allocate residual yolk to postnatal growth, and determined whether residual yolk served as a significant energy source for nest emergence. We also tested whether yolk catabolism contributed to neonatal metabolic rate. Comparisons of growth trajectories between control and yolkectomized turtles were not significantly different. Both treatments exhibited 100% survival rates until residual yolk was absorbed in control turtles. Shell size and wet mass increased significantly after hatching in all treatments, but dry mass did not. Comparisons of crude protein and crude fat content between freshly laid egg yolk and residual yolk were not different. Metabolic rates of control and yolkectomized turtles were not significantly different. Nest emergence did not significantly reduce residual yolk dry mass. In summary, post-hatch growth in mass and shell size appear to be dependent on water uptake rather than residual yolk. Short-term survival was not dependent on residual yolk, and residual yolk did not fuel nest emergence activity. Our results suggest that residual yolk does not fulfill many of the hypothetical uses of postnatal provisioning in *A. mutica*.

***45.7*** VAN GRIETHUIJSEN, L.I*; TRIMMER, B.A.; Tufts University; *linnea.van_griethuijsen@tufts.edu*
***Anticipation of obstacles in soft bodied terrestrial locomotion***
Animals moving in complex environments must identify objects in their path and know the relative position of the object to their limbs. For soft bodied locomotion this is a particularly difficult problem because tissues can deform and proprioceptive information may not predict body position. In the absence of remote sensing such as vision or sonar, objects must be detected by touch. Object avoidance could be achieved by gathering mechanosensory information in leading parts of the body and then using it to adjust movements in the following limbs. Another strategy is to respond directly to local touch without any need for anticipation. *Manduca sexta* caterpillars can negotiate small objects in their path by stepping on top of them. During such a step, the maximum upward velocity of the approaching leg in the first quartile of the swing phase was much higher than that of a normal step (45 trials from 5 animals. Max. y velocity: obstacle: 0.25 cm/s, step: 0.12 cm/s, $p<0.0001$), indicating that information about the upcoming obstacle was present. In some cases, when the proleg was further away from the obstacle at lift off, there was a second velocity peak during the later part of the swing phase. The distance from the obstacle at which this adjustment occurred was significantly reduced when the sensory hairs on the prolegs were experimentally cut short (0.21 cm in intact animals (45 trials), 0.18 cm short-hair animals (58 trials), $p=0.043$). In this subset of the data, the first peak of upward velocity was still significantly higher than in a normal step both in intact ($p=0.001$) and short-hair animals ($p<0.0001$). These results suggest that *Manduca* can use intersegmental information to anticipate objects and that it also fine-tunes movements using local touch sensors.

***30.5*** VAN MAURIK, L.N.*; WORTHAM, J.L.; MCRAE, M.G.; University of Tampa, FL; *Lvanmaurik@ut.edu*
***The Setal Patch of a Macrobrachium Shrimp: Grooming function, a Sexual dimorphism, or our Black box?***
Many crustaceans expend a great amount of time grooming and decreasing fouling. Grooming behaviors include cleaning of structures used in chemoreception, respiration (gills), reproduction, feeding, and general cleaning of the body. The Hawaiian river shrimp, *Macrobrachium grandimanus*, migrates between freshwater and marine habitats and is exposed to environmental pressures that may increase the need for grooming. This species has a dense “setal patch” found on the larger cheliped that may be useful in grooming behaviors. There have been no behavioral or functional morphology studies on this species. The frequency and duration of all grooming behaviors for *M. grandimanus* were documented during thirty minute time periods (N=62) or 24-hr continual observation periods (N=32). Morphometric analyses were also conducted to determine if differences existed between sexes and size classes with respect to the size and structure of the chelipeds. Microscopic imaging was used to elucidate possible functions of the setal patch. *M. grandimanus* had a large time budget for grooming when compared to other crustaceans. Males and females differed in their grooming behaviors. The body regions groomed most frequently were the antennae and antennules while their sub-carapace region was groomed the most in terms of time; the “setal patch” was rarely groomed and never involved as a grooming appendage. The two main grooming appendages used were the third maxilliped and the first pereiopod, not the “setal patch” cheliped. Based on morphometric measurements, four different chela morphotypes were classified. The “setal patch” does not appear to have a function related to grooming.

***57.4*** VAN TRUMP, WJ*; COOMBS, S; DUNCAN, K; MCHENRY, MJ; Univ. of California, Irvine, Bowling Green State University; *wvantrum@uci.edu*
***A hammer, not a scalpel: gentamicin ablates all hair cells in the lateral line system.***
Aminoglycoside antibiotics have been used to ablate lateral line hair cells to test the role of this sensory system in the behavior of fish. Studies assessing hair cell damage with SEM have suggested that one of these antibiotics, gentamicin, is toxic to hair cells in one class of lateral line receptor (canal neuromasts), but not the other (superficial neuromasts). This selective toxicity provided the basis for the use of gentamicin as a tool to evaluate the individual roles of the two receptor classes in behavior. The present study investigated the effects of gentamicin on lateral line hair cells in vivo for the first time. This was done using florescent vital dyes (DASPEI and FM1-43), which label functioning hair cells. Contrary to the findings of SEM studies, we found that gentamicin disrupts hair cell function in both receptor classes. Furthermore, by labeling hair cells prior to gentamicin exposure we can conclude that this damage must at least partially be attributed to cell death. These findings were simultaneously discovered in two independent labs working with zebrafish (*Danio rerio*) and Mexican blind cave fish (*Astyanax fasciatus*). Our results suggest that gentamicin cannot selectively block classes of lateral line receptors. In light of this result, we have re-evaluated the results of numerous behavioral studies to develop a new view of the role of the lateral line system in fish behavior.

***63.7*** VAN UITREGT, V.O.*; HURST, T.P.; WILSON, R.S.; The University of Queensland, Queensland Institute of Medical Research; *v.vanuitregt@uq.edu.au*

***The evolution and thermal dependence of inducible defences in mosquito larvae.***

Temperature profoundly influences the reaction rates and efficiency of all physiological systems. During predator-prey interactions we often expect temperature to directly influence the locomotor capabilities of both predator and prey, and thus alter the dynamics of the system. However, predation is seldom just a simple game of 'cat and mouse'. Prey can induce behavioural and morphological defenses that increase their chances of escape and survival. Prey can commonly achieve this by reducing their activity and making themselves less conspicuous to predators. However, reducing activity constrains total foraging time and can lead to substantial energetic costs. For ectothermic prey, increases in temperature could magnify these costs by increasing total metabolic demands. We tested this idea by examining the effect of temperature on the costs of behavioural responses to predators in mosquito larvae. Larvae of the urban mosquito *Aedes notoscriptus* avoid predation by reducing activity. Our previous research has shown that the response is indeed costly, retarding growth and development and manifesting smaller adults that have a shorter adult lifespan when not fed. We expect these costs to be exacerbated in larvae reared at higher temperatures or, larvae will trade-off the increased costs by limiting their behavioural response at warmer temperatures. This study provides an examination of the influence of temperature on the costs of inducible defences in prey and provides insight into the subtle effects of the thermal environment on ecosystem dynamics.

***90.5*** VAN VALKENBURGH, Blaire*; SAMUELS, Josh/X; BIRD, Deborah; MEACHEN-SAMUELS, Julie; Univ. of California, Los Angeles; *bvanval@ucla.edu*

***Respiratory and Olfactory Turbinate Dimensions in Aquatic and Terrestrial Carnivorans***

The mammalian nose contains an extensive set of scroll-like, paper-thin bones known as turbinates (or turbinals). The turbinates are a fundamental feature of the class Mammalia and key to two of their hallmark features, endothermy and olfaction, and yet we know relatively little about their anatomy and function. We used high-resolution CT scan data to quantitatively analyze turbinate structure and scaling in a wide range of carnivorans. Measurements include nasal cavity volume, respiratory, and olfactory turbinate surface areas. The varying thermoregulatory, locomotor, and olfactory demands among living carnivorans suggest that species with differing ecologies should have different turbinate dimensions. For example marine species are expected to have enhanced respiratory surface area in response to greater demands for heat and water conservation. A comparison of aquatic and terrestrial species in four families (Ursidae, Mustelidae, Otariidae, and Phocidae) reveals that aquatic species (both freshwater and marine) exhibit reduced olfactory surface areas and greatly expanded respiratory surface areas. The one exception is the extinct, tropical Caribbean monk seal ( *Monachus tropicalis* ) that has a respiratory surface area similar to that of terrestrial species. This, and the fact that the river otter ( *Lontra canadensis*), a species with ready access to drinking water, has expanded respiratory surface area, suggest that the primary function of the respiratory turbinates is heat rather than water conservation in both the aquatic piinipeds and mustelids.

***S2.2*** VAN VOORHIES, W.A.*; GOTTSCHLING, D.E.; New Mexico State University, Fred Hutchinson Cancer Research Center; *wvanvoor@nmsu.edu*

***Metabolic Function and Aging in Yeast***

The most widely proposed mechanistic explanation for the aging process links the production of free-radicals and other oxidants produced during aerobic respiration to biomolecular damage that results in aging. While the scientific origins of this concept extends back nearly 100 years, considerable controversy currently exists regarding the importance of metabolic rate to longevity. We are pursing another potential explanation for aging-the increase in genomic instability that occurs during aging. This phenomenon has been most extensively characterized in the budding yeast, Saccharomyces cerevisiae, in which there is a large increase in the rate at which genetic heterozygosity is lost in the daughter cells of aging mother cells. Recent research indicates that the age-induced increase in genomic instability may be caused by defects in the biogenesis of iron sulfur clusters (ISC) in the mitochondria. These defects produce cells that are unable to carry-out oxidative phosphorylation because of damage to mitochondrial DNA. This mitochondrial dysfunction may lead to increased rates of genomic instability and a loss of respiratory capacity. Yeast cells in this state experience a crisis in which they show reduced growth rates, high rates of cell cycle arrest, and an increase in nuclear genome instability. This is thought to be caused by a reduction in the mitochondrial inner membrane potential which causes defects in molecular transport into and out of the mitochondria, affecting ISC biogenesis. We will present the results of experiments in which we track the localization of fluorescently labeled ISC proteins for yeast grown on different metabolic substrates and as cells recover from the metabolic crisis induced by a loss of mitochondrial DNA. Additionally we will discuss the affects of mutations in ISC proteins on yeast metabolic function.

***50.2*** VAN WASSENBERGH, S.*; ROOS, G.; AERTS, P.; Univ. Antwerpen, Antwerpen; *sam.vanwassenbergh@ua.ac.be*

***The head-down posture of seahorses: an adaptation for pivot feeding?***

Syngnathid fishes capture prey by rotating their head quickly towards prey, and subsequently sucking it into their snout. Previous studies showed that head pivoting is driven by elastic recoil of the epaxial muscle tendons. However, not only the head moves during pivot feeding in syngnathids: the head pushes off against the anterior part of the trunk, which is displaced in the opposite direction. Since the position of the trunk relative to the head is unique (for a fish) in some species of Syngnathidae (e.g. seahorses, seadragons), this could have consequences (or even be an adaptation) for pivot feeding. To study the effects of several mechanical characteristics of the head and trunk during pivot feeding, a forward dynamic model of a pipefish (closely resembling the ancestral condition) and a seahorse (phylogenetically most derived condition) was developed using Matlab-Simulink. In all simulations, an equal amount of elastic energy is released to actuate the joint between head and trunk. Increasing the pipefish's head-to-trunk orientation from parallel to perpendicular changes the path traveled by the mouth to become more distant from the initial location of the eyes, which increases the volume of water around the eye in which the synganthid fish can strike at prey. In addition, the head-to-body angle of our seahorse model appeared to be optimized for this variable (eye to prey distance), which could imply that the head-to-body posture of seahorses may have evolved for this purpose.

***55.6*** VANCE, Jason T.*; HUMBERT, J. Sean; University of Maryland, College Park; *jvance@umd.edu*
***Mechanisms of gust rejection in the honey bee, Apis mellifera***
Insects' ability to vary aerodynamic force production impacts flight-dependent behaviors, whether in response to task-specific demands such as load carriage, or in response to their dynamic and heterogeneous environments, such as turbulence and transient gusts of wind. The purpose of this study is to characterize the kinematic and aerodynamic mechanisms used by insects to reject gusts of wind. Honey bee foragers were flown in a clear, acrylic chamber and were perturbed with a low-pressure burst of compressed air to simulate a lateral wind gust. Body and wing kinematics were analyzed from flight sequences, recorded using three high-speed (6006 fps) digital video cameras. Here, we present bees' response to lateral gusts that caused body rotation about the roll axis. To arrest the 'gust-induced' body roll, bees asymmetrically varied stroke amplitude, angle of attack, and lift between the right and left wings to generate a counter-torque and, subsequently, a 'response-induced' body roll in the opposite direction. These asymmetric wing strokes continued as body roll approached a horizontal orientation. However, this 'response-induced' body roll overshoots horizontal in a pendulum-like fashion; symmetric wing stroke kinematics were then employed throughout the following reversal in body roll and return to the horizontal roll orientation. Bees also extended their legs and increased their body angle (pitch axis) throughout the gust response, which increased inertia about the roll axis. These results suggest that gust rejection depends on a combination of mechanisms: an active phase characterized by the modulation of aerodynamic forces in direct response to the perturbation; and, a passive phase consisting of aerodynamic damping and inertial stabilization.

