Speed Talk Session			
July 19 **Chair: Zeynep Temel, Carnegie Mellon University**			
Order	Speaker	Title	Abstract
A01	Adriane Fernandes Minori	Power Amplification for Jumping Soft Robots Actuated by Artificial Muscles	Robots composed of soft materials can passively adapt to constrained environments and mitigate damage due to impact. Given these features, jumping has been explored as a mode of locomotion for soft robots. However, for mesoscale jumping robots, lightweight and compact actuation are required. Previous work focused on systems powered by fluids, combustion, smart materials, electromagnetic, or electrostatic motors, which require one or more of the following: large rigid components, external power supplies, components of specific, pre-defined sizes, or fast actuation. In this work, we propose an approach to design and fabricate an electrically powered soft amplification mechanism to enable untethered mesoscale systems with continuously tunable performance. We used the tunable geometry of a liquid crystal elastomer actuator, an elastic hemispherical shell, and a pouch motor for active latching to achieve rapid motions for jumping despite the slow contraction rate of the actuator. Our system amplified the power output of the LCE actuator by a factor of 8.12 × 103 with a specific power of 26.4 W/kg and jumped to a height of 55.6 mm (with a 20 g payload). This work enables future explorations for electrically untethered soft systems capable of rapid motions (e.g., jumping).
A02	Michael Dickey	Soft Actuators Based on Liquid Metal	This talk will discuss recent progress in utilizing gallium-based liquid metals for actuation. The promise of soft devices—wearable electronics, implantables, soft robotics, e-skins, sensors—has accelerated the demand for soft, flexible, and stretchable energy sources and actuators. The speed talk will discuss the use of liquid metals for actuation via the use of interfacial tension. Liquid metals have the largest surface tension of any liquid at room temperature. The interfacial tension can be modulated significantly using electrochemical reactions. These changes in tension can generate forces to create actuators, muscles, and jumping droplets. This work is interesting because it provides a route to actuate devices using entirely soft materials that are controlled electrically.
A03	Yue Zheng	Anomalous inflation of a nematic balloon	Inflation of an elastomer balloon is important for both fundamental and engineering studies. Here I introduce a new phenomenon during the inflation of a cylindrical balloon made from nematic elastomer, which can generate large deformation through fast actuation. We found that with a small increment of inflating pressure, the balloon contracts significantly along its axial direction while it expands in its radial direction. With further increase of the pressure, the balloon expands mainly in the radial direction while maintaining its length almost unchanged. Finally, the balloon expands both in the radial and axial directions abruptly with a tiny increase of inflating pressure, often leading to rupture of the balloon. The sudden "jump" on the deformation of the nematic balloon can be controlled by an additional axial load. To quantitatively understand the experiments, we adopt a quasi-convex free energy function of nematic

			elastomer to derive the relationship between the inflating pressure and its deformation state. The contraction of nematic balloon with inflating pressure resembles pneumatic artificial muscle.
A04	Katthearine Jensen	Adhesive contact dynamics	When a soft solid establishes a new adhesive contact with a rigid asperity, adhesion energy drives the compliant surface to conform to create as much contact area as possible as quickly as possible. Meanwhile, elasticity and solid surface tension resist this overall deformation and material dissipation mechanisms affect the timescales of contact equilibration. However, much remains unknown about this complex interplay of adhesive, elastic, and capillary driving forces, which potentially must contend with both viscoelasticity and poroelasticity in soft gels. In this work, we directly investigate contact initiation between soft polymer gels and rigid microsphere indenters. We report experiments that combine sensitive, high-speed force measurements with 2D and 3D optical imaging. By varying the microsphere size, adhesion energy, and gel material properties, we gain insight into the different physical processes that dominate contact initiation across length and time scales.
A05	Michael Rosario	Making Materials Testing and High Speed Kinematics Accessible with Open Source Tools	When studying the mechanics of high speed movements in biology, two foundational techniques that are used often include materials testing and high speed kinematic analysis. Together, these techniques form two of the most fundamental tools used to quantify and capture high speed movements. Unfortunately, the equipment needed to train students in these techniques can be prohibitively expensive, thereby limiting access to educational opportunities at smaller institutions and in secondary education. In this talk, I will present a combination of open source hardware (raspberry pi, 3D printing, etc.) I've used to create an affordable materials testing machine used in an RET program in the Center for Engineering and Mechanobiology. Additionally, I will present some preliminary results demonstrating the possibility of using open source machine learning algorithms to create a cheap high speed video alternative. By leveraging open source technology, it is possible to increase the training opportunities for a wider range of students.
