# *Washington NASA Space Grant Consortium*

# *2011 Summer Undergraduate Research Program*

# *Abstracts*

**Diagnostics Using Two Dimensional Paper Networks**

*Luke Allpress, Junior, Bioengineering*
*Mentor: Paul Yager, Bioengineering*
*Mentor: Gina Fridley, Bioengineering*

The Paul Yager Lab in the University of Washington's Bioengineering Department has been researching the dynamics of fluids on two dimensional paper networks of nitrocellulose. Knowledge of this science will allow for the development of distributed diagnostics, akin to pregnancy tests, that can be used in remote settings without access to electricity or medical supplies. By testing the storage and flow of various proteins and carbohydrates on nitrocellulose, we are developing lateral flow enzyme-linked immunosorbent assays (ELISAs) for the diagnosis of various diseases. My research involves the control of proteins once they are already on the nitrocellulose membrane. By printing proteins and carbohydrates in various conformations onto the nitrocellulose, we were able to test the effectiveness of our methods for delaying and mixing protein flow. We showed that you can delay protein flow by printing a wall of sugar around the protein that needs to dissolve before the protein can flow with the liquid. We tested the flow patterns of two consecutive patterns of proteins and found that we can predict the time and efficiency with which they arrive at the downstream mixing site. We also developed ways to effectively load up to 1ml of solution onto the nitrocellulose strips. This research will be useful in the eventual development of a working ELISA, when combined with other results from researchers in the lab.

**Engaging Students in Thermodynamics: Integrating Scientific Literature with Weekly Homework Sets**

*Caitlin Bannan, Senior, Chemistry*
*Mentor: Munira Khalil, Chemistry*

It is a common dilemma for undergraduate students to feel like their class material is inapplicable to the real world. This project aims to enhance traditional homework assignments with problems based on current scientific literature. The current class of interest is Physical Chemistry for Biochemists I at the University of Washington, taught by Dr. Munira Khalil. I developed homework questions using journal articles that focused on concepts of thermodynamics important in biochemistry. The questions test the students' comprehension of the article and their ability to solve quantitative problems based on research presented in the article. These questions will be integrated with traditional assignments already given in this course. Dr. Khalil's class in Fall 2011 will serve as a test run for the literature focused homework assignments. At the end of this course, students will evaluate the homework through an online survey. These evaluations will give insight into how learning about research influences a student's interest and performance in the class.

**Integrating a Microwell Array with a Nano-Patterned Substrate for High-Throughput Stem Cell Culture Experimentation**

*Derek Britain, Junior, Pre-Engineering*
*Mentor: Deok-Ho Kim, Bioengineering*

The vast majority of cell culture data analysis involves taking bulk averages of cell colonies. However, cells are typically heterogeneous, expressing unique phenotypes. To better analyze individual cells, we integrated a PDMS microwell array with a nano-patterned substrate. The microwell array created regularly spaced culture wells measuring 500µm by 500µm. The PEG-GelMA nano-patterned substrate was formed using capillary force lithography, and consisted of parallel ridges and grooves with a width of 800nm and a height of 500nm. GFP-Brachyury Mouse Embryonic Stem Cells were seeded on the device, and live-cell microscopy was carried out for each microwell. Isolating cells in parallel microwells allowed us to characterize the effects of nano-topographical cues on individual stem cell differentiation. Our device also achieved high-throughput, as the microwell array created over a hundred cell culture experiments that could be monitored simultaneously. High-throughput monitoring of individual stem cells could yield novel insights in tissue engineering and regenerative medicine

**Effects of Prenatal Ultrasound Exposure on Autistic-Like Behavior in Mice**

*Chelsea Brossard, Freshman, Chemistry*
*Mentor: Pierre Mourad, Applied Physics Laboratory: Center for Industrial & Medical Ultrasound*

We are exploring the effects of ultrasound exposure *in utero* to determine whether ultrasound correlates to increased cases of autism. The Williams and Casanova Triple Hit Hypothesis suggests that autism is caused by a combination of genetic predisposition, vulnerability during development, and environmental factors. We believe that ultrasound may be an environmental factor contributing to autism in those who are genetically predisposed. Studies have shown that ultrasound exposure *in utero* can cause changes in behavior and neuronal migration, the process by which neurons move to their specialized locations in the brain. In order to test our hypothesis, we will expose three strains of mice to ultrasound for a period of time relevant to human fetal exposure. When the mice pups are 3 and 6 weeks of age, we will use a variety of behavioral tests to assay for autistic-like characteristics. These tests will observe for lessened play, anxiety in open areas, less curiosity for a novel mouse, and affinity for darkness. We will also study the brain anatomy of the mice to determine the effects of ultrasound on neuronal migration. Results of our study may relate ultrasound exposure to autism, which would lead to recommending avoidance of prolonged exposure to ultrasound in the future. Our study will potentially be a basis for further research concerning the effects of ultrasound exposure on prenatal development.

**Coding a Python Program to Triangulate the Location of Subsurface Moorings**

*Amit Burstein, Freshman, Computer Science and Engineering*
*Mentor: Ren-Chieh Lien, Applied Physics Laboratory: Ocean Physics*
*Mentor: Barry Ma, Applied Physics Laboratory: Ocean Physics*

In order to understand the development of typhoons in the Indian Ocean, our team will deploy three subsurface moorings for up to one year. Attached to these underwater buoys are instruments that measure water conductivity, temperature, pressure, and velocity. Given that these moorings lie at such depths that GPS instrumentation cannot function, our goal is to create a program using Python that will triangulate their positions using acoustic signals, so these expensive instruments can be retrieved. A command from the ship is transmitted to an acoustic release device on the mooring which gives the range between the two and the device is located anywhere in a circle surrounding the ship with that given range as the radius. Once this process is repeated two or more times from different locations, these circles converge at the mooring's location. The program receives latitude, longitude, and distance input from the user, suggests locations for triangulation, and gives the mooring's final location. Also included in the program is a graphical mapping component, allowing the user to visualize the circles to ensure they converge. Given the relative proximity of the triangulation points to the mooring's location, we expect the calculations to be accurate within a hundred meters. Upon the program's successful completion, the team plans to use it for mooring cruises in other parts of the world, minimizing the time required to do guesswork or triangulation calculations by hand.