***39.3*** VANDENBROOKS, John M.*; HARRISON, Jon F.; Arizona State University; *jvandenb@asu.edu*
***Atmospheric Oxygen Influences on the Size of Modern and Fossil Insects***
Recent modeling has estimated that over the last 500 million years atmospheric oxygen has varied from as low as 12% in the Triassic to as high as 31% in the Permian. While there have been many hypotheses linking oxygen variation to evolutionary events (i.e. insect gigantism, extinctions, and dispersals), the majority of evidence is correlational. To test the effects of oxygen on physiology and evolution and move from correlation to causation, we have reared a wide variety of insects under historical oxygen levels including beetles, cockroaches, moths, fruitflies, grasshoppers and dragonflies. What has become evident is the wide diversity of responses of insect body size to variation in rearing oxygen. While the majority of species show decreased body sizes in hypoxia, the responses to hyperoxia are quite variable. For example, the body size of *Schistocerca* grasshoppers were unaffected by hyperoxia, while *Blatella* cockroaches were progressively smaller with hyperoxia. *Manduca* moths showed no effect of mild hyperoxia, but were smaller at high levels of hyperoxia, yet *Zophobas* beetles showed increased body sizes under hyperoxia up to a threshold value beyond which they decreased in size. Throughout all the species, atmospheric oxygen affected not just maximum body size, but also strongly influenced average body size. When we begin to examine the fossil record, we also see that certain groups have responded more strongly to historical variation in oxygen. While taxa such as *Protodonata*, *Paleodictyoptera*, and *Arthropleura* exhibited gigantism, *Blattodea* show little variation in maximum size, but do show shifts in average size. Here we examine the differential responses in modern organisms and the implications for the fossil record. This research was supported by NSF EAR 0746352 and DOD 3000654843 subcontract to JFH.

***S3.6*** VAUGHN, D.*; ALLEN, J.D.; Univ. of Washington, Friday Harbor Laboratories, College of William and Mary; *dvaughn@u.washington.edu*
***The peril of the plankton***
The pelagic environment is characterized by unevenly distributed resources and risks. Such unpredictability presents adaptive challenges to diverse planktonic organisms including the larvae of benthic invertebrates. Estimates of mortality during planktonic development are highly variable, ranging from 2% to 100% per day. Predation is considered a significant source of this mortality, but what explains the variability in estimates of the mortality of marine invertebrate larvae? While differential exposure of larval prey to predators may explain these widely variable estimates, adaptations that reduce vulnerability of marine larvae to predators may also be important. Although there are excellent reviews of larval mortality, predation and defenses, nearly 15 years have elapsed since the topic was formally reviewed. In this talk, we will highlight recent advances in understanding the behavioral, chemical and morphological defenses that larvae possess and assess their effectiveness in reducing predation risk. While recent work confirms that larval mortality is generally high, it also demonstrates that larvae can reduce their risk of predation in several ways including 1) temporarily escaping the benthos during vulnerable early stages, 2) producing chemical compounds that reduce palatability, 3) possessing morphological defenses such as spines and shells, and 4) exhibiting induced defensive responses whereby larvae can alter their behavior, morphology and life histories in the presence of predators. Taken together, these studies indicate that marine larvae are not hapless victims but instead possess a sophisticated suite of defensive phenotypes that have allowed them to persist in the life cycle of benthic invertebrates for eons.

***16.5*** VELASQUEZ-CARVAJAL, D.*; SHERARD, K.M.; ROBIN, F.B.; MUNRO , E.M.; University of Washington and University of Antioquia, University of Washington, University of Washington and University of Chicago, University of Washington and University of Chicago; *davidvelasc@gmail.com*
***Computational approach to neural tube closure***
Neural tube closure in ascidians occurs by unidirectional zippering of epithelial and neural tube cells, and involves several distinct cellular processes. On each side of the leading edge of the zipper, filopodia protrude, make contact and pull the edges together until the cells form new adhesions. At the same time, a "V" of localized acto-myosin contractility is progressively activated in just a few cells as they reach the zipper's leading edge, and experiments inhibiting this contractile "V" demonstrate it is essential for closure. It is not clear how the filopodia, formation of adhesions, and localized contractility work together to generate neural tube closure. We used a two-dimensional computational model in which individual cells could exhibit these behaviors to varying degrees to explore their relative importance. We found that a combination of localized "V" contractility and filopodial action best reproduced the shape changes observed in real embryos. In contrast, uniform purse-string contractility failed to form a long tube, while filopodial action alone was ineffective at sealing the tube. Localized "V" contractility could drive normal closure kinematics, but only a for very restricted set of parameter choices. Further, the model was able to reproduce an experimental observation from partially ablated embryos, in which the "V" had a wider angle than under normal conditions and neural tube closure failed. A concomitance of different cell and tissue conditions are needed for a morphogenetic process to occur properly, and computional modeling provides a means, complementary to experiments, to separate key features essential to such processes.

***96.1*** VENDETTI, Jann E.*; FAY, Scott A.; Univ. of California, Berkeley; *jannv@berkeley.edu*
***Predation at a snail's pace: time-lapse photography and analysis of predatory mode in neogastropod whelks***
Time-lapse photography has been used to elucidate and digitally capture diverse biological phenomena across the tree of life. Within the Gastropoda, time-lapse technology has chronicled behaviors such as drilling predation in muricids, desiccation avoidance in mud snails, and the tracking of mucus trails in freshwater pulmonates. In this study, the time-lapse technique was used to record the predatory behaviors of neogastropod whelks in the Family Buccinidae. Members of this family range in feeding preference from specialist carnivores to generalist predators and scavengers. The predation behaviors of buccinids *Kelletia kelletii* and *Busycotypus canaliculatus* were observed during laboratory trials using bivalve molluscs as the prey item. Time-lapse photography allowed for comprehensive observation of prey handling, use of the foot and proboscis, and predation mechanisms (e.g. between-valve wedging, marginal chipping, smothering, engulfment, use of tetramine toxin, etc.). Success rate, duration of attack, and number of attempts were also recorded, as was resulting damage to the shells of the bivalve and/or the gastropod predator. Predatory mechanisms of these and other taxa across the Buccinidae are considered in the phylogenetic framework of a recent analysis of 28S (large subunit rRNA) and mitochondrial CO1 (cytochrome oxidase subunit 1) genetic data from selected buccinids.

***49.3*** VENESKY, Matthew*; WASSERSUG, Richard; PARRIS, Matthew; Univ. of Memphis, Dalhousie Univ.; *mvenesky@memphis.edu*
***Labial tooth number affects feeding kinematics in a ranid tadpole***
We used high-speed videography to explore how missing labial teeth alters the feeding kinematics and foraging performance of Southern Leopard Frog (*Lithobates sphenocephalus*) tadpoles. In Experiment 1, we used overwintered tadpoles to test if the degree of natural tooth loss correlated with the amount of time that tadpoles grazed upon an algal-covered substrate. In Experiment 2, we controlled the pattern of tooth loss by surgically removing one row of teeth to test how this altered the feeding kinematics of tadpoles. We then conducted foraging efficiency trials to test if tadpoles with fewer teeth foraged less effectively than control tadpoles. In Experiment 1, linear regression revealed a significant positive relationship between duration of time the labial teeth were in contact with the substrate and the number of labial teeth present. Thus, loss of teeth resulted in a shorter portion of the gape cycle during which tadpoles acquired food. In Experiment 2, the teeth of tadpoles from the surgery treatment were in contact with the substrate for a shorter duration of time than control tadpoles. Surprisingly, tadpoles with missing teeth obtained similar amounts of food as tadpoles with intact mouthparts. However, tadpoles with missing teeth completed approximately 25% more foraging bouts per unit time. Our data indicate that tadpoles missing labial teeth forage less effectively than tadpoles with undamaged dentition and tadpoles with missing teeth compensate for inferior feeding kinematics during mouth closing in each gape cycle by increasing the number of gape cycles per unit time.

***78.5*** VICKARYOUS, MK*; ZWEERMAN, CL; University of Guelph; *mvickary@uoguelph.ca*
***Morphology and histology of the earliest stages of tail regeneration in the leopard gecko, Eublepharis macularius.***
Many lizards are able to voluntarily self-detach (autotomize) a portion of the tail as a strategy to escape predation. Autotomy ruptures all the major tissue types of the tail and results in the creation of a relatively large wound. Unlike mammals, the cascade of healing events that follow wounding does not lead to scar formation. Instead, most tail-autotomizing lizards are able to regenerate a functionally equivalent replacement tail. Using the leopard gecko, *Eublepharis macularius*, we investigated the anatomy and histology of tail loss at multiple intervals beginning shortly after the detachment event through to the initial outgrowth of the new (regenerate) tail. We identify three sequential stages during this timeframe. Stage 1 begins immediately after autotomy and is characterized by retraction of the spinal cord, the collapse of adjacent skin over the wound, and the formation of an exudate clot. In stage 2 a stratified wound epithelium develops deep to the clot, mesenchymal cells begin to proliferate adjacent to the spinal cord, and numerous multinucleated osteoclasts are observed remodelling bone. In stage 3 the clot is lost, thus exposing a thickened wound epithelium (the apical epithelial cap), and angiogenesis begins within the mesenchymal mass. Later an outgrowth of the spinal cord (the ependymal tube) invades the mesenchymal tissue. Available evidence indicates that the leukocytic response to tail loss is limited in duration.

***16.1*** VIRTA, V. C. ; University of Washington; *virta@u.washington.edu*
***Structural Components and Morphogenetic Mechanics of the Zebrafish Yolk Extension Developmental Module***
In order for a vertebrate embryo to attain a functional morphology, it must fundamentally change its shape from a sphere to an elongated rod. While cell movements on the dorsal side of the embryo have been extensively studied, morphogenetic cell behaviors shaping the ventrum have not been described at the same level of detail. The zebrafish yolk extension ontogenesis module serves as an excellent model for morphogenetic movements reshaping the ventrum because (1) the zebrafish embryo is optically transparent; (2) yolk extension ontogenesis occurs relatively quickly; and (3) the yolk cell isolates the tissues elongating the ventrum from the rest of the embryo. Furthermore, the zebrafish is an ideal taxon in which to perform studies of ventral cell movements, as these results can then be compared both to other teleosts, and other vertebrates.

From the core to the cortex of the embryo, three histological compartments comprise the yolk extension developmental module (1) the yolk cell; (2) the mesendodermal mantle; and (3) the embryonic integument. These structural compartments are hypothesized to interact with one another in a hierarchical manner, resulting in the morphogenesis of the elongated embryonic zebrafish ventrum. Time-lapse videomicroscopy and experimental manipulation show that the yolk mass is a viscoelastic, high-internal-phase emulsion, which resists compression. Moreover, ventral posterior mesoderm separates Kupffer’s Vesicle from the yolk cell. Finally, the embryonic integument is contractile and contributes to yolk extension formation. These experiments constitute an initial assessment of the morphogenetic mechanics underlying the zebrafish yolk extension ontogenesis module.

***59.4*** VITOUSEK, Maren N.*; MITCHELL, Mark A.; ROMERO, L. Michael; AWERMAN, Jessica; WIKELSKI, Martin; University of Colorado, Boulder, University of Illinois at Urbana-Champaign, Tufts University, Tufts University, Max Planck Institute for Ornithology and Princeton University; *maren.vitousek@colorado.edu*

***To breed or not to breed: stress and reproductive decision-making in Galapagos marine iguanas***

It is unusual for seasonal breeders to frequently skip opportunities for reproduction. We investigated the relationship between physiological state and reproductive decision-making in Galápagos marine iguanas *(Amblyrhynchus cristatus)*, a species in which females typically reproduce biennially, although the proportion of breeding individuals varies significantly across years. Nearly all adult-sized females initiated follicular development prior to the lekking period, but 38% of females resorbed all developing follicles 5-15 days before the start of copulations. Receptive and non-receptive females differed in reproductive hormones during the mate choice period. Testosterone peaked in receptive females immediately prior to copulation. Non-receptive females showed significant peaks in both testosterone and progesterone during follicular atresia. Both baseline and stress-induced corticosterone levels were significantly lower in receptive females two to three weeks prior to the period of reproductive decision-making (and the onset of follicular atresia in non-receptive females). Females that continued to develop follicles were also in higher body condition and initially produced larger follicles. Reproduction is extremely costly in this long-lived species, and increases the likelihood of mortality in the year following breeding; females could therefore gain significant benefits from being attuned to indicators of reproductive success. We suggest that corticosterone may modulate reproductive decisions by altering individual sensitivity to both internal and external cues of the likelihood of successful reproduction.