A06	Boyuan Chen	Towards Generalist Robots through Visual World Modeling	Despite the accelerating progress in robotics, robots today remain relatively narrow in their capabilities. To have robots that can work seamlessly with humans, I will advocate building “generalist robots” that are good at multiple tasks, in various complex environments. My research studies how to build generalist robots by learning to model the world. I will show that current ideas on building generalist robots have produced powerful results such as robot face that learns to mimic human facial expressions with a self-image, robots that play hide-and-seek by predicting the opponent’s visual perspective, and algorithms that can distill compact physical knowledge from video recordings of multiple dynamical systems. Future directions will enable robots to have strong flexible and adaptable behaviors, rich perception systems from multiple modalities, and novel scientific discoveries for dynamical system modeling and control.
A07	Jacob Harrison	Ultrafast motion and cavitation	Organisms use latch-mediated spring actuation (LaMSA) to enhance their mechanical power output, allowing them to achieve ultrafast motion. Interestingly, repeated-use (i.e., not self-destructive) LaMSA is only found in mechanisms larger than ~1 µg. Recent work in mantis shrimp larvae and snapping

		emerge at the millimeter scale in juvenile snapping shrimp	amphipods has begun to explore some of the smallest repeated-use LaMSA systems; however, establishing where this lower size-boundary falls requires a transition within an organism from a non-LaMSA to a LaMSA mechanism across a size-range. We leverage the development of LaMSA mechanisms across ontogeny to determine at what size organisms transition to using LaMSA. Here we establish the development of the snapping shrimp LaMSA mechanism. Snapping shrimp are a clade of decapod crustaceans of over 400 species that use enlarged chelipeds (snapping claws) to fire cavitation bubbles at opponents during interspecific contests. We hatched and raised juvenile Alpheus heterochaelis using eggs collected from gravid adults in Beaufort, North Carolina. We found that the snapping claw and snapping behavior develop 1-2 months after settlement when the claws are ~1mg. High speed video of strikes show that juvenile A. heterochaelis are among the smallest repeated-use LaMSA mechanisms and generate among the highest accelerations measured for repeated-use, ultrafast movements (5.8 x 105 m/s^2). These findings reveal the scaling and onset of ultrafast motion in snapping shrimp as well as a size-based transition to LaMSA that is congruent with the other tiny, repeated-use LaMSA systems.
A08	Justin Jorge	Comparative biomechanics of energy storage and release across seed-shooting witch hazels	The seed-shooting fruits of three confamilial species shoot their seeds at similar speeds despite their seeds spanning an order of magnitude in mass. The fruits of Fortunearia sinensis, Hamamelis virginiana, and Loropetalum chinense use the same pinch-based mechanism: a spring-like structure surrounding each seed pinches on the seed to eject it. As a spring-actuated system, fruits shooting more massive seeds are expected to have significantly lower seed ejection speeds if the other seed-shooting components are held constant. Given that this is not the case, we investigate how the fruits of these species adjust to launch larger seeds. We collected measurements of seed mass, spring mass, energy storage, and energy release. We found remarkable variance in compensation strategies across species that use seemingly similar seed-shooting components. We conclude that fruits can compensate for larger seeds by storing more energy or by more efficiently converting stored elastic energy into kinetic energy.
A09	Bingyang Zhang	Modeling biological puncture: a mathematical framework for determining the energetics and scaling	A viper injects venom into prey using its fangs, a mantis shrimp harpoons a fish with its spear-like appendage, a cactus disperses clones via spines attached to passing mammals. These are just a few examples of the wide-diversity of biological puncture systems. Although disparate in materials, kinematics, scale and function, all three examples must adhere to the same set of physical laws that govern puncture mechanics. While the interplay between morphology, material response, and puncture performance has been experimentally demonstrated in individual systems, these underlying rules lack formalization and generalization. To fill in this knowledge gap, we have developed a mathematical model to determine puncture energetics based on energy balance in soft materials subjected to the penetration of a conical puncture tool. Here, we present the structure and validation of the model. We established scaling relationships between three energy contributions necessary for puncture fracture propagation (elastic strain energy, work to fracture, and work to overcome friction) and the depth of puncture as a characteristic length scale. A combination of finite element visualization and dynamic puncture

			experiments reveals the significant role of puncture tool shape and material elastic and failure properties in determining fracture surface morphology and the relative magnitude of puncture-related energies. Based on the energetic theory, we construct a dimensionless puncture efficiency coefficient that integrates all these underlying factors to offer a quantitative approach to multi-variable, comparative analysis of puncture performance.