**Neuromodulation in Rats Using Focused Ultrasound**

*Nathaniel Coulson, Sophomore, Bioengineering*
*Mentor: Pierre Mourad, Applied Physics Laboratory: Center for Industrial & Medical Ultrasound*

The brain is a complex organ that communicates via electrical impulses to other parts of the brain and body. Many diseases can interfere with these signals, causing abnormal function and behavior. These abnormalities can include chronic pain, epilepsy, autism, multiple sclerosis, depression, and a host of other symptoms. We are exploring ways to correct these abnormal signals. Specifically, the goal in my lab is to alter brain function (neuromodulation) by applying pulsed ultrasound to specific brain regions. In particular, we'd like to either excite regions of the brain, suppress activity in other regions, or a combination of both. Our equipment consists of a ring transducer, made up of two piezoelectric crystals driven by separate amplifiers and function generators. These take electrical signals generated by the function generators, and turn them into ultrasound. Our transducer must propagate sound through water so we have developed a special cone to allow for in-vivo experiments in rats. Based on work done by William J. Tyler, we know that focused ultrasound pulses to the brain can produce physical responses and movement in rats. Thus far we have generated the desired signals in a water tank and within the brains of rats; however, we have not yet modulated brain function. Next we will stimulate the motor cortex of the brain in order to induce observable movement. As an example of how we might apply this technique, consider autism. This is one of the diseases that produces changes in brain activity by, among other things, suppressing the social centers in the brain. With further testing and work we hope to be able to simultaneously activate the social and learning centers of the brain while exposing autistic children to social environments, in essence training them out of autism.

**Survey of Classical Be stars for a New Polarization Diagnostic**

*Zachary Draper, Junior, Astronomy and Physics*
*Mentor: John P. Wisniewski, Astronomy*

Classical Be stars are middle-aged, massive B-class stars which rotate rapidly near their critical rate. Through a yet unknown flaring mechanism, material is ejected from the star into a circumstellar disk which gives the star a polarization signature from free electron scattering. A survey of Classical Be stars was conducted by the Pine Bluff Observatory using the HPOL instrument from 1989 to 2004, which cataloged spectropolarimetery for over 50 stars. We develop a pipeline code in IDL to take the archived observations and remove interstellar polarization caused by dust in the line of sight to each star, thereby allowing us to measure intrinsic changes in polarization from their disk. We apply a new polarimetric diagnostic tool to some of these data to help us better understand the mechanisms which cause these stars to form circumstellar disks.

**Identifying Novel Components Involved in Antimicrobial Peptide Resistance in /Salmonella /Typhimurium**

*Mauna Edrozo, Senior, Microbiology*
*Mentor: Samuel Miller, Medicine, Microbiology, Genome Sciences, and Immunology*

/Salmonella enterica /serovar Typhimurium is a Gram-negative pathogen that causes gastroenteritis and has evolved mechanisms to avoid detection and killing by the host immune system. In many animal species, cationic antimicrobial peptides (CAMP) represent a critical component of the innate immune system. The anionic bacterial cell surface is disrupted by CAMP interactions that increase outer membrane (OM) permeability and CAMP access to the inner membrane. To resist CAMP killing /S./ Typhimurium activates the PhoPQ two-component system, which is essential for pathogenesis. PhoPQ activates transcription of factors that decrease the net negative charge of the outermembrane by modifying lipid A, a component of lipopolysaccharide, thereby repelling CAMP access. However, many PhoPQ-regulated enzymes are dispensable during infection. To identify new components of the PhoPQ regulon involved in maintaining the outer membrane permeability barrier to antimicrobial peptides, we performed forward genetic screening. Originally identified as a regulator of capsule synthesis, the RcsFCDB phosphorelay system specifically senses envelope stress induced by CAMP. Transposon mutagenesis was performed in a strain constitutively active for PhoPQ signaling and harboring an Rcs gene reporter (*/wza-lacZ/*). Transposon insertion mutants with increased /wza /promoter activity were selected by blue white colony screening. Mutants exhibiting increased */wza/* expression on solid media were validated by β-galactosidase assays from broth grown cultures. Transposon insertion sites were mapped by semi-random PCR. Sequencing revealed transposon insertions in genes encoding a variety of membrane proteins including transporters, phospholipid and LPS biosynthetic enzymes and efflux pumps, as well as regulatory proteins. Currently, we are determining whether increased */wza/* expression caused by these mutations is dependent upon the PhoPQ and Rcs phosphorelay systems. In addition, we are testing mutants isolated from our screen for outer membrane permeability defects and resistance to CAMP.

### Design of Multi-Agent Coordination and Control Testbed

*Andrew Girardeau-Dale, Senior, Aeronautics and Astronautics and Math*
*Mentor: Mehran Mesbahi, Aeronautics and Astronautics*

Distributed systems have been identified as an enabling technology for future space exploration and commercialization. Many tasks performed by singular monolithic spacecraft could be completed by networks of smaller craft that offer modularity and avoid costly repairs. The coordination and communication between such craft requires advancements in control systems theory. Such advancements behest a testbed where ideas can be worked out in the physical domain. We are attempting to create such a testbed in the Distributed Space Systems Lab at the University of Washington that will contain blimps, ground robots, and other vehicles in place of spacecraft. Though the number of agents is limited to between two and twenty, the principles examined should relate to systems with more agents. The position of each craft is determined by cameras overhead at a rate near 100 Hz. These are relayed to a computer in real time, which translates absolute positions to each craft's velocity as well as the relative positions and velocities of its neighbors. For most craft, this data is then used to make all decisions to the point of motor actuation on the computer, though some craft require onboard stability control in addition.