***74.4*** WADA, H*; BERGERON, CM; MCNABB, FMA; TODD, BD; HOPKINS, WA; Virginia Tech; *hwada@uwo.ca*

***The effects of excessive dietary mercury on thyroid-mediated processes and fitness- related traits in wood frog tadpoles***

Mercury (Hg) is a neurotoxicant known to cause developmental and behavioral abnormalities in vertebrates. Increasing evidence suggests that Hg can also disrupt endocrine functions and endocrine-dependent processes. For example, dietary Hg has been shown to delay tail resorption during metamorphic climax, a process mediated by thyroid hormones (TH), in southern leopard frogs. However, the direct link between Hg, hormone disruption, and developmental delays in amphibians has not been explored. Therefore, we examined the effects of dietary Hg (0.01, 2.5, and 10 ug/g, dry wt) on TH concentrations and development, growth, performance, and survival of wood frogs (*Rana sylvatica*). We predicted that TH concentrations in individuals exposed to dietary Hg would be reduced, resulting in developmental delays, particularly near metamorphic climax when TH levels typically peak. Tadpoles accumulated Hg in a dose-dependent manner; total Hg concentrations in Gosner stage 42 tadpoles fed the three diets were 0.03, 1.06, 3.54 ug/g, dw, respectively. During metamorphic climax, tadpoles eliminated 35% of the inorganic Hg from their tissues but retained most of the more toxic methylmercury that they had accumulated. Contrary to our predictions, we found no effect of Hg on the duration of larval development, size at metamorphosis, tail resorption time, or hopping performance. Consistent with the lack of effects on development, we also detected no differences in whole-body TH concentrations among our dietary treatments. Our results suggest that amphibian species may differ in their sensitivity to dietary Hg, perhaps due to differences in the length of the larval period or other life history factors.

***99.4*** WAGNER, G. P. *; YOUNG-BRIM, R. ; Yale University; *gunter.wagner@yale.edu*

***Towards the mechanistic basis of digit identity frame shift in birds***

One of the most enduring conflicts in homology assessment is the evidence concerning the identity of anvian digits in the wing. Anatomical and paleontological evidence shows that the three definite digits of the avian hand are digits 1, 2, and 3, while the embryological evidence shows that these digits arise from digit condensations 2, 3, and 4. To solve this conflict it has been proposed that, in the stem lineage of birds, digit identity has been transferred from their ancestral positions 1,2, and 3 to the positions 2, 3, and 4 as found in the bird hand. In support of this hypothesis it has been shown that in five digited anmniotes, mouse and alligator, digit 1 is distinguished by the absence of HoxD11 and HoxD12 expression. In the bird wing it was found that this gene expression signature is found in the most anterior digit, i.e. the digit that develops in position 2. Digit identity frame shift can also be induced experimentally and are also associated with a posterior shift in HoxD expression. Here we present evidence that chick wing development is associated with a two day reduction of HoxD gene expression relative to the hind limb. No corresponding decrease in forelimb gene expression is found in mouse limb development. In contrast, no difference could be found in Shh expression. We thus conclude that the genetic difference, which leads to the digit identity frame shift in the bird wing, acts downstream of Shh signaling and upstream of HoxD expression. We hypothesize that the cis-regulatory elements of HoxD12 and HoxD11 have a derived responsiveness to a transcription factor specifically expressed in the anterior autopod.

***64.9*** WAGNER, K.A.*; SABINS, A.M.; PHARR, C.M.; HANCOCK, T.V.; Eastern Washington Univ.; *wagner.katie@hotmail.com*

***Swimming ability and morphological traits in coho salmon reintroduced and subjected to greater migration distances in the Columbia Basin***

Coho salmon (*Oncorhynchus kisutch*) were extirpated from upper Columbia Basin tributaries in the 1900s. The Yakama Nation and Nez Perce Tribe are currently reintroducing coho into Mid-Columbia and Snake River tributaries, respectively. These stocks are primarily derived from a basal stock originating from the Clackamas River of the lower Columbia, thus reintroduced stocks must migrate dramatically further than basal runs. Natural runs of Fraser River coho exhibit differences in locomotor ability and morphology over varying migration distances. To determine if selection is acting upon similar traits in reintroduced stocks, we are analyzing critical swimming speed ($U_{crit}$), using a Blazka-type swim tunnel and several underlying physiological and morphological traits, juvenile hatchery coho derived from successful returnees of the Mid-Columbia and Snake Rivers were compared to the basal stock. Reintroduced Mid-Columbia stocks have a lower $U_{crit}$ coupled with an increase in ventricle size, indicating a possible tradeoff of maximal swimming speed for endurance swimming. These reintroduced stocks also demonstrate decreases in fineness ratio, peduncle length and body width and increases in head length, snout-pectoral length, pelvic fin length; median fin areas; and condition factor. Traits of the reintroduced Snake River stock appear less diverged, which may be a result of continued basal stock introduction. Future analyses of muscle enzymes and fiber type, size, and number may further elucidate any potential adaptations.

***101.3*** WALDROP, LD; Univ. of California, Berkeley; *lwaldrop@berkeley.edu*
***Discrete odor sampling of the Oregon shore crab Hemigrapsus oregonensis during ontogeny***
Crabs, like many malacostracan crustaceans, sense chemical signals in their fluid surroundings using chemosensory hair arrays on antennules to discretely sample odor-laden fluid (sniffing). Sniffing occurs when a quick downstroke of the antennule forces water to flow in between the hairs of the array and a slower return stroke traps fluid within the array. Sniffing is a critical part of olfaction for not only adult crabs but for juvenile crabs which can be up to two orders of magnitude smaller than adults. Since sniffing in crabs relies heavily on a narrow range of antennule velocities and dimensions in order to effectively capture and hold fluid, are juvenile crabs that are significantly smaller able to sniff during ontogeny? To address this question, antennule kinematics were recorded using high speed videography and antennule morphologies were examined using scanning electron micrographs from Oregon shore crabs *Hemigrapsus oregonensis* ranging in size from 4 to 28 mm carapace width. These data were used to both characterize allometric growth patterns from juveniles to adults and to construct dynamically-scaled physical models of antennules representing animals at different stages of growth. Particle image velocimetry (PIV) was used to visualize fluid flow in the hair array of each model during realistic antennule movement to determine if each stage could discretely sample odors. The scaling relationships of antennule kinematics and morphology and PIV results will be presented.

***55.3*** WALKER, S.M.*; THOMAS, A.L.R.; TAYLOR, G.K.; Oxford University; *simon.walker@zoo.ox.ac.uk*
***Kinematics and control in free-flying hoverflies***
Hoverflies show exquisite manoeuvrability while flying, yet we are still some way off from understanding how this level of control is achieved. Recently, we have found evidence that an accessory flight surface, known as the alula, plays an important role in hoverfly flight control. The alula is a small flap near the base of the wing and can operate in two discrete states, either in plane with the wing or flipped approximately normal to it. High-speed digital video cameras were used to film hoverflies in a range of free-flight manoeuvres. We applied photogrammetric techniques to make automatic measurements of wing deformations in a free-flying insect and allowed us to measure the body and wing kinematics of over 400 wingbeats from six individuals. In this talk we will describe how the kinematics of the body are controlled by changes in the wing kinematics, playing particular attention to the previously unrecognised role of the alula.

***50.4*** WALKER, J.A.*; ALFARO, M.E.; FULTON, C.J.; Univ. Southern Maine, Univ. California, Los Angeles, Aust. Nat. Univ.; *walker@maine.edu*
***Fluid Dynamic Drag, Body Shape, and Endurance Swimming Performance among Coral Reef Fishes***
The repeated evolution of streamlined body shapes among large, fast aquatic animals is a textbook example of evolutionary convergence. The oft-cited functional explanation is simple: streamlining reduces drag. A component of streamlining is fineness, which is the ratio of body length to diameter (a combination of depth and breadth). In a common but naïve model, endurance swimming performance is expected to increases monotonically if not linearly with fineness. A more hydrodynamically informed model recognizes that streamlined bodies have an optimum fineness ratio and that endurance performance should decrease as fineness moves away to either side of this optimum. Hoerner's empirical drag data, however, show that the relationship between fineness and drag depends on how bodies are scaled. Drag decreases monotonically if bodies are scaled by length but there is a distinct minimum if bodies are scaled by cross-sectional area or volume. A problem with using these data to understand body shape variation is that Hoerner's data were collected on rigid bodies while most fish undulate the body to power endurance swimming. While rigid bodies generate a distinct pressure drag (something that can be minimized), self-propelled undulating bodies generate a pressure distribution that ultimately contributes to thrust. Consequently, we explored the association between body shape (fineness) and swimming performance in 58 species from 5 families of coral reef fish that maintain a rigid body while powering endurance swimming using the pectoral fins. Regardless of how the fish body is scaled, swimming endurance increased with increasing fineness. This result is consistent with the naïve model but inconsistent with the more hydrodynamically informed models.

***S11.1*** WALKER, J.A.; Univ. Southern Maine; *walker@maine.edu*
***Introduction to the Symposium: Contemporary Approaches to the Study of the Evolution of Fish Body Plan and Fin Shape***
The evolution of fish body shape is one of the central problems in vertebrate morphology. Because of the apparently obvious form-function mapping of fish body shape, comparisons of shape among fishes have been central to many recent studies in local adaptation, adaptive plasticity, competition, and evolutionary constraints. But comprehensive, well-tested models for body shape variation are wanting. The core of the problem is that fish body shape affects many, many functions, so asking "what is this body shape for" is a doomed approach, and that many different phenotype combinations can result in similar levels of performance. These problems are compounded by (1) the many other phenotypic traits that affect these functions and (2) the feedback across generations between selected traits and the genetic and developmental processes that build the body. No. 1 confounds attempts to build simple models of form-function mapping because of intertrait correlations, functional compensation or redundancy, and interaction effects. No. 2 suggests that any explanation of fish body shape diversity must take into account the genetic and developmental architecture of fish body shape. Explanations of form or variation in form, then, are complicated by the different levels of organization in biological design, the complexity of the causal mapping (or regulatory control) from lower to higher levels, and the feedback from higher to lower levels of organization. The speakers in this symposium were invited to specifically address the genetic, developmental, functional and ecological architecture of fish body shape and more generally address how their work facilitates the advancement of current models of the proximate and ultimate mechanisms regulating the development and evolution of fish body shape.

***S11.4*** WARD, A. B.*; MEHTA, R. S.; Adelphi University, Univ. of California, Davis; *award@adelphi.edu*

***Axial Elongation in Fishes: Using Morphological Approaches to Elucidate Developmental Mechanisms in Studying Body Shape***

Fishes are highly variable in body shape: from nearly spheroidal in some Tetraodontiformes to extremely elongate in Anguilliformes. The elongate body shape has evolved at least twenty times independently within the ray-finned fishes, providing a unique situation for examining the underlying anatomical modifications associated with body elongation in a comparative context. Body elongation involves dramatic changes to the axial skeleton. Most elongate species have more vertebrae than closely related non-elongate relatives; those increases in vertebral number tend to be specific to one region of the vertebral column. Some lineages also show lengthening of the individual vertebral centra as the primary mechanism leading to body elongation. Additionally, highly elongated forms tend to have changes to other parts of the body including the fins and gastrointestinal tract. In previous studies, comparative analyses have provided hypotheses of developmental mechanisms that have led to morphological evolution. Many developmental studies are focused on mutations in model systems. Comparative morphological analyses can illuminate the findings of developmental studies by determining whether mutants in model systems correspond with morphological variability in a specific trait. In this study, we will review the evolution of body elongation across actinopterygian fishes and describe anatomical traits that are correlated with body elongation in these lineages. Finally, we will discuss hypotheses concerning the developmental control of body elongation in fishes.

***72.10*** WARD, Chelsea K; Auburn University Montgomery; *cward3@aum.edu*

***Temperature effects on the Anuran immune system***

Temperature has long been known to affect physiological processes in ectotherms. It is generally accepted that an increase in temperature will increase physiological processes, including immune processes, up to a thermal maximum. The temperature effects are supported by ectotherm behaviors. Animals that are infected with pathogens often bask or choose warmer areas. We tested whether an increase in temperature would cause an increase in the activity of the Anuran immune system. Fifty-six marine toads, *Bufo marinus* (*Rhinella marina* ), were collected from Dade Co., Florida and placed in ten gallon aquariums. The toads were divided into two temperature treatments. Cool toads (n=28) were kept at room temperature (22°C) and warm toads (n=28) were kept at 24°C. These temperatures are within the normal range for this species. Toads were allowed to acclimate for two weeks. Half of the cool toads (n=14) and half of the warm toads (n=14) were given lipopolysaccharide from *E. coli* to mimic bacterial infection. Phagocyctic activity, complement activity, antibody production, and histamine levels were then measured in all toads, each week, for 6 weeks. A two degree increase in temperature negatively affected all measures of the immune system. Antibody production to a novel antigen and phagocytic activity were significantly decreased in both healthy and pseudo-infected toads ($p<0.05$). Complement activity and histamine levels were significantly decreased in pseudo-infected but not healthy toads ($p<0.05$). This data is counter intuitive to the current understanding of ectotherm physiological processes and may provide a link between climate change and the pathogenic infections believed to be a leading cause of amphibian decline.

***93.1*** WARK, A.R.*; GREENWOOD, A.K.; PEICHEL, C.L.; Fred Hutchinson Cancer Research Center, Seattle and University of Washington, Seattle, Fred Hutchinson Cancer Research Center, Seattle; *awark@fhcrc.org*

***Genetic analysis of variation in schooling behavior among threespine stickleback populations***

Threespine sticklebacks (*Gasterosteus aculeatus*) adapted to diverse habitats have evolved extensive variation in a number of behavioral traits, including feeding, courtship, and anti-predator behaviors. Schooling behavior is thought to be an anti-predator behavior in fish, but it has not been extensively studied in sticklebacks. Because the costs and benefits of schooling vary in different ecological conditions, we hypothesized that schooling behavior would differ between marine and freshwater stickleback populations and that this behavioral difference would be genetically controlled. We developed two novel assays (the Open Arena Tournament and the Model School assay) to quantitatively assess schooling behavior in the laboratory in both naturalistic and experimentally-controlled social environments. Using these assays, we show that Japanese Pacific Ocean marine sticklebacks school significantly more strongly than freshwater lake sticklebacks from Paxton Lake, British Columbia. These experiments were performed in fish reared in a common laboratory environment, suggesting a heritable basis to this variation. To characterize the genetic architecture underlying schooling behavior divergence, we are performing a genetic linkage analysis in a Paxton Benthic x Japanese Pacific F2 intercross using these complementary assays. Results of our genetic analysis will be presented.