A10	Philip Anderson	Modeling biological puncture: Applying a mathematical model to physical experiments and biological diversity.	A viper injects venom into prey using its fangs, a mantis shrimp harpoons a fish with its spear-like appendage, a cactus disperses clones via spines attached to passing mammals. These are just a few examples of the wide-diversity of biological puncture systems. Although disparate in materials, kinematics, scale and function, all three examples must adhere to the same set of physical laws that govern puncture mechanics. While the interplay between morphology, material response, and puncture performance has been experimentally demonstrated in individual systems, these underlying rules lack formalization and generalization. To fill in this knowledge gap, we have developed a mathematical model to determine puncture energetics based on energy balance in soft materials subjected to the penetration of a conical puncture tool. Here, we place this model into the broader context of biological puncture. The energy contributions quantified in the model (energy to deform the tissues, energy to create new fracture surface and energy to overcome friction) scale unevenly with puncture depth, helping to explain the results of previous and ongoing high-speed puncture experiments. The puncture efficiency coefficient derived from the model is directly relatable to theoretical work on biological cutting and fracture mechanics in soft tissues and is being used to inform ongoing work concerning the diversity of puncture tool form across phyla. Broadly, the theoretical framework established by this model enables exploring the scaling and complexities of highly disparate biological puncture systems through parameterization and systematic characterization.
A11	Nak-seung Patrick Hyun	Bifurcation Analysis of Latch Mediated Spring Actuated (LaMSA) System	Ultra-fast motions are commonly observed in many small-scaled biological systems, including a mantis shrimp striking and the snapping of the trap-jaw ant. The source of such impulsive movements is the sudden release of the stored potential energy in the exoskeleton held by a "latch" or geometric linkage restrictions. Once the latch is removed, the stored potential energy is transferred to the kinetic energy to generate the impulsive motion. The system which enables such energy transfer mediated by the latch is called "Latch Mediated Spring Actuation" (LaMSA system). In this talk, the dynamics of the LaMSA system, which induces fast motions, are studied with respect to the bifurcation of the system depending on the latch's movement. A simple toy model of the LaMSA system is considered for the analysis. The on-set and off-set of the latch provide the constraints on the dynamics, making the system become a switching system. As a result, the set of equilibrium is also changed by the dynamics of the latch, which indicates the system may experience bifurcation during the latch release phases. The saddle equilibrium point exists within the latched phase (where the latch is engaged to obstruct the projectile's motion), and the saddle point disappears as the latch retraction force increases. Once the latch is fully removed, only one equilibrium point (created by the spring) exists within the system, and the impulsive motion begins

			by unloading the spring. Hence, the control of the latch induces the system's bifurcation, and eventually leading to an impulsive motion within the system.
A12	Marie Janneke Schwaner	Latch you step! Evidence of a LaMSA mechanism in the distal leg of guinea fowl.	Bipedal walking can be modeled as spring-loaded inverted pendulum, with the leg is represented as a stiff compressive spring during stance. High leg stiffness results in a trajectory with the body highest at mid-stance and passive exchange between kinetic and gravitational potential energy. Leg angular cycling and leg length actuation present the two basic modes of leg movements that influence the motion of bipedal gaits. Bird-bot, a recently developed bipedal robot, mimics bird-like multi-articular muscle-tendon linkages and includes a latch-mediated spring actuation (LaMSA) mechanism with distal joints that lock the leg spring into a high stiffness state during stance. Stored elastic energy is rapidly released at the end of stance. By using this elastically actuated mechanism at different speeds, bird-bot can run and walk economically. We hypothesize that guinea fowl use a similar elastically actuated mechanism in walking. If so, the distal joint kinematics and the timing of stance-swing transitions should be dictated by the rate of leg angular cycling, as in bird-Bot. To test this, we varied treadmill belt speed to elicit perturbations in foot speed and leg angular trajectory, without inducing changes in joint posture and gravitational loading. The belt speed perturbations influenced the rate of leg angular cycling (via hip angle), and the timing of swing and stance transitions; however, the trajectories of joint angles, leg length, leg angle, and center of mass oscillations remained similar. This suggests a stereotypical kinematic pattern that can be played fast or slow, consistent with a LaMSA mechanism.