### Bleaching in Colloidal Cobalt-Doped Zinc Selenide Quantum Dots

*Arin Greenwood, Sophomore, Chemistry*
*Mentor: Daniel Gamelin, Chemistry*

Motivated by recent interest in developing compact, inexpensive, and reliable eye-safe lasers, the effect of quantum confinement on a saturable absorber material, cobalt-doped zinc selenide ($Co^{2+}$:ZnSe), was explored in colloidal quantum dots. $Co^{2+}$:ZnSe diluted magnetic semiconductor quantum dots (DMS-QDs) are semiconducting nanocrystals with structural lattices that include substitutional magnetic ions in addition to the primary metal cations. While previous work has been conducted on the saturability of optical absorption in bulk $Co^{2+}$:ZnSe, the research presented here focuses entirely on quantum-confined colloidal DMS-QDs. The ability of these particular DMS-QDs to behave as saturable absorbers was explored in depth. This property is directly related to the long lived $^4T_2$(F) excited state of the $Co^{2+}$ dopants, which gives rise to bleaching of the $Co^{2+}$ ligand field transitions, leading to increased transmission of light upon irradiation at high powers. Specifically, absorbance features associated with excitation of ground-state electrons localized in the d-orbitals of the dopants are lost. To examine the saturable absorber behavior of $Co^{2+}$:ZnSe, we looked at the optical transmittance of the quantum dots as a function of photoexcitation power. This was done by slowly increasing the power of a

pump laser exciting the sample and observing changes in the absorbance spectrum at characteristic $Co^{2+}$ ligand-field transition features. The bleaching of the ligand field $Co^{2+}$:ZnSe in its nanocrystal form demonstrates that these colloidal materials are candidates for saturable absorbers in Q-switched eye-safe lasers. From this point, it should also be possible to explore excitation of the electrons from the first excited state ($^4T_2$(F)) into higher energy states (excited-state absorption).

**Design and Construction of an In-Space Plasma Propulsion System Modeled after Coronal Mass Ejections**

*Sarah Harvey, Junior, Physics*
*Mentor: Robert Winglee, Earth and Space Sciences*

The Coronal Mass Ejection In-Space thruster is a new plasma thruster design that attempts to replicate solar plasma ejection events. Plasma thrusters present an alternative to the inefficient and heavy chemical rockets often used in space today. By accelerating plasma using electric and magnetic fields, these thrusters may be capable of generating much higher exhaust speeds compared to chemical rockets, are more efficient, and may be activated for longer periods of time. The Coronal Mass Ejection (CME) In-Space Thruster System draws inspiration from the physics of the Sun's ejections of large quantities of plasma at very high velocities during CME events. It is believed that this phenomenon is caused when oppositely directed magnetic field lines looping over the surface of the sun reconnect, releasing energy and ejecting an unconnected magnetic field carrying plasma with it. Using a toroidal chamber wrapped in current-carrying wire and a helicon plasma source, we are able to generate a strong axial magnetic field that will bulge through an opening in the torus. This should generate successive magnetic reconnection events and eject plasma through the gap in the torus. The University of Washington Advanced Propulsion Lab and Eagle Harbor Technologies are investigating whether these projected effects will occur in a way that generates useful thrust. I have focused on MATLAB modeling of this thruster and attempting to optimize it to our specifications and resources. The outcome of this CME thruster experiment could present new design opportunities in the field of plasma propulsion.

**Cadmium Adsorption to Bacterial Spores**

*Mikaela Hertel, Sophomore, Math*
*Mentor: Drew Gorman-Lewis, Earth and Space Sciences*
*Mentor: Zoë Harrold, Earth and Space Sciences*

The transport of heavy metals in the environment poses serious threats to ecological and human health. One major factor that influences the transport of heavy metals in the environment is interactions with microbial surfaces. To better understand the influence that endospores, a ubiquitous microbial surface in the environment, have on metal transport, we studied cadmium adsorption onto endospore surfaces. We focused on four main experiments: how fast metal adsorbs to spore surfaces (kinetics), the reversibility of metal-spore adsorption, how quickly spores produce dipicolinic acid (DPA) when exposed to aqueous conditions, and what affect DPA has on cadmium-endospore interactions. This data are essential to deriving thermodynamic parameters that may quantify the interactions under conditions not directly studied in the laboratory. The ultimate goal of this research is to give environmental engineers the ability to incorporate microbe-metal interactions into geochemical models of contaminant transport and possibly aid in optimizing bioremediation strategies using endospores.

**Relationship of Perchlorate and Nitrate Salts Relate to Past Rainfall Activity on Earth's Deserts and Mars**

*Brooke Hess, Freshman, Pre-Engineering*
*Mentor: Mark Claire, Astronomy*

Highly soluble perchlorate and nitrate salts have been found to accumulate on Mars, which is a cold planet with no liquid water cycling at the surface. On Earth, the only places where nitrate and perchlorate salts are known to accumulate are the Atacama and Mojave deserts, two of the driest places on Earth. By characterizing the mobility of these salts in Earth's soil, we can better understand what the vertical distribution of these salts can tell us about past rainfall patterns on Earth and, by extension, past aqueous processes that may have affected Mars. We created and calibrated Ion-Selective Electrodes (ISEs) to measure concentrations of salts in the soil. ISE and Ion Chromotography measurements will be compared to determine the reliability of the ISEs. We are running controlled laboratory experiments where we simulate rainfall and track the real time moisture content of soils. Our results so far suggest a higher abundance of these salts in drier areas, and varying levels of these salts at different depths, which are assumed due to varying amounts of precipitation. In the future, we hope to simulate diurnal cycles in temperature and relative humidity under terrestrial and Mars-like conditions.

**Identifying the Genes Involved in *Drosophila* Dendrite Maintenance**

*Joanne Hsu, Junior, Neurobiology*
*Mentor: Jay Parrish, Biology*

Dendrite arborization patterns are known to be integral to neuronal function, as defects in dendrite morphology have been correlated with cognitive disorders such as autism and Down syndrome. However, the genes and mechanisms involved in the development and maintenance of dendritic arbors remain largely unknown. Using the *Drosophila* peripheral nervous system (PNS) as a model system, I will conduct a genetic screen to identify genes that are required cell-autonomously in neurons for dendrite maintenance. The genetic screen involves the following steps: First, I will treat *Drosophila* males with the mutagen EMS (ethylmethanesulfonate), which induces random point mutations. Next, I will set up crosses to screen more than 1000 unique mutations using genetic mosaic analysis, which allows for analysis of single cells (neurons in this study) that are homozygous for a mutation of interest when every other cell in the host (the *Drosophila* larva) is heterozygous for that mutation. In the mosaics, PNS neurons will express a membrane-targeted fluorescent protein allowing me to use time-lapse confocal microscopy to monitor dendrite development in living *Drosophila* larvae. Finally, mutations of interest will be characterized in more detail, and the gene affected by each mutation will be identified using meiotic recombination-based analyses.