***81.2*** WARNE, R.W.*; GILMAN, C.A.; GARCIA, D.A.; WOLF, B.O.; Vassar College, NY, University of New Mexico; *rw.warne@gmail.com*

***Dietary quality effects on resource allocation in lizards: A quantitative stable isotope analysis***

The degree to which lizards can alter resource allocation to reproduction or growth in response to variation in environmental resource availability remains an open question. Using carbon stable isotopes and manipulation of the dietary resources available to experimental prairie lizards (Sceleporus undulatus consubrinus) we quantify the plasticity in their allocation of stored-endogenous resources versus recent dietary intake to the competing demands of growth and reproduction. We show that reproducing females can vary their use of stored resources for egg production by more than 60% in response to reduced resource availability prior to hibernation. When fed a high quality diet during the spring - after hibernation, however, these females showed rapid 'catch-up' growth and comparable reproductive effort to lizards fed an ad libitum diet both before hibernation and during vitellogenesis. These results show that dietary conditions have a strong affect on the trade-off between resource allocation to growth vs. reproduction. Furthermore, this study demonstrates that variation in resource quality during periods of resource accumulation (e.g. preparation for hibernation in the fall) can have strong delayed and long-term effects on subsequent life cycles events (e.g. reproduction and growth in the following spring). We also present similar isotope and reproductive data for eight species of wild caught lizards with diverse life histories to examine the interactions between environmental resource variation and evolved life history strategies.

***104.2*** WATERS, James S*; HARRISON, Jon F; Arizona State University; *james.waters@asu.edu*
***Geometric characterization and phenotypic plasticity in the tracheal networks supplying insect flight muscle***
Tracheal networks extend throughout the metabolic tissues of insects and are responsible for providing pathways for the transport of critical respiratory gasses. The structure of these networks in the flight muscle of *Drosophila melanogaster* was investigated using confocal microscopy, taking advantage of the autofluorescence of tracheal chitin to visualize tracheae and tracheoles ranging from 20 to 0.5 micrometers in diameter. Flies were reared from egg to adulthood in 10, 21 or 40% oxygen atmospheres, and killed and fixed on the fourth day of adulthood. The extent to which the distal branches of these networks approximate fractal structures was quantified by means of topology, box counting, allometry, Horton analysis, and comparing an inverse power-law distribution with an exponential model. Tracheole density was strongly inversely proportional to the concentration of atmospheric oxygen, demonstrating that the adult tracheal system exhibits a major compensatory response to the larval oxygen environment. This research was supported by NSF GRFP to JSW and NSF IBN 0419704 to JFH.

***S11.9*** WEBB, Paul W*; COTEL, Aline J; University of Michigan, Ann Arbor; *pwebb@umich.edu*
***Eddies: Potential impacts of turbulence on fish-swimming form and function***
Ideas on the relationships between water flow and form of fishes over the past century are derived largely from assumptions of relatively steady flow. Instead, generating thrust and the natural habitat experienced by fishes are both characterized by unsteady water motions typical of turbulence. The occurrence of turbulence has received attention primarily in terms of boundary-layer control, delay of separation and similar drag-reducing forms and functions. A few historical studies have explored eddies, the structures of turbulent flow, in terms of their formation by propulsive movements. In the past decade, detailed study of eddy creation during swimming and in natural habitats has greatly increased, but consideration of the potential impacts of these eddies on form is very limited. Studies of fish wakes show that most of the mechanical energy associated with propulsive movements is dissipated to the wake, reversing the historical assumption that energy loss is associated with translocation of the body itself. Given the large energy loss in the wake, adaptations to minimize these losses would be anticipated. We suggest that requirements for fast-starts and other maneuvers limit the ability to minimize energy losses to the wake during steady swimming. In addition, we recognize that the archetypal streamlined “fish” shape not only minimizes resistance during glides and in turns, but also minimizes wake energy losses, and reduces linear and rotational perturbations as a result of swimming into eddies with circulation of magnitudes known to overwhelm fish stability control systems.

***22.3*** WEBER, M.X.*; FAY, S.A.; LIPPS, J.H.; Univ. of California, Berkeley; *mxweber@berkeley.edu*
***The biogeography of Symbiodinium from giant clams (Tridacnidae)***
Tridacnidae, the giant clams, are one of many groups of host organisms for *Symbiodinium*, a diverse clade of dinoflagellates that structurally and energetically support coral reef communities. These algae are found in symbiosis with corals, sponges and foraminifera as well as giant clams. Using DNA sequence data I identified *Symbiodinium* hosted by various populations of tridacnids in the Red Sea, the Indian Ocean and the Pacific Ocean. This study described *Symbiodinium* ecology and biogeography over the complete distribution of a single host clade. Phylogenetic analysis grouped the symbionts into three major subgeneric clades, A, C and D. Giant clam symbionts were most diverse in Papua New Guinea and along the East African coast although most *Tridacna* populations hosted several different *Symbiodinium* lineages. However, at the extreme eastern end of the host distribution, I identified only one species of clam, *T. maxima* hosting only one type of symbiont. The Red Sea *T. maxima* populations hosted a unique lineage of symbionts not found in other tridacnids from other regions. I analyzed patterns in the symbiont distribution with respect to several ecological variables including temperature, reef environment and three spatial dimensions: latitude, longitude and depth. Giant clam symbiont diversity was limited compared to other hosts. The same symbiont phylotypes were identified in clams from disparate localities despite evidence for a variety of alternative types available in other hosts such as corals or foraminifera. Biogeographic patterns can be attributed to the geologic history of the Indo-West Pacific and the ecology of the symbiosis. These data suggested that giant clams select specific *Symbiodinium* lineages to optimize the mutualism.

***100.2*** WEBSTER, M.*; ZELDITCH, M.L.; Univ. Chicago, Univ. Michigan; *mwebster@geosci.uchicago.edu*
***Evolutionary lability of integration in Cambrian ptychoparioid trilobites***
Phenotypic integration can constrain evolution by channeling variation into few dimensions: lineages characterized by strong and invariant integration structures should have little capacity to generate morphological novelty, especially if integration arises through direct interactions (DI) among developmental pathways. The level and structure of integration are compared in two species of exquisitely preserved ptychoparioid trilobites. Landmarks and semilandmarks were digitized on mature, silicified cranidia of *“Eokochaspis” metalaspis* (Lower Cambrian) and *“E.” nodosa* (Middle Cambrian). The correlation structure of variation among individuals and of fluctuating asymmetry reveals the structure of phenotypic integration and DI, respectively. The level of integration among nine anatomical partitions of the cranidium in *“E.” nodosa* was markedly higher than that in *“E.” metalaspis*. The species are not even significantly similar in either the structure of phenotypic integration or that of DI. Phenotypic integration in *“E.” nodosa* is moderately but significantly influenced by DI among developmental pathways, but these play little role in patterning phenotypic integration in *“E.” metalaspis*. These differences in level and structure of integration are surprising given the close morphological similarity and recent common ancestry of the species. Developmental systems were evolutionary labile in these early ptychoparioids. While macroevolutionary implications of a two-species comparison are limited, it is intriguing that a higher level of integration and greater contribution of DI are detected in the stratigraphically younger species. Such study of integration level and structure through time offers the potential to discover whether and how developmental constraints shape macroevolutionary diversification.

***69.1*** WEINER, Susan A*; NOBLE, Katherine; FLYNN, Galen; WOODS, William A; STARKS, Philip T.; Tufts University, Smith College, University of New Hampshire; *susan.weiner@tufts.edu*
***A role for the cost of flight in the Polistes dominulus invasion***
*Polistes dominulus* is an invasive paper wasp from the Mediterranean that has rapidly spread throughout North America since it was first observed in 1978. *P. dominulus* is more successful than its New England congener, *P. fuscatus* because *P. dominulus* produces larger nests with more reproductives. One reason for this is that *P. dominulus* produces workers earlier in the season. In the pre-worker period, *P. dominulus* foundresses make more foraging trips, which may help speed the growth of the early workers. If flight is less energetically expensive in *P. dominulus*, that lower cost might help to explain how *P. dominulus* foundresses are able to make more foraging trips. In this experiment we studied flight metabolic rate (FMR) in *P. dominulus* and *P. fuscatus* at a variety of temperatures. *P. dominulus* was shown to have a steeper slope of increasing FMR with increasing temperature and a lower FMR than *P. fuscatus* at low temperatures. This suggests that, at the low spring temperatures that occur during the pre-worker period, *P. dominulus* foundresses may be able to forage with greater energetic efficiency. This increased efficiency may allow them to bring more prey to their developing workers, and thus produce a first brood earlier in the season.

***79.4*** WEINTRAUB, J.P.*; JENKINS, K.P.; SMITH, R.A.; WIEGMANN, B.M.; NESCent (National Evolutionary Synthesis Center); *jory@nescent.org*
***Evolution Education Resources From The National Evolutionary Synthesis Center***
Teaching evolution has myriad challenges, not the least of which is sorting through all of the existing modules, podcasts, videos, links and other resources available, to distinguish between the good, the bad and the ugly. This session will facilitate that process by describing useful evolution education resources that have been generated or compiled by the Education & Outreach group within NESCent (The National Evolutionary Synthesis Center – an NSF-funded evolution research collaboration of Duke University, UNC Chapel Hill and NC State University). In addition, this session will describe the findings of several NESCent-sponsored working groups focusing on evolution education and their implications for improving the process at the undergraduate level.

***S9.8*** WEISBLAT, D.A.*; CHO, S.J.; LYONS, D.C.; VALLéS, Y.; WANG, J.K.; Univ. of California, Berkeley, Duke University; *weisblat@berkeley.edu*
***D quadrant specification in a leech (Helobdella; sp.): comparison with other spiralians***
In spiralian development, D quadrant specification is key to forming the second embryonic axis. In unequal cleavers, e.g. clitellate annelids (oligochaetes and leeches), the D quadrant is established by the segregation of determinants to one cell during the first two mitoses. In equal cleavers, by contrast, the cells of the 4-cell stage are equipotent; the D quadrant is specified later, by a stochastic process involving cell-cell interactions. One possible mechanism of D quadrant specification entails a "master regulator" which, when segregated to the prospective D quadrant, elicits the complex developmental program associated with the D quadrant fates. Alternatively, one might postulate an "emergent process" in which the features of the D quadrant fates arise as outputs of a network of cellular and molecular interactions, and that quantitative differences between cells are more important than the qualitative differences implicit in the master regulator model. I will summarize our current understanding of D quadrant specification in *Helobdella*, which suggests a hybrid of these alternatives. While unequal cleavage is homologous among clitellates, the cell biological mechanisms of the unequal first and second cleavages differ between *Helobdella* and *Tubifex* (an oligochaete), as is the process by which determinants segregate within the zygote. Curiously, the Notch, Wnt and MAPK signaling pathways are deployed in the 2-cell embryo of *Helobdella*; are they required for D quadrant specification? Could this reflect an evolutionary acceleration of the stochastic D quadrant specification process in an equally cleaving spiralian ancestor? Insights gained from studying *Helobdella* should aid in understanding D quadrant specification in other spiralians.

***77.1*** WEISS, S/L; FRITZSCHE, A/F*; University of Puget Sound, Tacoma WA; *afritzsche@gmail.com*
***Chemical Cues Indicate Familiarity And Body Size In Striped Plateau Lizards***
Reptilian chemical cues may communicate information about discrete character states such as species, gender, and individual identification, as well as continuously varying characteristics such as individual body size and condition. Here, we investigate whether chemical cues of the striped plateau lizard, *Sceloporus virgatus*, allow for the assessment of familiarity and body size. We first tested male tongue-flicks and other chemosensory behaviors in response to familiar vs. novel sociochemical environments (i.e., tanks with paper substrates marked by the focal male and a familiar female or by an unfamiliar male-female pair). We found that males performed significantly more chemosensory behavior in the novel environment. Male response to the novel environment was unrelated to the body size of the previous male resident but was positively related to the body size of the previous female resident, though only in one of two test years. To further investigate whether males gain information about female body size via chemical signals, we used a choice-test paradigm to assess male response to chemical cues from females that differed in body size by ~12%. We found that males responded more strongly to the largest and smallest females than they did to the intermediate-sized females. Combined, these results suggest that S. virgatus chemical cues provide information about familiarity and female body size. However, male response is more complicated than expected; we did not find a consistent preference for the cue from the largest available female, as is expected based on the selective advantage of mating with larger, more fecund females.