A13	Ophelia Bolmin	Interlocking Metasurfaces: a joining technology for bio-inspired fast moving robots	The assembly of latch-mediated spring-actuated (LaMSA) bio-inspired robots rely heavily on traditional joining techniques (i.e., adhesives, solders, mechanical fasteners). Such joining techniques tend to lack robustness under vibration which can prevent LaMSA robots from repeatedly performing fast movements. In this talk, we present a joining technology enabled by additive manufacturing: interlocking metasurfaces (ILMs). ILMs are architected arrays of latching features that create non-permanent joints. Selected designs are fabricated at different scales and experimentally evaluated. Because of their advantages over traditional joining techniques, ILMs are promising candidates to create robust joints for fast moving small robots and other applications.

July 20 **Chair: Jeff Olberding, California State University Fullerton**			
Order	Speaker	Title	Abstract
B01	Jarrod Petersen	Evidence of multiple sites of power amplification in frog muscle	Rapid movements are energy-dense events that can be produced by both biological and engineered systems. Amplifying the power output of a system through the interplay of 1) a source of mechanical work, and 2) material that can store and release energy, is one way to achieve the energy requirement of rapid movement. In many engineered systems, these structures are often distinct and separate. For example, a bow and arrow shooting a projectile at high velocity is achieved through muscle as the source of mechanical work, and an elastic bow that can release stored energy rapidly. In biological systems these two components (energy source and spring) are also usually assumed to be distinct and separate; a frog jump occurs when muscles in the hindlimb contract against the elastic tendons which can store and release elastic strain energy at high velocities. But muscle is intertwined with elastic tissues that may be capable of storing and releasing energy, present even in the force generating fibers that act as a source of mechanical work. The present study utilized high speed videography of isolated muscle to quantify several possible sources of power amplification during an active shortening contraction in frog muscle. We find that evidence of power amplification (i.e., instantaneous power production in excess of peak isotonic power) within a muscle fiber, within the muscle belly, tendon, and the bone attaching the muscle to the rigid clamp. These data demonstrate an example of power amplification from spring elements at multiple levels of organization which may be common in biological systems, but likely not in engineered systems.
B02	Corrine Avidan	A power amplification dyad	Throughout the tree of life, organisms repeatedly evolved elastic elements that store energy and, when released, accelerate appendages more rapidly than ubiquitous limits on the power capacity of fast-contracting muscles would allow. Such latch-mediated spring actuation (LaMSA) systems normally consist of a single elastic element and actuate a single mass. Here I reveal a dual-LaMSA system in seahorses, in which two elastic elements actuate two masses: the head as it rapidly swings towards the prey, and the water mass sucked into the mouth to prevent the prey from escaping. This novel system makes seahorses extraordinarily high-performance feeders, enhancing the speeds of both head rotation and suction flows ten-folds compared to similarly sized fish. Furthermore, the dual system provides temporal coordination between head rotation and suction flows, a novel function for LaMSA. These findings extend the known function, capacity, and design of LaMSA systems.
B03	Amy Rutter	Woodpecker drumming mechanics: A fast	How do woodpeckers (Aves: Picidae) drum at such high frequencies? A woodpecker's drum communicates territorial information, and its creation relies on an external substrate (e.g., wood). Many species drum around 15Hz with some species as fast as 40Hz. To reach such frequencies, the muscles likely produce high forces at high velocities, which would be

		drummer or a fast drum?	mechanically demanding. Is woodpecker drumming solely muscle-powered or could an elastic drumming substrate assist in accomplishing the behavior? Specifically, an elastic substrate could return impact energy back into the system during rebound as it springs back into shape after being deformed. My preliminary research used a servomotor and beak-like indenter to conduct material testing of various woods and measure resilience, the fraction of energy returned after impact. The non-rotten wood substrates tested had resilience values above 0.8, meaning more than 80% of the impact energy was returned to the system. Such high energy returns leave open the possibility that woodpeckers utilize elastic energy return to reduce demand on the muscular system. I speculate that woodpeckers may select more elastic substrates to assist in modulating and producing this fast frequency signal.
