WiSE Undergraduate Summer Research

Mini-Conference

Friday, July 29th 2016

9:00 am – 1:00 pm

Schedule

9:00 – 9:30	Coffee and Pastries
9:30 – 9:40	Introductory Remarks
9:40 – 9:50	Hilina Gudeta *Professor Eva Kanso*
9:50 – 10:00	Helen Chung *Professor Irene Chiolo*
10:00 – 10:10	Emily Waggoner *Professor Wiebke Ziebis*
10:10 – 10:20	Abbey Saville *Professor Pin Wang*
10:20 – 10:30	Anna Wright *Professor Naomi Levine*
10:30 – 10:50	Break
10:50 – 11:00	June Park *Professor Malancha Gupta*
11:00 – 11:10	Samantha McVety *Professor Amy Childress*
11:10 – 11:20	Sung Min Kim *Professor Kelly Sanders*
11:20 – 11:30	Alyssa Viscio *Professor Megan McCain*
11:30 – 11:40	Monica Saripella *Professor Bruce Herring*
11:40 – 11:50	Closing Remarks
Noon	Lunch

Measuring Surface Tension with Faraday Waves

Hilina Gudeta, Jesus Castellanos, Lionel Vincent, Professor Eva Kanso

Surface tension is a macroscopic property of liquids caused by differences in molecular cohesion forces between the bulk liquid and the interface. Surface tension determines the wettability and absorption of liquids. As such, it has important implications in large scale industrial processes, including detergent industry, cosmetics and drug discovery. State-of-the-art techniques in measuring surface tension, such as the Du Noüy ring method, contact angle measurement, or pendant drop method, all require either relatively large amounts of fluid, expensive equipment or exposure to the fluid. This may be prohibitive when considering biological fluids, or scarce, toxic, or expensive materials. Here, we propose to use a novel technique for measuring surface tension based on generating two-dimensional Faraday waves in small, confined cells. The Faraday waves are generated by exciting liquid in a Hele-Shaw cell using frequency from woofers. We then combine results from dynamical systems with high-speed photography and image processing techniques to extract the time-dependent shape of the liquid interface and, consequently, the value of the surface tension. Our results show that this approach is effective in determining the surface tension in a variety of liquids provided that the wavelength is experimentally calculated and excitation frequency is known. In particular, we show that this method works in closed, highly confined geometries, and thus requiring very small amount of fluid and no exposure. These findings will allow the development of methods for characterizing surface tension properties using only small liquid volumes, signifying low-budget and thus accessible measuring instruments that can enhance research and industrial processes.

Novel Roles of Histone Modifiers in Heterochromatin Repair

Helen Chung, Laetitia Delabaere, Professor Irene Chiolo

Heterochromatin is a region of DNA consisted of repeat satellites that make it susceptible to aberrant repair during double strand breaks. Improper repair thus leads to persistent DNA damage that may result in many diseases, including cancer. For normal progression of repair dynamics, histones are modified and serve as DNA markers that indicate regions of damage to the cell, but minimal research has been conducted to identify the different modifications that occur. Through previous mass spectrometry analysis, we've identified the protein Tip60 as a histone modifier that acetylates histones such that proper progression of repair may occur. To better analyze the effects of Tip60 and other possible histone modifiers, we have used the CRISPR/Cas9 and AsiSI restriction enzyme systems to create targeted double strand breaks in order to see the specific modifications that occur at these sites. Ultimately, this research will shape a better understanding of DNA repair systems that is necessary for more targeted and efficient cancer treatments.

Benthic Cyanobacteria and Their Role in the Production of Nitrous Oxide

Emily Waggoner, Jake Lehman, Bingran Cheng, Professor Wiebke Ziebis

While atmospheric nitrous oxide (N_2O), a harmful greenhouse gas, is currently seen at low levels, its potency rate is 300 times the rate of carbon dioxide. Thus, studying the production of N_2O in an environment can be difficult due to the complex systems and interactions of microbial communities. The natural environment presents many varying conditions, such as temperature fluctuations and low levels of oxygen (O_2), and many intertidal zones also experience the addition of nitrate in a runoff event. The extent to which this variability affects photosynthetic benthic cyanobacteria remains unclear. Because nitrous oxide is indirectly produced during the photosynthetic processes of cyanobacteria, the goal of this research is to gain unprecedented insight on the role that cyanobacteria play in the production and consumption of oxygen and nitrous oxide, and how those rates fluctuate under the varying environmental conditions. Intact sediment samples were taken from Santa Catalina Island for conducting simulation experiments on the microbial communities. Micro profiling with amperometric sensors and high-resolution nutrient sampling methods were used to trace the zones of N_2O and O_2 production and consumption. Under high and low light conditions, N_2O increased at a range of 7-15 µM and when exposed to anoxic conditions, the O_2 levels raised from 50-145 µM. These results confirm that the microbial communities play a significant role in the oxygenation of the environment as well as reveal the extent to which nitrous oxide is being produced. Further research will be conducted on the effects of nitrate, a nutrient addition, to simulate anthropogenic impacts, and tidal flushing to simulate real world intertidal zone fluctuations.