***45.8*** WEISSBURG, M.J.*; BERKENKAMP, K.; MANKIN, D.; GA Tech; *marc.weissburg@biology.gatech.edu*

***Turbulent mixing inhibits discrimination of attractive vs. aversive chemicals in crabs by eroding small scale filament structure impinging on antennulary chemosensors***

Animals distinguish chemicals in environments where cues from different sources may be mixed. Although the role of the fluid mixing has been investigated in the context of tracking, there is little work on the role of the physical environment in mediating the ability of animals to discriminate different chemicals, despite the obvious relevance of this problem. We examined whether blue crabs could discriminate an attractive from an aversive odor (food vs injured blue crab metabolites, resp) under various mixing conditions, using the ability of crabs to track to the source in a flume as the behavioral endpoint. When attractive and aversive cues are emitted from separate sources, blue crabs recognize the presence of food and locate the attractive source at a frequency indistinguishable from that occurring without the aversive substance. Discrimination of the attractant occurs despite the fact that qualitative flow visualizations indicate attractive and aversive odor streams intermingle. In contrast, increased turbulent mixing eliminates the positive response to food odor, which is similar to the behavior observed when attractive and aversive substances are released from a single source. Thus, turbulent mixing, which is associated with filament homogenization, diminishes the capacity to register the presence of the attractive substance. Significantly, animals with antennulary chemosensensors rendered non-functional (using distilled water) respond to the attractive source in dual plume experiments, even in the presence of enhanced mixing. This suggests antennulary receptors are responsible for discrimination, and that spatial discreteness of odor filaments at this scale is a necessary signal feature

***23.5*** WESSELS, F. J.*; HAHN, D. A.; University of Florida; *fwessels@ufl.edu*

***Productive Procrastination: Stable Isotopes Reveal Benefits Associated with a Reproductive Delay in Flesh Flies***

The timing and magnitude of reproductive resource allocation are not static, they are flexible and highly tuned to external conditions. However, a critical question is whether this plasticity is adaptive, allowing organisms to maximize fitness when exposed to variable environmental conditions. Before they can reproduce, most insects must reach a minimal nutritional threshold. Previous research has shown that the flesh fly, *Sarcophaga crassipalpis*, can reach the minimum nutritional reproductive threshold after a single protein meal. However, if flesh flies are provided with low quality resources, they will delay reproduction compared to individuals receiving high quality resources. This plastic delay may be adaptive if it provides female flies with more time to obtain additional high quality meals and enhances reproduction. To test if this reproductive delay is consistent with adaptive plasticity, we provided three sequential resource pulses early, middle, and late during the reproductive delay period. As expected, poorly fed flies delayed reproduction and flies that received a resource pulse during the delay period benefited from the additional nutrients. Flies that received a resource pulse earlier in the delay period had greater reproductive output and provisioned their eggs faster than flies that received a later pulse. In addition, by using diets with distinct $^{13}C$ stable isotope profiles we found that flies receiving the earlier pulse were able to incorporate more dietary carbon into their eggs and somatic tissue than those provided a later pulse. These results suggest that the reproductive delay in *S. crassipalpis* is consistent with adaptive post-threshold plasticity.

***25.3*** WEST, DM*; HU, DL; Georgia Institute of Technology; *dwest6@gatech.edu*

***Thermotaxis of Jumping Beans***

The Mexican Jumping Bean consists of a moth larva living inside a hollow seed. To avoid overheating by the sun, the bean rocks and rolls along thermal gradients. In this study we investigate the efficacy of the bean's thermal sensing and rolling locomotion. We build a one dimensional bean track with a fixed heat source at one end. Using time-lapse photography, we record the bean's path along the track and characterize its random walk by an average speed, u, and a diffusion coefficient, D (which is related to the standard deviation of the speed). We compare the speeds of the larva both with and without a shell, and find that the larva without a shell has a higher speed and a lower diffusion coefficient. Moreover, we use speed and diffusion to characterize the efficacy of the motion of the larva in different shell shapes.

***82.1*** WESTERMAN, E.L.*; HODGINS-DAVIS, A.; MONTEIRO, A.; Yale University; *erica.westerman@yale.edu*

***Naive mate preference modified by early experience in the butterfly Bicyclus anynana***

Female mate preference can either be innate or driven by social experience. While there are a variety of vertebrate models demonstrating the importance of mate preference learning in species with parental care, examples of female mate preference learning in invertebrate species without parental care are largely unknown. Here we explored whether female mate preference can be modified by social experience in a butterfly. Female *Bicyclus anynana* select mates based on the presence of UV-reflective white scales in the centre of the dorsal eyespots of male forewings. We determined the naïve preference of both Wild type (two eyespots) and Spotty (four eyespots) females for Wt or Spotty males via choice experiments. We then tested the influence of social experience on mate preference by isolating newly emerged Wt females, exposing them to three-day old Spotty males for three hours, and testing realized mate preference two days later in choice trials between Wt and Spotty males. Realized mate preference for Wt males was compared between isolated females not exposed to Spotty males prior to testing, females exposed to but not courted by Spotty males prior to testing, and females exposed to and courted by Spotty males prior to testing. Both Wt and Spotty females had a naïve preference for Wt males. Females courted by Spotty males had a realized mate preference for Spotty males, while exposed but not courted females had a realized mate preference for Wt males, similar to unexposed females. These results demonstrate that mate preference can be modified by social experience in a female butterfly, suggesting that learning may play an important role in mate preference in insects without parental care.

***91.11*** WEVER, JM*; HENRY, JJ; NEWMARK, PA; U Illinois - Urbana; *jwever2@illinois.edu*

***Bringing Lophotrochozoa into Studies of Comparative Eye Development and Eye Evolution***

Metazoan eyes have marveled both developmental and evolutionary biologists since Darwin wrote in *Origin of Species*, "to suppose that the eye with all its inimitable contrivances... could have been formed by natural selection, seems, I freely confess, absurd in the highest degree." Despite Darwin's misgivings, eyes did evolve through natural processes. While attempting to elucidate these processes, some researchers concluded that all metazoan eyes are homologous and have a single, monophyletic origin, while others argued for independent evolution across many lineages. Researchers have conducted extensive descriptions and comparisons of eye development between arthropods and vertebrates; however, the same processes are largely unstudied in Lophotrochozoans. Planarians, as basal members of Lophotrochozoa, offer an attractive opportunity to incorporate new data into the field of comparative eye development and eye evolution. Expression and functional analysis of transcription factors associated with eye development in *Xenopus laevis* and *Drosophila melanogaster* will be carried out in the planarian, Schmidtea mediterranea, to characterize the molecular mechanisms of planarian eye development and ultimately compare them to more highly-studied organisms. Additional candidate genes were identified from a *Xenopus* cDNA subtraction library saturated for transcripts upregulated during lens regeneration and are also expressed during eye development. Data from these studies will be presented and analyzed. Finally, the planarian eye cell transcriptome will be characterized using laser capture microdissection and 454 deep-sequencing technology, providing additional data for comparative functional analysis. These initial studies of eye development in a Lophotrochozoan will give valuable insight to researchers striving to compare eye development across phyla.

***15.10*** WHITAKER, Stacia E.*; COOLEY, James; SWEENEY, Sarah; DAVIDSON, Brad; University of Arizona; *staciaw@email.arizona.edu*

***Cdc42 activity drives fate specification of the heart lineage.***

The establishment of polarity and subsequent asymmetric cell division are required for differentiation throughout development. In *Ciona intestinalis*, such a division occurs in the heart founder cells, with each of four founders giving rise to a small heart progenitor cell and a larger tail muscle cell. Although FGF signaling occurs prior to division, ERK is activated only in the smaller daughter and results in heart cell-specific behaviors such as migration and proliferation. The underlying cause of differential ERK activation in response to FGF in the heart lineage is not yet understood. The Rho GTPase Cdc42 has been shown to influence both size and fate asymmetry in many systems. To determine whether Cdc42 is involved in the establishment of polarity in the *Ciona* heart lineage, we used wild type and signaling-active Cdc42 constructs expressed under the heart founder-specific Mesp enhancer. We found that Cdc42 activity promotes migration. To distinguish between effects on actin dynamics and cell fate, we employed the FoxF reporter construct as a heart cell marker. Our data shows that constitutive activity of Cdc42 results in a switch from tail muscle to heart cell fate, as well as disruption of size asymmetry. Cdc42 has a multitude of interactors that regulate actin dynamics, receptor endocytosis, polarity, and signal propagation. Polarized stabilization of the FGF receptor or differential transport may result in propagation of the FGF/MAPK signal in the heart progenitor. To further characterize Cdc42's role in establishing polarity, we will employ Cdc42 mutants that bind its effectors selectively.

***S6.11*** WILCOVE, D.S.; Princeton University; *dwilcove@princeton.edu*

***Conserving Animal Migrations: Key Research Challenges***

Around the world, animal migrations are fading away as a result of habitat destruction, barriers and obstacles, overexploitation, and climate change. Integrative biology has a crucial role to play in providing the knowledge needed to protect and restore populations of migratory animals. Four key areas for research include: (1) stopover ecology of aerial migrants, with an emphasis on determining the dispersion and characteristics of rest and refueling sites; (2) demographic connectivity—determining how events at any point in a migratory species' life cycle affect its overall population; (3) impacts of global climate change on migration, especially with respect to the cues animals use to time their journeys and the degree to which migrations of particular species are tied to key phenological events, such as fruiting seasons, leaf emergence, etc.; and (4) the extent to which species can alter the timing, route, or endpoints of their migrations in response to changes in land use or climate.

***59.8*** WILCOXEN, T. E.*; SCHOECH, S. J.; University of Memphis; *twilcoxn@memphis.edu*

***Age-related differences in HPG axis responsiveness to GnRH challenge in Florida Scrub-Jays***

Baseline concentrations of testosterone vary with age in male Florida Scrub-Jays (*Aphelocoma coerulescens*). Levels are relatively low in young and old male breeders and reach their highest average levels in birds aged 5 to 8 years. To determine which component of the hypothalamo-pituitary-gonadal (HPG) axis is responsible for these age-based differences, we used gonadotropin-releasing hormone (GnRH) challenges, delivered via intramuscular injection, of 27 male breeders during the 2009 breeding season. We collected an initial blood sample prior to injection, and subsequent samples at 15 and 30 minutes post-injection; thereby allowing assessment of pituitary and gonadal responsiveness by measuring plasma concentrations of luteinizing hormone (LH) and testosterone, respectively. Young birds had the greatest testosterone response to GnRH challenge and the middle-aged birds responded with a lesser, but significant, increase in T relative to the young birds. GnRH challenge did not significantly elevate testosterone in the oldest males. However, illumination of whether this evidence of reproductive senescence reflects a diminished capacity of the gonads or the pituitary awaits assay for LH in the near future.

***105.6*** WILLIAMS, T.M.*; NOREN, S.R.; BERRY, P.S.; Univ. of California, Santa Cruz, Disney Animal Programs-The Seas, Orlando, FL; *williams@biology.ucsc.edu*

***"Bending" the Rules: The role of cardiovascular exercise responses in protecting the brain of diving marine mammals***

Cardiovascular adjustments associated with the dive response have long been considered major factors for protecting the brain from hypoxic damage and decompression illness (the "bends") in marine mammals. A hallmark of this control is bradycardia, a marked lowering of heart rate during submergence. Seemingly in conflict with the dive response is the cardiovascular response to exercise which typically includes elevated heart rate and a redistribution of blood to active tissues. To determine how these competing responses may compromise neuroprotection in diving mammals, we examined variability in heart rate and diving-induced bradycardia in adult bottlenose dolphins, and used these data to model susceptibility to the bends. EKG signals were monitored continuously with an animal-borne microprocessor during rest and exercise when the dolphins were at the water surface or diving to 10 m. Regardless of position in the water column, swimming exercise resulted in a significant increase in mean heart rate over resting values ($t = -2.331$, $df = 13$, $P = 0.037$ for surface swimming; $t = -2.362$, $df = 20$, $P = 0.028$ for submerged). Exercise responses were superimposed on dive responses when submerged. Thus, mean heart rate during routine swimming was $113 \pm 6$ beats.min$^{-1}$ near the water surface, $47 \pm 4$ beats.min$^{-1}$ when submerged, and approx. 21% higher than the respective resting level for each position. This variability in bradycardia coincident with exercise provides an avenue for increased mobilization of gases associated with decompression illness. Furthermore, it may explain in part the differences in neuroprotecting brain globins observed for mammals specialized for fast swimming or slow diving. (Supported by ONR)

***12.6*** WILLIAMS, Tony D.; Simon Fraser Univ., Burnaby, Canada; *tdwillia@sfu.ca*

***Why do we know so little about mechanisms underlying avian reproduction?***

Recent evolutionary analysis of large, long-term population studies' data has shown that the traits which contribute most to individual variation in lifetime fitness in birds are longevity, clutch size and laying date (but not, for example, egg mass or chick growth). The critical importance of many of these traits, such as clutch size, has been recognised for over 60 years yet our current understanding of the physiological basis of variation in these key fitness-related traits remains poor. In this talk I will explore the reasons for this lack of progress, highlighting and contrasting the challenges and opportunities for specific life-history traits. For example, although there has been a large amount of experimental, physiological work on seasonal breeding we currently lack a basic model for the mechanism(s) underlying female control of onset of egg-laying (the key determinant of timing of breeding). In contrast, a very comprehensive model for physiological control of clutch size was proposed over 20 years ago but virtually no experimental work has been directed towards testing this model. Longevity (senescence) is a rare example of current mechanistic research being directed at a key life-history trait. Currently much of the research effort in avian physiological ecology is being directed at traits for which there is little or no evidence of long-term fitness consequences (e.g. minor egg components, such as hormones or antibodies). I aim to show how an evolutionary perspective should not only be driving our research focus, but should also dictate specific ecologically-relevant experimental design. Future progress in integrating avian evolutionary biology and physiology will require a major shift in research focus.