B04	Ethan Wold	Asynchronous muscle dynamics can allow bumblebees to exceed their mechanical resonance frequency	Centimeter-scale flapping flight in insects is the oldest and most speciose flight lineage in nature, despite being an extremely power-intensive form of locomotion. The wingbeat frequency of a flapping insect is a key determinant of their ability to produce lift, but also sets enormous demands on their neuromuscular system. A large swath of insects, called asynchronous insects, generate high frequency wingbeat oscillations in which the muscle contractile frequency and the neural drive are decoupled. They achieve this with a pair of antagonistic, delayed stretch-activated flight muscles that contract in respond to a strain rate impulse, self-exciting the system to steady-state oscillation. It has long been thought that the emergence of asynchronous wingbeat frequency must come from the mechanical resonance frequency of the thorax, allowing insects to generate efficient, high-frequency oscillations. By utilizing a closed-loop dynamics model of delayed stretch-activated muscle combined with materials testing of bumblebee exoskeleton, we demonstrate that asynchronous wingbeats may be more sensitive to muscle dynamics than thorax mechanics. We show that asynchronous insects can generate high frequency wingbeats far above resonance by precisely tuning the rate and strength of the delayed stretch response, suggesting that muscle physiology may be more important than thorax stiffness in determining an insect's wingbeat frequency.
B05	Elio Challita	How sharpshooter insects exploit biological superpropulsion to catapult their droplet pee	Sharpshooter insects feed on plants' xylem fluid using their pierce-sucking mouthparts. Due to the low-nutrient content of this ingested fluid, these insects suck up to 300 times their natural body weight per day in order to obtain adequate nutrients. Interestingly, these insects resort to a unique mechanism to discharge their fluidic waste: they catapult their droplet pee one at a time using a resilin-actuated anal stylus at high speeds and accelerations. In this talk, we show that by tuning the kinematics of their stylus to the physical properties of the droplet, these insects fling the droplets at higher speeds than their stylus in a phenomenon dubbed superpropulsion. Using a mathematical framework, we showcase the limits of superpropulsion in biological settings and we seek to disrupt this finely tuned mechanism by snipping their hydrophobic hairs. We also

			demonstrate how this mode of propulsion is energetically favorable compared to other mechanisms of waste disposal such as jetting at the length scale of these insects.
B06	Saad Bhamla	Fast movements in single cells - how they are powered and how to build synthetic cell “robots”	I'll discuss how single cells contract using calcium based supramolecular proteins, and our efforts on design of these structures for synthetic cells, to design fast moving structures at single cell level.
B07	Victor Ortega	Explosive jumping, aerial acrobatics and controlled landing of nematodes and springtails	Explosive jumping of tiny organisms had been broadly described in terms of kinematics, behavior, and energetics abroad several millimeter-sized taxa. However, because their ultra-rapid and violent launching, as well as their impressive body rotation rates, it has been erroneously assumed that these tiny animals perform poorly in terms of locomotion control. In this talk we will show that semiaquatic springtails and entomopathogenic nematodes perform in a similar way in terms of anchorage and latch via capillary forces during jumping. Furthermore, we found that both taxons can correct their body orientation in mid-air, and thus land with a favorable position most of the time. Locomotion control in these organisms in terms of aerial dispersion and predator avoidance is discussed. A bio-inspired jumping robot is presented which is capable to control its landing using a similar aerodynamic mechanism than small jumping animals. Thus, locomotion control at smallest scales seems to be more the rule than exception.
B08	Dwight Lawrence Whitaker	Optimality of peat moss vortex rings	On a warm day the sporophytes of peat moss (Sphagnum) dry out and shrink, creating a pressurized cylinder of gas. After about an hour of shrinking, capsules rupture along a disk at the top of the capsule and the gas inside is released as a vortex ring traveling upwards. This fluid flow carries the spores to a height of 10-15 cm where they are free of the turbulent boundary layer on the ground and can be carried by wind currents. We have numerically simulated the flow of gas from these pressurized capsules using ANSYS Fluent. By comparing the simulated trajectories of vortex rings to high-speed video recordings of capsule explosions, we find that the pressure inside the capsule is approximately 1.5 atm. Using the results of our simulations we can compare the vorticity contained in the leading vortex ring to the total vorticity produced in the explosion for a range of capsule pressures. We find that the observed pressure of 1.5 atm produces the strongest possible vortex ring, which contains all the vorticity produced in the explosion. This is considered an optimal vortex ring and is comparable to results for animals that produce vortex rings such as jellyfish and squid.