**Dynamic Magnetization of Nanoparticles**
*Loc Hua, Junior, Math and Physics*
*Mentor: Kannan Krishnan, Materials Science and Engineering*

The goal of this project is to develop a mathematical model to determine the magnetization of superparamagnetic nanoparticles in an alternating magnetic field. Superparamagnetic particles can be used for Magnetic Particle Imaging (MPI), a recent tomography technique exploiting the particles' induced magnetic field, as well as hyperthermia, the use of nanoparticles to generate localized heat. MPI's known advantages over other imaging techniques, such as MRI, are its relatively quick process and lower cost. The use of nanoparticles for hyperthermia can be used in adjuvant therapy, such as aiding chemotherapy where effectiveness varies with temperature, and can possibly yield enough heat to be directly used to eliminate unwanted cells. The importance of a rigorous model is to help determine characteristics of particles which lend themselves well to imaging and hyperthermia, and to expand current literature on the subject.

**Optimization the Morphology of Bulk Heterojunction Layer of Organic Solar Cells Using Self-Assembled Monolayers (SAMs)**
*Jenny N Huynh, senior, Materials Science and Engineering*
*Mentor: Alexander Jen, Materials Science and Engineering*
*Mentor: Kung-shih Chen, Materials Science and Engineering*

Organic solar cell is an alternative energy source because of its potential to produce clean and renewable energy at low cost and easy processing. Unfortunately, a barrier that prevents the organic solar cell from being popularly used is the low power conversion efficiency. One of the important factors that affect the performance of organic solar cells is the nanomorphology of bulk heterojunction (BHJ) active layer. BHJ active layer is basically the blending of a donor (polymer) and an acceptor (fullerene). Due to the natural characters of polymer and the spin coating process during fabricating organic solar devices, the structure of polymer has become very disordered. That limits the diffusion length of excitions in the BHJ layer. If the phase separation between donor and acceptor is greater than the ideal diffusion length, most of excitons will recombine before they reach the interface for dissociation. My goal of this project is to optimize the morphology of the BHJ layer of organic solar cells through surface energy control by using different kinds of self-assembled-monolayers (SAMs). The morphology of BHJ active layer is sensitive to the surface energy of the underlying substrate, which can be manipulated by the surface modification through the SAMs. More explicitly, in this project I focus on inverted solar cell which has the architecture of ITO/ZnO/ SAMs/ BHJ layer/ PEDOT:PSS/Ag. I will analyze the surface energy of ZnO thin film modified by different SAMs and characterize the morphology of the active layer to assess their correlations. Eventually, from the founded correlations, I believe that I could optimize the morphology of BHJ layer. Once the morphology of BHJ active layer is optimized, the performance of organic solar cells will increase significantly.

**Design of an Apparatus to Measure Mechanical Effects of Gene and Cell Therapy in Intact Cardiac Trabeculae from Infarcted Hearts.**

*Bryce Johnson, Senior, Bioengineering*
*Mentor: Michael Regnier, Bioengineering*

This project focused on understanding function loss due to myocardial infarction and ameliorating this loss via cell therapy. Previously, we have found cell therapy to improve contractility and other function in remote myocardium from infarcted hearts. Observing differences in calcium release and force production between infarcted and cell-injected hearts was the next step in understanding how cell therapy improves cardiac function following infarction. This project aimed to design a device to simultaneously measure intracellular calcium handling and contraction in cardiac trabeculae, and these measurements were compared between healthy, infarcted, and cell-injected myocardium. Myocardial infarction was induced to Fischer 344 male rats. The first experimental group was injected with cell-growth media only, while the second experimental group was injected with a solution of media and neonatal rat cardiomyocytes (NRCs). Sham operated rats (pneumothorax only) served as a control group. Cardiac function was measured *in vivo* via echocardiography, *ex vivo* via a whole working heart preparation, and *in vitro* via the designed intact trabeculae mechanics apparatus. Phosphorylation profiles were made to observe changes in myofilament phosphorylation between groups. Preliminary results showed that cell-therapy hearts had improved contractility and higher calcium release compared to infarct-only hearts.

**Evidence for Conserved Mechanisms of Transcriptional Activation of *CONSTANS* in Plants**

*Anna Josephson-Day, Senior, Molecular, Cellular and Developmental Biology*
*Mentor: Takato Imaizumi, Biology*
*Mentor: Shogo Ito, Biology*

Genetic engineering of plants is a process that may become key to feeding the earth's booming population. However, understanding the genetic networks responsible for plant flowering is a necessary precursor. The ability to understand and eventually control timing of flowering will enable farmers to better predict flowering schedules, plan crop rotations more efficiently and ultimately reduce crop wastage. The Imaizumi Lab studies regulation of the gene *CONSTANS* (*CO*), which activates expression of *FLOWERING LOCUS T* (*FT*), the "florigen" directly responsible for inducing flowering. Because the *CO-FT* functional module is conserved across many plant families, we hypothesized that transcriptional activation of *CO* might be similarly conserved. We recently discovered a group of basic-helix-loop helix (bHLH) proteins, transcription factors known to interact directly with DNA, which activate expression of *CO* in our model plant *Arabidopsis thaliana*. We named the genes encoding those bHLHs *Flowering bHLHs* (*FBHs)*. I performed time-course gene expression analysis of *Arabidopsis* seedlings overexpressing rice (*Oryza sativa*) and poplar (*Populus trichocarpa*) genes homologous to the FBHs we discovered in *Arabidopsis*. We found that the orthologs from poplar and rice induce expression of *CO* and *FT* in the *Arabidopsis* system. Activation of *CO* and *FT* expression in *Arabidopsis* by the poplar and rice derived *FBH* orthologs provides evidence for an evolutionarily conserved pathway between those three species. Determining precisely how the FBHs function in this pathway is a next step, as is examining whether these factors play the same key role in further plant species. Ultimately, genetic manipulation of the FBHs may prove to be a crucial development in the global effort to maximize crop efficiency and yield.

**Power Evolution of Lightning in Oceanic Thunderstorms**

*Ben King, Senior, Earth and Space Sciences*
*Mentor: Robert Holzworth, Earth and Space Sciences*
*Mentor: Michael Hutchins, Earth and Space Sciences*

Weather prediction has become an integral tool in our society, giving us the ability to prepare for storms and route aircraft and ships around dangerous weather. Achieving a better understanding of lightning, its causes, and the patterns involved in it will allow further improvement of weather modeling as well as better interpretation of existing data. We aim to better understand the electrical evolution of these storms and the local control of stroke power by using the World Wide Lightning Location Network (WWLLN) to track oceanic thunderstorms in a variety of environments while examining the radiated power of the lightning. The analysis of WWLLN data using MATLAB will allow us to evaluate trends as well as the factors affecting those trends.