***S2.8*** WILLIAMS, J.B; Ohio State University, University of Michigan; *williams.1020@osu.edu*

***Functional linkages for the pace of life, life-history, and environment in birds***

Although physiological systems have likely altered as a result of evolutionary diversification of life histories, our understanding of the functional linkages between life-history and physiological mechanisms remains poor. We studied metabolic rate, basal and peak, of tropical and temperate birds. Our data show that tropical birds have a 10-18% lower basal metabolic rate (BMR) than temperate birds, whereas their peak metabolic rates (PMR), elicited by low temperature or forced exercise, were 34% and 28% lower, respectively. This reduction in overall metabolic performance is related to long life span and low rates of reproduction, in contrast with temperate birds, which have higher BMR and PMR, and higher rates of reproduction and mortality. As a beginning to search for underlying mechanisms for differences in metabolic rate between these two groups, we measured their organ masses. Data showed that the mass of heart, liver, kidney, and pectoral muscle were smaller for a given body mass for birds in tropical envi-ronments, which may contribute to their reduced metabolic performance. In addition, we are now culturing fibroblast cells from birds. Thus far, we have compared fibroblasts from temperate birds with similar sized mammals. Fibroblast cells from temperate birds, which have a higher rate of metabolism per unit body mass than do mammals, are more resistant to various stress agents than similar sized mammals. Studies are underway to compare resistance of fibroblasts from tropical and temperate birds. Progress in understanding associations between metabolic rate, reproductive rate and longevity will require an understanding of the functional linkage between whole-organism metabolism and underlying physiological mechanisms that influence its magnitude.

***90.2*** WILLIAMS, S.H.*; SIDOTE, J.; STOVER, K.K.; DAVIS, J.S.; Ohio University, Athens, College of Charleston, Charleston; *willias7@ohio.edu*

***The mechanical loading environment of the jaw during ingestive and rumination chewing in goats***

Chewing mechanically breaks down food to facilitate chemical digestion in and passage through the digestive tract. In ruminants, ingestive chewing occurs upon initial food intake during feeding. Rumination chewing follows a prolonged period of microbial digestion in the rumen and subsequent regurgitation. Combined, ingestive and rumination chewing result in as many as 60,000 chewing cycles per day in domesticated species. Here, we compare the mechanical loading environment of the jaw during ingestive and rumination chewing in goats. Strains along the mandible during ingestive and rumination chewing were recorded using rosette strain gauges. The magnitude and orientation of principal strains, shear strain magnitude, the number of chews per sequence and chewing cycle duration during both behaviors were determined. Strain patterns, including the relative amounts of principal tension and compression on the working and balancing sides, do not differ considerably between ingestive and rumination chewing. However, absolute strain magnitudes during rumination chewing are as much as 200 microstrain higher than during ingestive chewing. When compared to rumination chewing, chewing-side shifts are more common within a sequence of ingestive chewing. Chewing cycle length does not differ markedly between ingestive and rumination chewing. During ingestive chewing, however, chewing sequence length is generally shorter and the number of chews per sequence is more variable. Thus, rumination chewing involves higher and more rhythmic loading of the mandible as compared to ingestive chewing. These data have implications for understanding the influence of chewing loading patterns on jaw form in ruminating artiodactyls.

***3.3*** WILLIS, M.A.*; WERNEIWSKI, M.; AVONDET, J.L.; Case Western Reserve University; *maw27@case.edu*
***Effects of loss of proprioceptive inputs on flight motor outputs of the moth, Manduca sexta L.***
Information from local feedback sensors is known to have profound effects on the flight motor patterns of tethered flying insects, and has been shown to effect maneuvering in freely flying insects. Much of what we know in this area is from studies of the locust, whose front and hind wing pairs are coordinated, but move independently each other. Little is known about the role of local sensory feedback on flight in the Lepidoptera, whose front and hind wings are linked and appear to function as one. We previously showed that freely flying male moths, *Manduca sexta*, which had a local feedback sensor known as the tegulae removed from all four wings, showed specific deficits in flight free flight performance. Moreover, the effects of these deficits were mitigated in a context-dependent way. Male moths without their tegulae flew better in female pheromone then in clean air. To understand the mechanisms underlying the observed decrease in free-flight performance, we recorded from the wing elevator and depressor muscles from *M. sexta* males in tethered flight preparations, both before and after tegula removal. After the tegulae were removed the wing beat frequency decreased and the activity of the wing elevator muscles became less regular, both with respect to each other and the wing depressor muscles. Supported by AFOSR #FA9550-07-1-0149.

***102.3*** WILSON, R S*; SMITH, M D; Univ. of Queensland, Australia; *r.wilson@uq.edu.au*
***What makes a great footballer? Trade-offs between athleticism and skill in human performance***
Animal performance during critical behaviours such as predator-escape, prey-capture and fighting is determined by a complex assortment of underlying traits. Maximal physical capacity is widely appreciated to be an important determinant of performance during these complex behaviours. However, the role of individual skill in determining performance is virtually unknown and its role in the evolution of physical function has been surprisingly dismissed. Skill is likely to be a key determinant of performance for many complex behavioural traits. For example, male fighting capacity is likely to be determined by more than just strength alone, but also fighting technique, coordination, and decision-making. Given the difficulties associated with assessing skill in non-human organisms, we used analyses of human performance to investigate the possible interactions and trade-offs between skill and athletic ability. Performance of individuals during staged one-on-one football games was used as our model complex performance trait. Footballing ability was assessed for 30 subjects (aged 17-31 yrs) and their performance in 16 different athletic and skills tasks was also quantified. We competed ten different models that evaluated the relationships between individual morphology, athleticism and skill to overall footballing performance. We found that most maximal athletic tasks were positively correlated, as were many skill component tasks. However, there was no evidence of any positive or negative correlations between maximal athletic performance and skill, suggesting these traits may be completely independent and under different selective pressures or even under separate genetic control. Implications of this work for the evolution of vertebrate physical performance will be discussed.

***15.4*** WILSON, Caroline H.*; CHRISTIE, Andrew E.; Denison University, Granville, OH , Mount Desert Island Biological Laboratory, Salisbury Cove, ME; *wilsonc@denison.edu*
***Distribution of allatostatin C-like immunoreactivity in the central nervous system of the copepod crustacean Calanus finmarchicus***
PICSF- or *Manduca sexta*- C-type Allatostatins(AST-C) are a family of neuropeptides known to regulate juvenile hormone in insects. AST-C peptide isoforms are conserved within pancrustacea, but it has not yet been characterized in a primitive crustacean such as the copeped. One species of copepod, *Calanus finmarchicus*, is abundant in the North Atlantic and is a major contributor to the summer zooplankton biomass, thus making it an important component of the marine food web. In order to assess whether copepods contain AST-C-like peptides, we used a pQIRYHQCYFNPISCF antigen to investigate whether AST-C was present in the nervous system of *C. finmarchicus*. Our results indicate AST-C is present in the neurons in the protocerebrum of the brain, several peripheral ganglia associated with feeding appendages, and in the ganglia controlling the swimming feet. Some of the AST-C containing neurons extend neurites into the periphery innervating muscles such as the ventral longitudinal muscles and extensors and flexors of the swimming feet. This labeling pattern appeared to be consistent across sexes and developmental stages, with only the youngest stages examined showing a difference in the swimming leg neurons. We also complimented the AST-C immunolabeling with other proteins (acetylated alpha tubulin, Allatostatin-A, and tachykinin-related peptide) to place our findings into context with the entire nervous system and other peptidergic neurons. Our results indicate that AST-C antibodies label a unique set of neurons in the copepod from other antigens and that several of these neurons are associated with feeding appendages.

***7.5*** WINDSOR , DJ*; OWENS, GL; ALLISON, WT; TAYLOR, JS; University of Victoria , University of Alberta ; *dianawin@uvic.ca*
***Characterizing the pattern of opsin gene expression in the retina: insight into how guppies (Poecilia reticulata) see their mate's true colors.***
Phenotypically guppies (*Poecilia reticulata*) display sexual dimorphism with regard to size and coloration, with males having a particularly colorful and polymorphic pattern. Interestingly, guppies also have one of the largest opsin gene repertoires yet described. This opsin repertoire includes one SWS1 gene, two SWS2 genes (A&B), four LWS genes (S180, A180, P180, S180r), one RH1 gene, and two RH2 genes (1&2). This expanded repertoire may allow for enhanced wavelength discrimination ability and/or precise tuning to the photic environment. Therefore guppies may look even more colorful to one another than they do to human observers. However, this all depends upon whether these genes are expressed in the retina at the same time and on the relative positions of cone cells expressing these different opsins. In order to investigate this we used *in situ* hybridization to determine when and where guppy opsin genes are expressed. This was undertaken in both males and females in order to determine whether sexually dimorphic expression was present. Understanding the color discriminatory ability of the guppy is pivotal to comprehending male color based sexual selection, a trait exhibited throughout the animal kingdom.

***62.8*** WINSTON, Judith E.*; MIGOTTO, Alvaro E.; VIEIRA, Leandro M.; Virginia Museum of Natural History, CEBIMar, University of Sao Paulo, Brazil; *judith.winston@vmnh.virginia.gov*

***The Interstitial Encrusting Fauna of Subtidal Sand, a Significant Understudied Habitat.***

Studies carried out at two subtidal sand bottom sites, off the Florida east coast in 1982-4 and off the coast of São Paulo State, Brazil in 2002, showed assemblages of encrusting bryozoans utilizing the surfaces of mineral grains and sand to gravel size shell fragments, both at the sand-water interface, and interstitially. Larvae of sand encrusting species settled preferentially on different sized sand and shell grains. Colonies also became sexually reproductive at much smaller sizes than colonies of species occupying larger substrata The mixed terrigenous and carbonate sand habitats also supported other kinds of encrusting organisms such as serpulid and spirorbid polychaete worms, hydroids, entoprocts, and forams, as well as the more familiar motile meiofauna. Twenty-two exclusively interstitial encrusting species have been found at the two areas so far. A re-collection at the one of the Brazilian stations in July 2009 found the same species thriving as in November 2002, indicating the persistence of the community despite its unstable environment. At both the Florida and Brazilian sites living and reproductive colonies of bryozoan species characteristic of larger subtidal hard substrata, were found on sand or gravel size grains, indicating the potential importance of an interstitial refuge in maintaining and dispersing subtidal and shelf encrusting organisms even where larger substrata are absent and taxa have short-lived larvae.

***36.4*** WOLF, BO*; MCKECHNIE, AE; Univ. of New Mexico, Albuquerque, Univ. of Pretoria, Pretoria; *wolf@unm.edu*

***Climate change increases the likelihood of catastrophic avian mortality events during extreme heat waves***

Predicting how human-induced climate change will affect animal distribution, abundance and diversity requires an understanding of the mechanisms underlying both the direct and indirect effects. Although little studied, among the most important direct effects may be catastrophic mortality associated with extreme heat and drought. Climate models predict an increase in both the frequency and severity of these extreme climate events, and historical records demonstrate the potential for catastrophic mortality. Here we quantify the functional mechanisms underlying avian mortality associated with heat stress and the lack of water. We develop a physiological model that predicts rates of evaporative water loss and survival times as a function of body mass and dehydration tolerance. Current and historical accounts already document catastrophic mortality caused by hyperthermia or through dehydration. Our projections suggest that increasing global temperatures, combined with increased frequency and intensity of heat waves and drought, will result in more frequent catastrophic mortality, and could depopulate regional bird communities.

***41.4*** WONE, B*; DONOVAN, E/R; HAYES, J/P; University of Nevada, Reno, University of California, Riverside; *woneb@unr.edu*

***Metabolomic evidence that increased basal metabolic rate is linked to elevated metabolism in skeletal muscle of mice selected for high maximal metabolic rate***

At the interspecific level, basal metabolic rate (BMR) and maximal metabolic rate (MMR) are typically correlated but the functional basis for this has proven elusive. The main contributors to BMR are the liver and kidneys while the main contributors to MMR are active skeletal muscles. Consequently, one of the pivotal challenges in the physiology of aerobic metabolism is elucidating the functional connection between BMR and MMR. We used gas chromatography-mass spectrometry (i.e., a metabolomic approach) to examine metabolites in the liver and skeletal muscles in *Mus musculus* from generation 7 of an artificial selection experiment on aerobic metabolism. After 7 generations of directional selection for increased mass-independent MMR, high MMR mice showed a 10.2% increase in mass-independent MMR and a concomitant 2.8% increase in mass-independent BMR compared to control mice. There were no significant differences between high MMR and control mice in the metabolic profiles of the liver or plantaris muscle. For the gastrocnemius muscle of mice selected for high MMR, multivariate statistics highlighted increased concentrations of acetylglutamic acid, aspartic acid, &beta-alanine, glutamic acid, succinic acid, and threonine—consistent with elevated metabolism in the skeletal muscle. These findings suggest that increased BMR in the high MMR mice is linked to elevated metabolism in the skeletal muscles that are more active during locomotion. Supported by NSF IOS 0344994.