Mass Spectrometry Analysis of T cell Co-Stimulatory Domain Activation

Abbey Saville, Jen Rohrs, Jeff Vu, Professor Pin Wang

Cancer immunotherapy has recently become one of the most effective forms of treating different types of cancer. Dominating these treatments are engineered T cell receptors called chimeric antigen receptor (CARs). These CARs allow T cells to bind to tumor cells, initiating a chain reaction of intracellular signaling which stimulates the T cell to kill that cancer cell. CARs can incorporate different intracellular signaling domains; they generally include the CD3ζ-chain as well as a number of different co-stimulatory domains that modulate the internal signaling. The purpose of my research this summer is to improve cancer immunotherapy by using mass spectrometry to analyze the kinetics of CAR intercellular co-stimulatory domain activation. CARs are currently being used in several clinical trials to treat B cell lymphoma. However, when CARs have been implemented to treat other forms of cancer, such as HER2-positive breast cancer, the application of these CARs has killed the patients. My research is crucial to create a better understanding of the effects of applying CARs in order to minimize their potential risks and optimize future successes.

Small organisms with a large climate footprint: Variation in DMS(P) production by freshly isolated strains of the coccolithophore Emiliania huxleyi

Anna Wright, Erin McParland, Professor Naomi Levine

Dimethylsulfide (DMS) is an anti-greenhouse gas that plays an important role in Earth's albedo through changes in aerosol abundance and cloud condensation nuclei (Charlson et al. 1987). DMS is derived from dimethylsulfoniopropionate (DMSP), a metabolite produced by many marine phytoplankton (Stefels et al. 2007). Despite 30 years of research, there is no consensus of the cellular mechanism behind DMSP synthesis. One leading hypothesis suggests that DMSP is an antioxidant, whereby DMSP is upregulated when phytoplankton are under oxidative stress in order to react with free radicals and prevent cellular damage (Sunda et al. 2002). The coccolithophore Emiliania huxleyi (E. hux) plays an important role in the biological pump and has a unique DMS(P) phenotype as it is both a high DMSP producer and often contains DMSP lyases, which are enzymes used to cleave DMSP to DMS. Our study investigates the difference in intracellular DMSP concentrations and DMSP lyase activity (DLA) across 80 freshly isolated strains of E. hux. These isolates are unique as they were collected in coastal California waters only in the past year, whereas all previously screened coccolithophores have been in culture for more than 30 years. Using gas chromatography, we have screened 20 isolates of E.hux for DMSP concentrations and DLA. Preliminary results show total DMSP concentrations range between 3.6 and 8.3 fmol/cell, and surprisingly, no significant DLA has been found in any of the 20 strains screened thus far. Our findings demonstrate that intracellular DMSP concentrations vary considerably between strains of E. hux and can be significantly lower than previously reported. In addition, also contrary to previous assumptions, DLA is not a ubiquitous feature of all E. hux strains. The next steps of this project will be to quantify the differential response of E. hux strains to UV radiation, an oxidative stressor. As DMS(P) is thought to behave as an antioxidant system, it is possible that DLA which was undetectable under non-stressed conditions will be upregulated under UV stress. This research will provide valuable data to help improve our understanding of DMS(P) mechanisms, and will ultimately help models better predict DMS production in the future.

Modification of ABS with Oxygen Plasma and HEMA for Biomedical Applications

June Park, Christine Cheng, Professor Malancha Gupta

3D printing is revolutionizing the fabrication of biomaterials by providing efficient and affordable prototyping of a wide array of morphologies. Acrylonitrile butadiene styrene (ABS) is a commodity plastic commonly used in 3D printing, but has drawbacks as a biomaterial because of its hydrophobicity and non-biocompatibility. These limitations can be combated via surface modification by covalently attaching a functional polymer coating such as poly(2-hydroxyethylmethacrylate) (pHEMA), a common hydrogel. In this study, ABS samples were 3D printed and modified using oxygen plasma treatment followed by initiated chemical vapor deposition (iCVD) to target grafted pHEMA on ABS. Chemical cross-linking using poly(ethylene glycol) diacrylate (pEGDA) was utilized to enhance grafting coverage. Captive bubble contact angle goniometry was used to monitor wettability and grafted pEGDA coverage over time. Partially grafted pEGDA on plasma treated ABS was stable for several days. This process could be used to improve the grafting of pHEMA on 3D printed substrates.