**Detecting Bar Codes in Real Time for Blind Accessible Mobile Applications**

*Michael Lam, Graduated 2011, Applied and Computational Mathematical Sciences and Computer Engineering*
*Mentor: Richard Ladner, Computer Science and Engineering*

With bar codes still prevalent today, smart phones with cameras are able to scan them and retrieve useful results from the Internet. While mobile applications currently exist on the market to read bar codes, most are not accessible to blind people or those with low vision. Such applications require users 1) to know precisely where the bar code is located on the product and 2) to aim the phone steadily at the bar code for a photo, which are both difficult tasks for blind people. The goal is to develop an application that automatically detects bar codes while the user is physically searching the product with the smart phone's video camera. In order to detect bar codes, computer vision algorithms and techniques are used. It is hypothesized that applying the Discrete Cosine Transform (DCT) to small blocks within video frames may yield fast and accurate results for smart phones. Sample video footage of bar codes from grocery stores are processed with DCT and evaluated for good precision and recall. If the hypothesis is correct, then the DCT algorithm is suited for phone applications.

**How about Cosmogenic Nuclides in Glacial Geology**

*Danielle Lemmon, Sophomore, Physics*
*Mentor: John Stone, Earth and Space Sciences*

Little is known about the glacial history, ice-sheet dynamics, and deglaciation in the Transantarctic Mountain region between the Reedy and Hatherton glaciers. Knowledge of how a glacier has thickened and thinned over hundreds of thousands of years can be improved by analyzing bedrock samples from different elevations along the glaciers, and applying the cosmogenic nuclide methodology. Cosmogenic nuclides are rare isotopes of certain elements found in bedrock, such as Chlorine-36, Aluminum-26, and Beryllium-10 that are created by nuclear reactions from extraterrestrial radiation, i.e. cosmic rays. The buildup of these nuclides dates how long a rock has been exposed to cosmic rays. As a glacier melts and thins, for example, the ice will cease to shield sub-glacial mountain bedrock, thereby exposing it to cosmic rays. By determining the concentration of the nuclides in bedrock samples from different elevations, we can compile a chronology of how a glacier has thickened and thinned over time and make observations about how the retreat and advance of glaciers in the Antarctic have contributed to the rise and fall of sea level throughout the recent past of the Holocene age.

**Using Mathematical Modeling to Quantify Gliomas**

*Evan Leon, Sophomore, Computer Engineering*
*Mentor: Russ Rockne, Pathology*
*Mentor: Kristin Swanson, Pathology and Applied Mathematics*

Gilomas are uniformly fatal brain tumors that can invade on the cellular level. Their diffuse nature makes treatments ineffective and only able to give the patient a slightly longer life expectancy at best. A semi-automated procedure is used to segment regions of interest from 2D MRI slices and compile them into a total tumor volume. The tumor’s volumes at two different visibility thresholds are acquired using a T1GD MRI, which shows tumor blood vessels, and T2 MRI, which extends to the surrounding edema. We use this pre-treatment MRI information to estimate parameters of a mathematical model of glioma growth. With the tumor profiled at two different concentrations given by T1Gd and T2 MRI, we can calculate $\lambda$, the relationship between D (net rate of diffusion) and $\rho$ (net rate of proliferation). When using two time points we can calculate linear radial velocity, with this velocity and $\lambda$ we can calculate D and $\rho$. We enter these patient specific parameters into our reaction-diffusion model for tumor growth to predict tumor cell concentration over space and time. The predictions from this model can give us information about the patient's responsiveness to different treatments and insight into prognosis.

**Salts and Soils on Mars: Analysis of Phoenix Aqueous Chemistry in the Context of Previous Lander Data**

*Alysia Letourneau, Junior, Pre-Engineering*
*Mentor: David Catling, Earth and Space Science*

In 2008, NASA's Phoenix Mars Lander analyzed Martian soil using a Wet Chemistry Lab (WCL) instrument. The goal of this project is to better understand the WCL data to determine the origin of salts in the soil. The WCL consisted of four cells where the protocol for each cell was to mix ~1 g of soil with water and measure dissolved ion concentrations with 15 ion-selective electrodes (ISEs). The ISE data are unexpectedly noisy. The thermostat for each WCL cell was a simple off/on heater system that likely influenced the ISE readings. Interpolation and correlation methods are being used to determine how temperature cycling affected the data. Through mathematical filtering methods, such as a Kalman filter, noise in the data may also be removed while calculating statistical uncertainties. After cleaning up the data, we may use aqueous chemistry models and work backwards to determine the combination of ions in various soil minerals before they were dissolved. Knowing the chemical makeup of the soil enables us to hypothesize about chemical and possible biotic processes on Mars.

**Identifying Mutations in the *TBX3* Gene that Cause Ulnar Mammary Syndrome**

*Weiyi Li, Junior, Biochemistry*
*Mentor: Michael Bamshad, Pediatrics*
*Mentor: Heidi Gildersleeve, Pediatrics*

Ulnar-Mammary Syndrome (UMS) is a congenital syndrome that is characterized by ulnar abnormalities and breast hypoplasia. The Bamshad Lab discovered that UMS is caused by mutations in the gene, *TBX3*. The goal of our project is to find novel *TBX3* mutations that cause UMS, and expand the knowledge of how different mutations correlate to the severity of the disease. We collected DNA samples from three UMS families, and sequenced the exons of *TBX3* via Sanger sequencing. Sequence analysis software allowed us to search the sequence for mutations and their locations within the gene. In the family K31928, previous screening showed that the proband and her sister, have a mutation called 1294_1301dup8. We screened the parents for mutations in *TBX3*, and we found that the father had the insertion mutation as well. The father's clinical findings were very mild, but this screening confirmed that he passed the mutation causing UMS to his daughters. No mutations were found in members of the other two UMS families. The next step of this project is to investigate, in the families without *TBX3* mutations, other candidate genes, as well as regulatory regions of *TBX3*, for mutations that could cause UMS.