***S10.4*** WOODIN, S.A.*; WETHEY, D.S.; VOLKENBORN, N.; University of South Carolina, Columbia; *woodin@biol.sc.edu*

***Infaunal hydraulic ecosystem engineers: the cast of characters, biogeography and possible impacts.***

Porewater bioadvection results from behavior specific, hydraulically generated pressure fields that change in direction and magnitude over time scales of minutes to hours and have a radial extent of 50 cm or more. Hydraulic activities thus create transient conditions within the sediment from the depth of individuals' biotic activities, radially outward to the sediment surface. Our focus is three fold. First, which organisms show such activities and are there species and behavior specific bioadvective signatures in either porewater movements or pressures? Secondly, where do such organisms occur and at what densities; so, what is the biogeographic distribution of bioadvective dominance? Finally, what are the impacts on the functioning of benthic systems and how do bioadvective dominated systems differ from diffusion based sedimentary assemblages or bioturbation based sedimentary assemblages?

***28.3*** WOODS, H. A.*; POTTER, K. A.; Univ. of Montana, Univ. of Arizona; *art.woods@mso.umt.edu*
***Life in leaf boundary layers: how two millimeters of still air affects the performance and ecology of small insects***
An allometric claim: what we know about an animal's environment scales to its body size with $b > 1$. That is, we know disproportionately a lot about environments around big things but astonishingly little about environments around small things; for a physiological ecologist, there is plenty of room at the bottom. Here we explore microenvironments occurring on leaf surfaces and ask: how do they affect the physiology and ecology of an insect herbivore, *Manduca sexta*? *M. sexta* are common in deserts of the southwestern United States, and females oviposit primarily on two host species, *Datura wrightii* and *Proboscidea parviflora*. Eggs develop for several days and produce neonates that hatch and begin to feed nearby. Eggs and neonates are small enough (project ~ 1 mm from the leaf surface) to be immersed in leaf boundary layers most of the time. Using custom-built, field-deployable computers equipped with small sensors, we logged temperatures and humidities in leaf boundary layers of several pairs of host plants near the Chiricahua Mountains, in southeast Arizona. Leaf surface conditions on the two host species were radically different both from ambient macro conditions and from one another: both host species provided cooler, wetter conditions than ambient air, but *P. parviflora* much more so than *D. wrightii*. In some cases, leaf temperatures of *P. parviflora* were 10 °C lower and vapor densities twice as high, compared to *D. wrightii*. Moreover, these biophysical differences translated into different amounts of water lost by eggs, which we showed by tracking masses of eggs glued onto host plants and control surfaces (paper) for 48 hours. Do these differences in water lost matter for egg performance? A series of lab experiments suggests that they do, but the outcome depends on the evolutionary history of the eggs and on host plant identity.

***S5.2*** WULFF, Janie; Florida State University; *wulff@bio.fsu.edu*
***Sponge regeneration in ecological context***
Creative application of new imaging and molecular techniques to sponge larval development and a variety of sub-organismal levels in adult sponges has recently demonstrated greater potential for integration and co-ordination of developmental and physiological responses within individuals than had previously been imagined (e.g., Leys, et al., 2009. ICB 49:167-177, and references therein). Nevertheless, by comparison with other metazoans, adult sponges are structurally simple and homogeneous. Rather than being a liability, simple homogeneous design may allow sponges to regenerate, reorganize and reorient, and propagate asexually to a greater extent than other animals; and the resulting morphological flexibility may contribute significantly to the continued success of sponges. Comparisons among sponge species in how effectively they recovered after damage by a hurricane revealed an inverse relationship between resistance to damage and recovery from damage, suggesting the possibility of trade-offs between traits that promote regeneration and traits that prevent the need for regeneration. Data accumulated from experiments and long-term monitoring of Caribbean sponges typical of coral reefs, seagrass meadows, and mangrove prop roots evaluate sponge regeneration in the contexts of partial mortality due to consumption by predators (fish, starfish, nudibranchs), physical disturbance, disease, and smothering by neighbors (colonial ascidians, other sponges). Fragment generation and reorientation experiments demonstrate differences in regeneration capacities of different portions of a sponge individual under some circumstances. As frequencies of different sources of partial mortality change (e.g., fewer predators), and the contexts for evaluating the adaptive significance of regeneration change (e.g., increasingly obstructed recruitment surfaces), variation in regeneration capabilities may play a key role in shifting the balance for and against particular sponge species.

***27.2*** WYNEKEN, J*; SALMON, M; HAMANN, M; Florida Atlantic Univ., James Cook Univ.; *jwyneken@fau.edu*
***Swimming and Early Diving Behavior by Juvenile Flatback Sea Turtles (Natator depressus)***
Flatback sea turtles lack an oceanic phase in their early life history. Instead, the turtles grow to maturity in shallow turbid shelf waters of tropical Australia. We compared (i) frenzy and postfrenzy swimming to migratory swimming in species with an oceanic stage and (ii) diving behavior development in the neonate flatbacks. Swimming data were obtained from hatchling turtles. We speculated that the risk of predation selected for the flatback activity patterns that decline little. During 4 days of observations, nocturnal flatback activity declined little compared with other sea turtle hatchlings that migrate into the open ocean. Diurnal activity was similar in all species. Dive data were collected from 1 – 7 wks old turtles during 30 min trials in shallow (9-12 m) turbid waters near Townsville, QLD, Australia. A total of 194 dives (21 turtles) was recorded. Most were short and shallow; yet even at 4-weeks old flatbacks could dive to the bottom. We compared dives among species to identify behavioral differences in flatback dive development from leatherbacks (*Dermochelys coriacea*) and green turtles (*Chelonia mydas*) that at the same age, live in clear, deep oceanic waters . Most flatback dives had V- or W-profiles whereas most leatherbacks dives had V-profiles, while in green turtles, dives had V- or U-profiles. Flatbacks, unlike the other species did not dive deeper or longer as they grew older. Most flatback swam slowly during dives (like leatherbacks) but in some cases flatbacks swam much faster than green turtles. Flatbacks could dive repeatedly with just a brief pause at the surface to breathe. We speculate that flatback diving form, in their murky habitats, enables: (i) efficient searching for prey thru the water column, (ii) minimizes surface time allowing return to previously attractive locations, and (iii) rapid escape from predators.

***56.1*** YAMAMOTO, Y*; LUCKENBACH , JA; GOETZ, FW; YOUNG , G; SWANSON, P; Univ. of Washington, Seattle, Northwest Fisheries Science Center, Seattle, Univ. of Wisconsin, Milwaukee ; *yojifish@u.washington.edu*
***Gene Expression Changes during Early Secondary Oocyte Growth and Onset of Atresia in Coho Salmon***
Mechanisms regulating the normal progression of oocyte growth versus onset of ovarian atresia are poorly understood. To gain a better understanding of these processes, we exposed previtellogenic, two-year old coho salmon to prolonged fasting to induce ovarian atresia, while maintaining control fish on a normal diet that would promote continued development of the ovary. Fasted salmon showed significantly lower gonad weights, oocyte diameters, and plasma estradiol-17β levels relative to normally fed animals by week 14. A higher proportion of atretic oocytes was observed in ovaries of fasted fish at week 14 and numbers further increased by week 17. Suppression subtractive hybridization (SSH) cDNA libraries using ovaries from fed and fasted animals at week 14 were generated. The library composed of genes up-regulated in the fed ovary included steroidogenesis-related genes and TGFβ superfamily members, such as 3β-hydroxysteroid dehydrogenase (*hsd3b*), P450-aromatase (*cyp19a1a*), and anti-Mullerian hormone (*amh*). The library composed of genes up-regulated in the fasted ovary included genes associated with apoptosis, such as programmed cell death protein 4 (*pdcd4*) and lipopolysaccharide-induced TNF factor (*litaf*). The differential expression of genes identified by SSH was confirmed with quantitative PCR over the time course of the study (0-17 wks). Interestingly, ovarian mRNA levels for *hsd3b*, *amh*, and *pdcd4* were significantly different between fed and fasted fish by week 9, before endocrinological and histological differences were observed. This study has identified ovarian genes involved in normal early secondary oocyte growth and potential markers of atresia onset.

***90.3*** YEH, K.D.; POPOWICS, T.*; RAFFERTY, K.; HERRING, S.; University of Washington, Seattle; *popowics@u.washington.edu*
***The Effect of Occlusion on Alveolar Bone Biomechanics in the Miniature Pig, Sus scrofa***
This study investigated the role of occlusion in the biomechanical properties of alveolar bone in the miniature pig, *Sus scrofa*. The hypothesis tested was that the periodontium supporting an occluding tooth would show greater stiffness and less strain than that of a non-occluding tooth. Teeth opposing the erupting lower first molar ($M_1$) were extracted on one side and occlusion was allowed to develop on the contralateral side. A terminal experiment measured *in vivo* buccal alveolar bone strain on occluding and non-occluding sides. *Ex vivo* alveolar strains were measured on mandibular segments through application of axial compression at 0.3mm/s until 890N using a materials testing machine (MTS/Sintech). Principal strains were calculated at 890N, and whole specimen stiffness was calculated at low load (200-445N) and high load (445-890N) ranges. *In vivo* buccal shear strains were higher in the alveolar bone of the occluding side vs. the extraction side (mean of 471με *vs*. 281με, respectively; Wilcoxon signed ranks test, p=0.04). *Ex vivo* shear strains, however, showed no significant differences in magnitude between sides. Stiffness differed significantly between extraction and occlusion side specimens in the low load range (344 *vs*. 668MPa, respectively; Wilcoxon signed ranks test (p=0.043), but were similar within the high load range (935 *vs*. 1216MPa). Greater *in vivo* shear strains may indicate more forceful chews on the occluding side, whereas the similarity in *ex vivo* bone strain magnitude suggests a similarity in alveolar bone structure and occlusal load transmission regardless of occlusal status. The greater stiffness of occluding side specimens at low loads, however, indicates fortification of the periodontal ligament to resist occlusal loads. Supported by NIH/NIDCR DE 015815.

***13.1*** YEN, J*; CHANG, Y; , ; Georgia Tech, Atlanta, ; *jeannette.yen@biology.gatech.edu*
***Locomotory kinematics of the pteropod Limacina helicina***
Limacina helicina is a thecosome pteropod that exists exclusively in the plankton, where swimming as well as other buoyancy mechanisms are required to offset the weight of its shell. When not feeding, swimming is employed for predator evasion and migratory purposes. Kinematic analyses of shipboard records of locomotion in 3D and fluid flow generated by 1-3 mm L. helicina revealed a distinctive swimming movement that propels the body in a radial axis, pitching negatively and positively during the stroke cycle. Swimming episodes included straight trajectories the majority of the time along with helical paths. Swimming individuals rotated their bodies to move in a mean vertical direction upwards followed by instances of straight descents. The wing stroke is a complex, three-dimensional motion with elements of rowing and flapping as well as rotation. Its erratic flight pattern is brought about by an asymmetry in the shell that manifests itself as an asymmetry between the left and right angular wing displacements. Mean speeds varied from 13-44 mm s-1 for straight ascents to a little higher for helical paths. Sinking speeds were 5-45 mm s-1 whereas wing beat frequencies decreased with size from 4.5-9.4 Hz. Living in a Re range between 20-100, this pelagic pteropod exhibits a fascinating mode of locomotion.

***25.1*** YOO, E.H.*; CARROLL, A.M.; BIEWENER, A.A.; Harvard University, University of Evansville; *edwinyoo@gmail.com*
***Forelimb dynamics and kinetics during landing jumps in African pygmy Goats (Capra hircus)***
Studies of jumping behavior have primarily focused on long jumps and climbing jumps that raise the center of mass. Previous jumping behavior studies have focused their analysis on the function of the hind limb as the primary source of propulsion. In contrast, landing jumps require the use of forelimbs and have received far less attention. To explore the dynamics and kinetics of forelimb during landing jumps, we collected kinematics and ground reaction force data from a single forelimb of three adult male African Pygmy goats (*Capra hircus*) performing landing jumps from a 1.3 m platform using high-speed video and force plates. Inverse dynamics analysis was used to calculate external power, work, and moments for elbow, wrist, and metacarpal joints. This research was partially funded by the National Science Foundation IGERT Grant DGE #0221682

***101.8*** YOUNG, BA; Univ. Massachusetts Lowell; *Bruce_Young@uml.edu*
***Neural Control of the Snake Leg***
In vertebrates rhythmic alternating bilateral movements, such as the movements of the appendages typically seen during locomotion, are generated by a group of spinal motor neurons commonly termed a central pattern generator or CPG. While the CPGs associated with a variety of movements have been described from several vertebrate taxa, little is known about the evolution of this local neural control. The evolutionary loss of the snake leg may be a promising system in which to explore phylogenetic transitions in the CPG. The presumed ancestral varanoid radiation used robust hind limbs for tetrapodal locomotion, early snake fossils have hind limbs, many of the extant basal snakes have pelvic and/or hind limb skeletal elements, while the derived snakes lack all such bony features. Analysis of the neural control of the snake leg can address the central hypothesis that evolutionary loss of the hind limb was not accompanied by change in the associated CPG, thus the controlling neural system evolves in a pattern and rate that is separate from that of the musculoskeletal elements being controlled. The initial exploration of this system has centered on the ball python (*Python regius*) a basal macrostomatan in which the males have a pelvic girdle coupled to femora that project externally (the cloacal spurs). Stimulation of the femoral protractor coupled with fluorescent retrograde labeling permits identification of the spinal motor neuron pool associated with this muscle. Extracellular recordings from these motor neurons can then identify rhythmic alternating discharge patterns characteristic of CPGs.