A Synergetic Solution to Small Scale Water Challenges

Samantha McVety, Professor Amy Childress

For small communities, disconnected from sources of energy and water, and with small technical capabilities, in semi-arid climates worldwide, solar powered membrane distillation (SPMD) has the potential to produce much-needed potable water from ocean water and brackish groundwater.

While many researchers have investigated different solar desalination systems, no single system has yet proven to be either technically or economically best.

This research analyzes the potential for low-cost decentralized water production using membrane distillation systems fed with thermal energy from plastic solar thermal. Plastic solar thermal offers low capital costs with potentially similar performance to conventional solar thermal, which may drastically reduce the cost of a SPMD system. In order to evaluate the performance of plastic solar thermal for use with MD, experiments were run during solar hours to collect time-varying temperature data. The results demonstrated that plastic solar thermal would be a suitable option for coupling with MD technology. These findings will also be useful in future work, which will involve developing and testing a complete SPMD system and performing a robust cost analysis with comparison to existing technologies. This work will facilitate the development of a novel, low-cost plastic SPMD system that will provide environmentally-friendly fresh water resources even in remote areas without access to electricity or other conventional energy sources.

The Climate-Power-Water Nexus: A Global Investigation of Power Generation Disruptions Resulting from Climate-Related Water Constraints

Sung Min Kim, Professor Kelly T. Sanders

There are strong interdependencies between electricity production, climate and water use. Most power plants, for example nuclear, coal, natural gas and hydropower, are dependent on water available in sufficient volumes and, at sufficiently cool temperatures, at the time and location of electricity generation. Many water resources that power plants depend on are warming and evaporating at higher rates in recent years due to severe drought and heat waves, resulting in power plant efficiency losses, power curtailments and shutdowns due to water constraints in many regions. Since hot temperatures are also correlated to electricity demand increases, these disruptions often coincide with times of heightened electricity demand, adding additional strain to the grid. There are already existing tensions between electricity production and water use that have caused harmful, and potentially life-threatening, consequences for populations of people around the world. However, these tensions have not been documented in a systematic way.

The objective of this research project is to investigate and characterize these tensions between electricity generators and water availability to inform future power development, especially in sensitive regions of the world. Based on news articles, we have compiled a database of water-related power curtailments complete with each power plant's location, generation type, power capacity affected, curtailment event date, affected water source and details about the incident to detect trends. The goal of the database was to obtain a holistic picture of how power plants are currently being affected by the climate-related events. Approximately 200 cases were documented and included incidences of full plant shutdowns, capacity reductions and instances where thermal discharge regulations were exceeded.

Nuclear, hydro and coal-fired power plants were most commonly affected by water-related disruptions, with high incidence rates in France, India, Venezuela, South Africa, and Brazil. The database compiled through this data collection effort will be insightful to inform future power development plans. For example, in environmentally sensitive regions such as the Arabian Gulf, current plans to expand nuclear power capacity will likely be complicated by rising water temperatures. By the end of this century, areas of the Gulf are expected to be hit by heat waves and humidity so severe that simply being outside for several hours could threaten human health. Without proper consideration of water availability, reliable power generation could be threatened, and in extreme cases, public safety could be at risk in cases where nuclear power plants cannot be safely cooled.

Engineering 3D Skeletal Muscle Bundles

Alyssa Viscio, Nethika AriyasingheProfessor Megan McCain

Skeletal muscle makes up 30-40% of human body mass and is essential for movement, adaptation, and survival. Unfortunately, skeletal muscle degeneration is an inevitable process that occurs with aging. For patients with inherited muscle diseases, such as muscular dystrophy or cerebral palsy, this degeneration is further accelerated, leading to severe problems with mobility later in life. These diseases are almost always incurable. Thus, there is a need for an engineered skeletal muscle construct as a platform for modeling muscle disease and testing drugs. Growing skeletal muscle has proved to be a great challenge in the field of skeletal muscle tissue engineering. In our primary study, we successfully determined the optimal substrate for the long term culture of C2C12 murine myoblast cells, which is a mouse cell line. In growing cells on gelatin hydrogels and PDMS-coated coverslips, we found that the gelatin hydrogels resulted in more mature muscle for a longer period of time. While this platform does enable further study of skeletal muscle, our current study goes a step further— a 3D model. The 2D construct, though successfully created, may lack the architecture of native muscle. The hope of the 3D skeletal muscle bundle is to be able to study contractile function and response to stimuli, both electrical and chemical. We are working on determining the optimal substrate for creating bundles so that we can begin measuring things like force production. We believe that this 3D model will better mimic both the structure and function of native muscle.