**Membrane Filtration of Fresh Water using Heated Aluminum Oxide Particles**

*Francesca Liburdy, Freshman, Pre-Engineering*
*Mentor: Mark Benjamin, Civil and Environmental Engineering*

Membranes are used frequently in water filtration to remove bacteria and contaminants from fresh water. Natural organic matter (NOM) collects inside the permeable membrane, and causes resistance against the water flow. As NOM collects, more force is required to move water through the membrane, and the energy required to continue the process increases. When water can no longer move through the membrane, the membrane has fouled. This project examines the filtration and adsorption of NOM in fresh water obtained from Lake Washington. Heated aluminum oxide particles (HAOPs) act as an adsorbent layer, trapping NOM and protecting the membrane from fouling. The HAOPs protect the membrane by collecting and removing NOM through deposition and backwash cycles. During deposition, twenty grams per meters squared ($g/m^2$) of HAOPs are pumped inside a plastic, tubular membrane with a pore size of 2-3 microns. Lake water is then pumped through the membrane at a flux rate of 200 liters per meters squared per hour (lmh), and trans-membrane pressures are measured within the system. Trans-membrane pressure is measured to calculate the amount of pressure necessary to move water through the membrane. Samples are collected periodically throughout a 20 hour run time and analyzed for UV absorbance. UV absorbance measures the amount of light able to transmit through a sample of lake water; the amount of light that travels through the water correlates with the amount of contaminants or NOM that remain in the water. HAOPs successfully remove NOM molecules and protect the membrane, preventing it from fouling quickly.

**Development of Thermal Sensor Strings for Glacial Deployment**

*Patrick Ma, Sophomore, Pre-Engineering*
*Mentor: Dale Winebrenner, Applied Physics Laboratory: Polar Science Center*

Conventional belief has held that the icy regions of our solar system and planet are too cold to support life. However, new research has suggested that below the surface of some moons, like Jupiter's Enceladus, lay pockets or oceans of liquid water. In addition, lakes, rivers, and whole ecosystems have been discovered beneath glaciers, areas previously thought devoid of such features. Unfortunately, accessibility remains a primary challenge to further study of these areas. One Applied Physics Laboratory experiment aims to provide a simple and practical alternative to current ice bore-hole technology by developing a heated probe that simply melts through the ice collecting data as it descends. As part of this project, I am designing and developing a thermal temperature string to be deployed behind the probe as it descends to monitor the conditions of the glacier at depth. The result will be a sensor array capable of providing data on the internal glacial temperature for prolonged periods of time. The thermal string will consist of a number of sensors evenly spaced along a 100 meter bus wire and controlled by a microcontroller. This microcontroller samples the temperature of the ice at each sensor and stores the resulting data in onboard memory. Currently, the prototype setup transmits the data to a computer, which then stores the readings in a text file. I have also created software to interpret this file, which converts the binary data into readable temperatures and in the future will apply a quadratic calibration correction to each sensor reading. With this calibration, accuracies of ±0.05°C or better are expected for each sensor, compared to ±0.5°C without it. We plan to use this sensor array as part of the available instrumentation onboard the probe in places like the Greenland ice sheet or Antarctica. The design can also be modified for other types of sensors or experiments.

**A Closer Look at the Pyroclastic Density Current Deposits of the May 18, 1980 Eruption of Mt St Helens**

*Chelsea Mackaman-Lofland, Junior, Earth and Space Sciences*
*Mentor: Brittany Brand, Earth and Space Sciences*

Pyroclastic Density Currents (PDCs) are the most dangerous hazard associated with explosive volcanic eruptions. Due to the danger associated with observing these ground-hugging currents of searing hot gas, ash, and rock in real time, their processes are poorly understood. In order to understand flow dynamics, including what controls how far PDCs travel and how they interact with topography, it is necessary to study their deposits. The May 18$^{th}$, 1980 eruption of Mt. St. Helens produced multiple PDCs, burying the area north of the volcano under 10s of meters of PDC deposits. The eruption is one of the best observed on record, and deep drainage erosion over the past 30 years has exposed the three-dimensional structure of the PDC deposits, making this intensive study possible. For each flow unit we measure deposit thickness, bedding style, clast size, density and sorting, and degree of pumice rounding with distance from source. The intricate vertical and lateral facies changes and complex cross-cutting relationships away from source, including rapid changes in bedding and granulometry characteristics within each unit, indicate that the currents interacted with complex topography early in their propagation. We use this observation and analysis to better understand and interpret flow dynamics. The data we collect will be used to refine and validate numerical models of PDCs, ultimately providing a more accurate hazard assessment for explosive eruptions.

**Determining the Density of Transiting Extrasolar Planets**

*Laura Mayorga, Senior, Astronomy and Physics*
*Mentor: Eric Agol, Astronomy*

In the search for habitable planets, density is crucial in allowing us to determine whether a planet is terrestrial or gaseous. We explore the method of measuring the flux from a star during a planetary transit to constrain the density and the mass of the planet. This method depends on our ability to detect a moon in the transit and chart minor fluctuations in moon velocity and moon position with respect to the planet. To determine the precision with which we can measure the density of a planet, we have created a model which produces a synthetic light curve from which we can attempt to extrapolate planet parameters. However, due to the fact that moon detection is a difficult task in the first place, we have found that the accuracy of planet density calculations is highly dependent on the noise of the sample. It may be necessary to combine our efforts with other methods, such as spectra analysis of Doppler shifts, to confidently differentiate potential life-bearing planets from those which are obviously not habitable.