B09	Maya deVries	Feeding in the benthos: morphology, material properties,	Acquiring energy is essential for any organism on Earth. The diverse morphologies that animals have evolved to acquire prey and fend off predators affect broad ecological patterns. It is therefore critical to understand how morphological feeding specializations contribute to trophic dynamics and ecosystem function. Given our rapidly changing world, it is also important to

		and trophic ecology of macroinvertebrates in coral reefs and kelp forests	determine how global change may alter these interactions between individual morphology and ecosystem dynamics. Using mantis shrimp as a model system and integrating tools in biomechanics, material properties, behavior, and ecology, I discuss how morphology and mechanics on the individual level can contribute to and even shape ecosystem dynamics. Smashing mantis shrimp are often touted as having highly specialized feeding morphology, because their predatory appendages produce extremely fast, powerful strikes. Yet, I have found that these smashing strikes broaden mantis shrimp diets to include both hard- and soft-bodied prey. I have also found that, unexpectedly, mantis shrimp and the material properties of their appendage exoskeleton are robust to future climate change impacts, such as ocean acidification and warming. Taken together, these findings reveals that a resilient and often overlooked coral reef predator is likely an important link between reef flat macro-invertebrates and larger, mobile animals.
B10	Jasmine Nirody	Environmentally-driven structural changes in bacterial flagella	Flagellated bacteria often have to navigate complex environments, which are heterogeneous and time-variable. As such, they must be able to sense and respond to mechanical stresses from their surroundings. Recent work has shown that the bacterial flagellar motor remodels its structure in response to changes in the external load on the motor, for instance due to movement through fluids of different viscosity or interaction with surfaces. Mechanosensitivity in the bacterial flagellar motor likely originates from a spring connection between the flagellar motor and the bacterial cell wall. Understanding the structural basis of this adaptive mechanism will provide insight into the effect of mechanosensitive remodelling on bacterial performance, as well as into its origin and diversification across bacterial species. Furthermore, investigating adaptive motility in swimming bacteria can have implications for bio-inspired engineering: what can this mechanism teach us about designing swimmers capable of moving through complex, time-varying environments?
B11	Henry C. Astley	Frogs as Two-Stage Rockets	Elastic energy storage and release drives many of the fastest and most powerful motions seen in nature, from the jump of the flea to the strike of the mantis shrimp. By storing energy in elastic structures capable of rapid recoil, these systems can circumvent the limitations on speed and power output imposed by muscle tissue. Recent work has shown that the fundamental mechanics of these systems make them more advantageous when the mass being accelerated is small, with masses above this limit (< ~20 grams) producing higher performance by muscular mechanisms alone. However, many species of frogs use power amplification in their jumping, including species exceeding this calculated limit by more than an order of magnitude. I hypothesize that frogs can effectively use elastic energy storage despite their size by employing a system similar to two-stage rockets: proximal leg segments use purely muscular propulsion to accelerate the body from rest, after which the springy distal elements provide additional propulsion. Preliminary calculations show that the addition of a secondary spring improves

			performance for a range of lower speeds at the end of stage one, depending on the mass, spring constant, and length of spring extension.
B12	Natasha Mhatre	Hydraulic forces for jumping in spiders	Jumping is usually considered a fast movement. Indeed, a range of animals are well known to use power amplification mechanisms to store and rapidly release energy to generate some of the fastest movements known to us. Other animals are more leisurely, and jump neither very quickly nor very far. Some of our recent work has shown that the small and deft jumping spider, Habronattus conjunctus, is not exceptional in speed, acceleration or take off time. However, it jumps using an interesting hydraulic mechanism. Spiders extend their legs using hydraulic pressure. They contract muscles in the cephalothorax which generate pressure within the circulatory system. Blood vessels from this circulatory system are distributed throughout the body including the legs. The increase in pressure generated in the cephalothorax, is transmitted via the circulatory system to legs joints. Within the joint, the pressure causes a compliant membrane to unfold and the joint volume increases. This rotates the joint and extends the leg, generating the jump force. In my rapid talk, I will present some back of the envelope calculations to show how small a volume change is generated during this process and is sufficient to generate lift-off forces. I hope to motivate a discussion on whether this may also be force amplification system based on Pascal's law.
B13	Rachel Crane	Mechanical fatigue and fracture of bivalve shells	Animals with rigid armor rely on these structures to defend against a lifetime of damage. Bivalve shells protect from a variety of potentially lethal predatory and environmental threats that range in frequency and magnitude from a single powerful predator strike to repeated insults from ocean waves. Shells' effectiveness at defending from such forces is traditionally quantified with a simple test of one-time breaking stress, or strength: a shell is compressed until it breaks. However, this technique cannot reveal how shells resist mechanical fatigue, a process in which low magnitude, repeated stresses weaken and break a material. The long-term threat posed by accumulating fatigue damage hinges on the animal's capacity to resist and to quickly repair fatigue damage.