The Effects of Autism-related Mutations on Synapse Structure

Monica Saripella, Professor Bruce Herring

In recent years, the genomes of several Autism patients have been sequenced, and various mutations that appear to independently give rise to Autism related behavioral phenotypes have been identified. Our lab has been studying mutations in Trio, a protein that promotes actin polymerization in synapses through signaling of another protein, Rac1, at its GEF1 domain. One such mutation that was identified is in the Rac1 signaling domain of Trio. I have been and will be using super-resolution structured illumination microscopy (SIM), among other methods, to determine the effects of this mutation on dendritic spine morphology, and ultimately its role in ASD. SIM images demonstrated that expressing mutated Trio leads to a dramatic increase in number of spines, a phenotype indicative of ASD related disorders. Moving forward, I will mutate a small portion of the spectrin repeat domain of Trio, which is implicated in interacting with other proteins, and identify its effects on synapse morphology.

Site-Directed Spin Labeling Studies of Site-Directed Spin Labeling Studies of the Conformation of (GGGGCC)n repeats of C9orf72

Alyssa Tsenter, Xiaojun Zhang, Professor Peter Z. Qin

In this study, we will be working on the small repeat sequence (G4C2)n found in the C9orf72 gene. Unusual expansions of this sequence have been linked to the pathogenesis of amyotrophic lateral sclerosis (ALS), a neurological, neurodegenerative, and neuromuscular disease. In unaffected individuals, the most common repeat size is between 2 and 8 units, while the repeat size in individuals affected by ALS is between 700-1600 repeats. This sequence has been shown to form a unique DNA secondary structure known as a G-quadruplex, which is act as transcription regulators. Understanding the folding structure can provide insight into the pathogenesis of ALS, yet there are no studies so far that confirm a folding conformation. The Qin research group uses a biophysical tool-kit to study nucleic acids such as DNA, RNA, and DNA/RNA-protein complexes called site-directed spin labeling (SDSL). A stable nitroxide radical (the spin-label) is attached at a specific location along the DNA or RNA and then Electron Paramagnetic Resonance (EPR) is used to detect the signal emitted from the free electrons on the spin-label. To study the folding conformation of this sequence, continuous wave-EPR (CW) was used to look at structure and dynamics at a specific nucleotide and then double electron-electron repulsion (DEER) EPR was used to measure intramolecular distances of the complex. From these measurements we can begin to elucidate the conformation of this GQ through comparison with molecular models of other known GQ folding patterns. Once we can solve the structure of the one unit GQ, future studies will look into longer repeats, which will more closely resemble the physiological folding.

How Can We Use the Snapping Shrimp's Hunting Ability in Everyday Engineering Applications?

Neta Glaser, Austin Simons, Alexander Ramirez, Professor Veronica Eliasson

Snapping Shrimp are considered one of the loudest animals in the ocean because they are able to produce shock waves from cavitation bubbles induced from the closure of an over-sized claw. However, the collapse of the bubble not only produces a loud "snap" sound, but it also emits a very quick flash of light. For such an occurrence, the water in the bubble must reach temperatures close to that of the surface of the sun. Our lab has developed a mechanical claw to match the shrimp's geometry on a 14:1 scale. The claw is contained in an aluminum tank with acrylic windows for high-speed imaging of shock and cavitation bubble dynamics. The claw is mechanically actuated with a torsional spring controlled by a motor. When released, the claw creates a bubble, which collapses to form a shock wave. Studying the fascinating phenomenon of the light emission and associated extreme temperatures could lead to novel designs for heating applications and water purification. In addition, this project allows for a better understanding of the effects of cavitation bubbles, such as analyzing the cavitation bubble-induced damage on propellers. This project will use our mechanical model of the Snapping Shrimp's claw to create cavitation bubbles, quantify the energy released, and study the resulting shock waves and sonoluminescence. Once this is achieved, we aim to design a device that uses cavitation to heat and purify water. Our hope is that such a device could provide clean water to places without access to large-scale filtration systems.