**_p_-type Doping of Zinc Oxide Diluted Magnetic Semiconductor Quantum Dots**
*Ryan McMorris, Sophomore, Chemical Engineering*
*Mentor: Xiaosong Li, Chemistry*

Diluted magnetic semiconductor technology combines the properties of a semiconductor with ferromagnetism. Nanoparticles doped with magnetic elements such as Manganese offer a prime example of this type of material. Our specific task was to analyze the effects of *p*-type doping with nitrogen in ZnO quantum dots which ranges from 1.5 to 10 nm in diameter roughly. *p*-type doping in this material involves the replacement of an $O^{2-}$ ion with an $N^{2-}$ ion, which has one less electron resulting in a hole due to an empty $N^{2-}$ p-orbital. We hypothesize that when p-type doping is combined with paramagnetic $Mn^{2+}$ doping, the unpaired 3d electrons of two $Mn^{2+}$ ions separated by an $N^{2-}$ ion will adopt a ferromagnetic orientation as opposed to their traditional antiferromagnetic state. Testing for this experiment was done with the development version of Gaussian. Energy calculations within this program and further data analysis reveal information such as the total energy of each state of the system, molecular orbital data, and energy diagrams concerning the semiconductor properties of these materials. Results show that the lowest energy state occurs when the $Mn^{2+}$ ions adopt a ferromagnetic arrangement with the $N^{2-}$ hole sharing this alignment. The potential for this QD and others with similar properties is extreme as many semiconductor applications could be revolutionized by DMSs. New applications such as solar cells made of DMSs are also under consideration.

**Lightcurves of Transiting Exoplanets**
*John Mehlhaff, Freshman, Physics*
*Mentor: Andrew Becker, Astronomy*
*Mentor: Praveen Kundurthy, Astronomy*

Relative to stars, exoplanets outside our solar system are markedly harder to detect and study. Designed specifically to address this challenge, the Kepler Space Telescope provides data for exoplanet research that is unprecedented in accuracy. Kepler regularly photographs a fixed area of sky to temporally gauge the brightness of stars in that area, including the slight dimming exhibited when an orbiting planet crosses the face of a star. These transiting exoplanets thus produce distinct u-shaped lightcurves plotting observed star brightness versus time throughout the Kepler data. Our tasks have been mainly to write computer code capable of efficiently accessing and sifting through Kepler's vast database. Future work will be to create mathematical models of Kepler's lightcurves in order to better understand the properties of the planetary systems they represent. These properties include exoplanet size, transit path, orbital semi-major axis, and orbital location with respect to the host star's habitable zone. As researchers continue to scrutinize the data Kepler collects, discoveries could include Earth-like exoplanets within their stars' habitable zones. Such findings could spark further queries such as the proportion of potentially life-supporting planets and the astrophysical conditions that support their formation.

**Biological Collision Avoidance Algorithm**

*Katherine Midkiff, Freshman, Pre-Engineering*
*Mentor: Kristi A. Morgansen-Hill, Aeronautics and Astronautics*

Engineered vehicles capable of matching the performance of natural systems in collision avoidance have not yet been developed. The purpose of our research is to translate the collision avoidance capability of schooling fish to an algorithm that could be applied to engineered vehicles. We want to determine if schooling fish use collision cones to avoid colliding into each other. The collision cone is a set of velocities for one fish that indicates it will collide with another fish. In order to avoid collision, the fish's velocity vector must lie outside all collision cones. Constraints with this method are that it only works under certain conditions: each vehicle has constant velocities, uniform and full view sensing, noiseless measurements, and planar motion. This method already works well for engineered systems under these conditions. Our research is exploring how to alter the conditions to encompass the biological characteristics of the fish. As of now, the data that has been collected has revealed promising results, if further research reveals that collision cones do not match schooling fish's collision avoidance capability, other algorithms will be explored. This research is significant in that it will impact the development of UAVs (Unmanned Aerial Vehicles) and other autonomous technology.

**Rock Weathering due to Diurnal Variation of Insolation**

*Kathleen Moore, Sophomore, Pre-Engineering*
*Mentor: Peter Mackenzie-Helnwein, Civil and Environmental Engineering*

All solid materials have a stress limit beyond which cracks and ultimately fractures will develop; we are analyzing the possibility of uneven solar heating as a process that causes cracking. Research at the Universities of NM and NC drew attention to patterns of near vertical cracks in desert rocks, which known weathering processes cannot sufficiently explain. To investigate, temperature and strain data as well as cracking events were recorded using an instrumented boulder.

Our working hypothesis is that uneven heating from the diurnal cycle of the sun creates tensile stresses sufficient to cause cracking in these rocks. We created a 3D-Finite-Element-simulation of the boulder incorporating thermal radiation, heat conduction, and thermo-mechanical stress analysis. Simulation provides the link between insolation and stresses, allowing us to assess size and shape effects on tensile stresses. The current focus is on model validation by comparing measured and simulated temperature and strain data. As an example, we are calculating the maximum and minimum strain for each surface collection point and validating them against provided data. Future research will include a comprehensive data analysis concerning stress distribution and orientation within spherical boulders of various sizes, and an assessment of potential crack growth rates and crack orientation.

**Designing a Probe to Study Sub-Glacial Lakes**

*Ross Olason, Senior, Mechanical Engineering*
*Mentor: Dale Winebrenner, Applied Physics Laboratory: Polar Science Center*

Life is abundant on planet Earth, but we have relatively few locations in which we can study environments similar to those on other celestial bodies. One possible terrestrial feature that is similar to those on some of the moons of Saturn and Jupiter is Lake Vostok, located under 4000 meters of ice in Antarctica. If we can prove that life can survive in that desolate environment, which has been covered by ice for the last 35 million years, there is a heightened chance that extraterrestrial life exists within our own solar system. To study this area, we are designing a probe that will melt through the ice and take measurements from the lake to determine if bacteria or other life forms can survive in such a harsh environment. The main goals of my project are to develop a mechanism that will allow the probe to move vertically in the lake via user control, determine the optimal cable and wire storage method for such a large endeavor, and eventually design a housing for the probe that can withstand immense pressure without leaking. This is done by using 3D computer aided design software and pressure and stress analysis tools. From these designs, I manufactured actual prototypes to test my concepts. Eventually, this work will lead to a functioning probe that will survey Lake Vostok and other sub-glacial lakes in an attempt to find evidence of life.

**Integrated Sensor Technology for Real-Time Recording of Dietary Intake**

*Eric Pepin, Senior, Electrical Engineering*
*Mentor: Alexander Mamishev, Electrical Engineering*
*Mentor: Junqing Shang, Electrical Engineering*

In recent years, electronic sensors and digital devices have been successful in improving the automated collection of personal activity data in a pervasive manner. Through these developments and expansive advancements in mobile computing, the ability to accurately record and maintain complex health records has been realized. Yet, although an instrumental tool in preventative medicine, dietary assessment remains an understudied and underdeveloped component within the sphere of electronic health records management. The challenge in designing a pervasive, electronic dietary assessment device is its need to facilitate real-time diet intake tracking, requiring considerable system optimization research and rigorous validation to confirm its superiority over current paper-based methods for self-report. As a prototype that promises to meet these specifications, we have developed the Dietary Data Recording System (DDRS). The foundation of this system is the duel employment of an electronic data collection device and an advanced image processing technique which enables food volume calculations. While the development of this prototype is significant, the automated diet intake tracking supported by the full realization of this system would provide the medical industry with an invaluable tool in definitively correlating the long term intake of certain foods to cancer, heart-disease, and diabetes.