***74.3*** YOUNG, R.C.*; HAUSSMANN, M.F.; BARGER, C.P.; KITAYSKY, A.S.; University of Alaska Fairbanks, AK, Bucknell University, Lewisburg, PA; *rebecca.young@alumni.iu.edu*
***Effects of nutritional stress during early development on sexual maturation and life expectancy in long-lived seabirds***
Nutritional stress during juvenile development is known to have long-term detrimental effects in many species. In long-lived seabirds it can have large effects on lifetime fitness by potentially delaying sexual maturation and decreasing life expectancy. By definition, it is expected that a long-lived species will be adapted to resist reductions in life expectancy even at the expense of rapid sexual development. We compared the effects of nutritional stress during early development on sexual maturation, as measured by development of reproductive systems, and life expectancy, as reflected in telomere dynamics. Our subjects were two closely related puffins, the rhinoceros auklet (*Cerorhinca monocerata*) and the tufted puffin (*Fratercula cirrhata*), whose chicks exhibit drastically different physiological responses to food shortages. For each species one group of chicks were fed ad libitum and another were food restricted. We expect that if nutritional stress affected the fitness measures of sexual maturation and life expectancy, that sexual maturation would be delayed before lifespan was shortened. Initial results suggest that both species may delay sexual maturation in response to food shortages. We will also present results comparing life expectancies, as reflected in telomere loss rates, between control and nutritionally stressed groups of rhinoceros auklet and tufted puffin chicks.

***62.6*** ZAKAS, C*; HALL, D; Univ. of Georgia; *zakas1@uga.edu*
***Can Asymmetric Dispersal Explain the Maintenance of Larval Dimorphism in the Benthic Polychaete Streblospio benedicti ?***
Offspring dimorphism is an unusual life history occurrence yet it has evolved in a broad range of taxa. The rarity of this strategy suggests that the circumstances under which two offspring modes can be maintained within a species may be very narrow, or that such a strategy is unstable and indicates an evolutionary transition. *Streblospio benedicti* is one such species that exhibits a larval dimorphism where individuals in the same population produce either small (~70µm) or large (~150µm) planktonic offspring. Small offspring have an obligate planktonic phase that lasts 2-3 weeks before settlement. Large offspring are competent to settle in only 1-8 days. This difference in development time could potentially lead to large differences in larval dispersal ability, and suggests a trade-off between larval retention within a site and migration to a new site. Our objective is to determine whether the difference in migration and retention between the two morphs is sufficient to maintain the two modes within a population. We use an analytical population model to address this question. When dispersal between sites is asymmetric, implying that some suitable habitats within a population are upstream from others, the model predicts stable maintenance of both types for some parameter combinations. In order for an equilibrium to exist, small larvae migrating downstream must have higher survival than those migrating upstream, and the fecundity through retained larvae must be relative low for small larvae compared to large larvae. We conclude that the maintenance of larval dimorphism in *S. benedicti* could reasonably be explained by asymmetric migration among suitable habitats.

***69.3*** ZANI, Peter A.; Gonzaga University; *zani@gonzaga.edu*
***Effects of nighttime temperature on reproduction of side-blotched lizards (Uta stansburiana)***
The life-historical responses of organisms are often temperature dependent, particularly in ectotherms, which respond to a favorable growing season by investing in growth and reproduction. Environmental variation in temperature (e.g., along latitudinal clines or between years) may affect reproductive investment and timing. However, as other factors that influence reproduction (e.g., food, moisture) may confound spatial and temporal variation, I used a surrogate for natural thermal variation in which I tested the effects of nighttime temperature on the production of second clutches of eggs in side-blotched lizards (*Uta stansburiana*). Starting on the first day of the reproductive cycle (i.e., the day after oviposition), females (12 in each treatment) were exposed to warm (27°C), cold (5°C) or intermediate (16°C) nights, but given a common-garden environment during the day with unlimited food and thermoregulatory opportunity. There was no difference among temperature treatments in the probability of females laying a second clutch (~75%). Nor was there any difference among treatments in clutch size (4.4 eggs), egg mass (0.34 g per egg), relative clutch mass (55% of dam mass), or egg incubation period (50 d). The only effect was on reproductive timing; females exposed to cold nights laid second clutches 6 d later than those from warm nights (inter-clutch interval = 40 vs. 34 d, respectively), with those from intermediate nights falling in between (36 d). These results indicate that nighttime temperatures do not affect life history via reproductive effort, but only timing. Furthermore, these effects do not hold over to embryo development. In other words, if given ample daytime thermoregulatory opportunity, female lizards are able to compensate for environmental variation in nighttime temperature in every way except reproductive timing.

***29.3*** ZATTARA, E.E.*; BELY, A.E.; University of Maryland,College Park; *ezattara@umd.edu*
***Evolution of developmental trajectories: regeneration and fission in naidid annelids***
Fission has evolved in many phyla, and several lines of evidence suggest that this new developmental trajectory arises by modification of pre-existing regenerative capabilities. To investigate how fission evolves from regeneration, we studied naidid annelids, small freshwater worms. Most naidids can regenerate a head or tail, and many can also reproduce asexually by fission. We performed a detailed comparison of fission and regeneration in one focal species, *Pristina leidyi*, as well as comparative studies of the two processes across multiple naidids. We focused on cell proliferation, general morphogenesis, muscle development and neural development, paying close attention to relative timing of events during regeneration and fission. When these trajectories are compared side by side, extensive similarities are apparent. However, several elements demonstrate timing shifts, most notably in the innervation of developing tissues and during reconstruction of the central nervous system, and each trajectory shows a number of exclusive elements, including aspects of muscle development, gut modification, and final number of segments formed. While similarities between fission and regeneration reflect a common developmental origin, differences may reflect adaptations in each trajectory to distinct functions (survival vs. reproduction) or may result from developmental systems drift between these two trajectories. Preliminary studies in other naidid species indicate that while the regenerative process looks similar across species, fission shows some striking differences, providing evidence, initially suggested by recent molecular phylogenies, that there have been two independent gains of fission within this group. Future comparative work will be aimed at identifying which components of regeneration and fission are robust to change and which are most evolutionarily labile.

***100.4*** ZELDITCH, M.L.*; SWIDERSKI, D.L.; Univ of Michigan, Ann Arbor; *zelditch@umich.edu*
***Integration of squirrel mandibles***
Understanding how developmental modules are assembled into functionally integrated morphologies is central to our understanding of biological organization. Morphological integration, a key part of that organization, coordinates variation among parts, maintaining relationships among them despite their individual variation. Integration can arise by direct interactions between developmental pathways or by genes expressed independently along two or more pathways, and both of these, or correlational selection, can coordinate evolutionary changes in form. To determine whether evolutionary integration might be directed by development, we examine integration of the mandible in a representative tree squirrel, *Sciurus niger*, analyzing phenotypic integration and that due to direct interactions and compare these components to evolutionary integration in a lineage of tree squirrels. To analyze integration, we subdivide the mandible into 11 parts, dissecting structures that arise from a single mesenchymal condensation to assess correlations within as well as between them. Evolutionary integration is higher than phenotypic integration or direct interactions because there are more connections between parts, and those connections are stronger, on average. It is also differently structured; evolutionary correlations include some unique to one of the two developmental patterns and those not found in either. The high level of evolutionary integration is not peculiar to the functionally and morphologically homogeneous tree squirrels; even higher evolutionary integration is seen in the more diverse group of ground squirrels and chipmunks, which have a greater density of connections to the incisors. These different patterns of evolutionary integration, neither of which resembles phenotypic integration, suggest that selection rather than development integrates mandibular evolution.

***S1.4*** ZELLER, R.W.; San Diego State University; *rzeller@sciences.sdsu.edu*
***Tunicate genomics: a window into chordate development and evolution***
Tunicates, particularly ascidians, are an excellent biological system in which to study gene regulatory mechanisms important during embryological development. Because of their phylogenetic position within the chordates, tunicates will provide insight into the evolution of chordate gene regulation. Three tunicate genomes have been sequenced to date: two ascidians – *Ciona intestinalis* and *C. savignyi*, and one larvacean – *Oikopleura dioica* – possessing the smallest known chordate genome. This wealth of genomic information, coupled with extensive EST collections from all three species, has allowed researchers to initiate genome-level investigations of tunicate development. The *Ciona* genome encodes about 15,000 genes, but is one twentieth the size of typical vertebrate genomes. Tunicate genomes lack extensive gene duplication events thus gene regulatory mechanisms are believed to be simplified compared to vertebrates. A review of the current *Ciona* genome assembly will be presented and examples from genome-scale research efforts will be discussed.

***31.7*** ZIGLER, Kirk S*; BYRNE, Maria; RAFF, Rudolf A; RAFF, Elizabeth C; LESSIOS, H A; Sewanee: The University of the South, University of Sydney, Indiana University , Indiana University, Smithsonian Tropical Research Institute; *kzigler@sewanee.edu*
***Natural hybridization in echinoderms: a case study from the sea urchin genus Pseudoboletia***
Confirmed cases of natural hybridization in echinoderms are limited to six genera, spread across the echinoids, asteroids, and holothuroids. We suspected hybridization between the sea urchins *Pseudoboletia indiana* and *P. maculata* based on the presence of morphologically intermediate individuals in a sympatric population at Sydney, Australia. We confirmed that hybridization was occurring by determining the mitochondrial cytochrome oxidase I haplotype, nuclear bindin genotype, and, when possible, egg size of individuals with a range of morphologies. We then characterized the conditions related to hybridization between these species by examining their distribution in the field, annual spawning cycles, cross-fertilization efficiencies, molecular divergence at the sperm protein bindin, and time since divergence from a common ancestor. We found that, (1) morphology is a good indicator of genetic background; (2) members of the two species can be found within a meter of one another in the field; (3) the two species have partially overlapping annual reproductive cycles; (4) they cross-fertilize easily, which is correlated with minimal bindin divergence; and (5) that the two species last shared a common ancestor around 2 mya. We compare these results to other examples of natural hybridization in echinoderms, and other animal taxa.

***77.3*** ZIMMER, Richard; Univ. of California, Los Angeles; *z@biology.ucla.edu*
***Food falls, feeding attractants, and organization of complex chemical signals***
Organic food falls play critical roles in structuring communities within coastal ocean, estuarine and deep sea environments. The aggregation of carrion feeders over time near enrichment sites can invite higher-order consumers, thus causing trophic cascades while increasing species richness and altering pathways of energy flow and community metabolism. Over the last 20 years, we have performed experiments on the chemistry of organic food falls and on the attraction of crustacean and molluscan scavengers and predators to enrichment sites. Across field sites (California, Alaska, South Carolina New Zealand), there was surprising concordance among results. Chemical composition of leachates from a wide range of carrion was extremely dynamic following animal sacrifice and introduction into each ocean habitat. Many of these changes could be attributed directly to microbial decomposition, but autolytic degradation also contributed to the overall signatures, especially in a growing correlation over time among dissolved-free (DFAA) and –combined (DCAA) amino acid pool compositions. Scavenger recruitment to food falls covaried positively with DFAA and DCAA fluxes from carrion, but did not scale according to either the flux of carbohydrates or lipids. For DFAAs, variation in scavenger abundance ultimately was attributed to the relative magnitude of release and not to differences in mixture blends. In summary, organic nitrogen often is a limiting dietary factor in ocean habitats, and thus, is a prized commodity. The combined strength of DFAA/DCAA release is, however, a reliable cue for scavengers tracking scents towards finding organic food falls and valuable nitrogen rewards.

***62.2*** ZIMMER, C.A.*; STARCZAK, V.R.; ZIMMER, R.K.; Univ. of California, Los Angeles, Woods Hole Oceanographic Inst., MA; *cazimmer@biology.ucla.edu*

***Where larval supply fails to forecast settlement***

Forecasting larval settlement from supply is critical in designing marine protected areas and developing recovery strategies for highly impacted regions. Such predictions have been seriously data limited. We simultaneously measured biological, physical and geochemical variables in a subtidal, muddy habitat, including settlement selectivity (24 h, flush trays); infaunal density in ambient sediments; larval/juvenile density in surficial flocculated particulates (floc); time series of near-bottom (0.75 mab) larval concentrations (moored, automated, zooplankton pump) and of flow (1 mab; S4 electromagnetic current meter). Polychaetes, presented here, were the most abundant taxon at the site. Supply did not predict settlement. The variables fluctuated widely, being decoupled from each other and the tidal currents. Recruitment into tray sediments was suggestive of active choice, but means were not significantly different due to high variances. Moreover, time series of near-bed larval concentrations were extremely spiky. Floc, with high larval/juvenile densities ($10^5$-$10^6$/$m^3$), may have an unsung role in settlement dynamics. Of the two most abundant species in floc, *Mediomastus ambiseta* was dominant at, and *Sabellaria vulgaris* (native to sands and cobbles) was absent from, the study site. *Mediomastus* was not collected in the near-bed plankton, but dominated the trays and cores, whereas *Sabellaria* was extremely abundant in near-bottom waters, but missing from the bed (trays and cores). With its substantial reservoir of potential settlers, floc touching down on the bottom may seed it with native fauna, while retaining species naturally residing elsewhere. Here, where larval supply failed to forecast settlement, mobile near-bed floc could be an important factor enhancing settlement variability.