**Modeling an X-Ray Detector for X-Rays Emitted By Charged Particles in the Upper Atmosphere**

*Amanda Sams, Freshman, Chemical Engineering*
*Mentor: Michael McCarthy, Earth and Space Sciences*

The Earth's magnetic field deflects most of the energetic particles contained in solar wind, but some are captured and trapped in regions called radiation belts. Sometimes, high-energy particles migrate from the radiation belts into Earth's upper atmosphere, where they interact with matter to produce X-rays. Our project focuses on attempting to understand radiation belt loss processes by analyzing the X-ray data. Professor Michael McCarthy and I modeled an existing X-ray detector on the computer and simulated electron populations (having various energy distributions) as they move through the upper atmosphere. We recorded the energy distribution of X-rays captured in the detector. We then compared this distribution with the actual X-ray energy distribution recorded by real experiments. This method of working backwards limits what the energy distribution of the original charged particles may have been. This is significant, because knowing the energy distribution of charged particles in radiation belts and understanding how they move into the upper atmosphere will allow engineers to design spacecraft and satellites that are more resistant to damage from high-energy particles and X-rays. It is also an interesting research question that will teach us about the radiation belts of other planets in the universe that have magnetic fields. Our project will soon be applied to more experiments; in January 2013, 20 balloons equipped with X-ray detectors will be released in Antarctica to monitor the upper atmosphere. Another extension of this work is to model the effects of high-energy protons from solar wind on Earth's upper atmosphere.

**Study of the Dynamics and Thermodynamics of the Upper Atmospheric Regions (Southern Hemisphere)**

*Andre Stone, Freshman, Pre-Engineering*
*Mentor: Michael McCarthy, Earth and Space Sciences*

We are studying Earth's upper atmosphere, one of the least understood atmospheric regions, wind and temperature fields to determine stimuli behind the movement of neutral particles (pushed, heated, interacted with charged particles, etc.). This project focuses on these regions in the Southern Hemisphere, which are essential to understanding movement in all areas of our atmosphere. The climate, long term trends, of the MLT (Mesosphere-Lower Thermosphere) will be studied via instrumentation at the Mount John Observatory (MJO) in New Zealand. The optical observations will provide characteristics, such as wind, kinetic temperature, and emission rates, for groups of species of molecules, which act as tracers for the ambient gas. The time series of motions and temperature from MJO, which provides an understanding of upper atmospheric behavior, extends slightly over one solar cycle. This extensive amount of data can provide us with a broader view into the effects of Global Climate Change. My role is to alter the spectrometer design to enhance the light collection section enabling improved measurements of the atmospheric changes and increased accuracy regarding wind/temperature. Future efforts consist of investigating effects of the lower on the upper atmosphere, and studying relative importance of the processes in action.

### Studying River Surface Roughness from Flow Generated Turbulence

*Thomas Stone, Senior, Physics*
*Mentor: Gordon Farquharson, Applied Physics Laboratory: Air-Sea Interaction & Remote Sensing*

Microwave radars are remote sensing devices that use electromagnetic waves to make measurements. One use of microwave radars is to measure the flow of moving bodies of waters such as rivers. These measurements are possible because microwave radars use electromagnetic waves that are sensitive to small-scale surface roughness (centimeter scale gravity-capillary waves) that exist on water surfaces. It is well known that surface roughness can be generated from wind blowing over the water at speeds greater than 1.7 m/s. However, it has not been determined under what conditions flow generated turbulence can generate a sufficient amount of surface roughness on a river. Currently, at the Applied Physics Lab, we are developing a **CO**herent **R**eal **A**perture **R**adar (CORAR) system to see if we can find a correlation between flow-generated turbulence and river surface roughness. The CORAR system generates a 9.36GHz electromagnetic signal directed at the river. The backscattered electromagnetic signal from the small-scale surface roughness is used to determine characteristics of the river such as the distance of the waves with respect to the radar and the Doppler shift of waves at various distances. If a correlation can be found between the flow-generated turbulence and surface roughness during low wind speeds, then microwave radars can be used to remotely estimate characteristics of rivers such as the discharge of water in the river and possibly changes in the topography of riverbeds. These characteristics can be used to study how a particular river can change throughout the year and help ships navigate rivers safely.

### Automation of Meteor Detection with a Distributed Passive Radar

*Kaiwen Sun, Sophomore, Electrical Engineering*
*Mentor: John Sahr, Electrical Engineering*

Hundreds of tons of meteors collide with the Earth's upper atmosphere each day, leaving trails of ionization that scatter radio waves. Although the trails last only a fraction of a second, this is sufficient for their detection by the Manastash Ridge Radar (MRR), which operates at 100 MHz. Observation of the trails yields information about the temperature of the atmosphere as well as the wind speed and direction at an altitude of 85 km. Because meteor events are relatively rare, and because there is a large amount of data, it is important to automate the detection of meteor trails so that they can be more easily studied. As part of this research, I have designed a software program that is able to detect the meteor signals in the radar data. Furthermore, I describe the algorithm that I used to automate the detection while providing a statistical summary of the results from our studies.

### The Effect of Octopamine on the Optomotor Responses of *Drosophila melanogaster*

*Talia Suner, Freshman, Pre-Science*
*Mentor: Michael Dickinson, Biology*

The Dickinson lab studies the neurobiology of fruit flies. Particularly, we tested the effects of the neurotransmitter octopamine on a fly's ability to respond to visual stimuli while flying and walking. Evidence shows that a set of visually sensitive cells that are thought to be involved in stabilizing reflexes during flight have different responsive properties with and without octopamine. To further investigate the role of octopamine in this system, we looked for optomotor response deficits in flies that do not produce octopamine. We used mutant *Drosophila melanogaster* flies that no longer have the gene for enzyme tyramine-beta-hydroxylase, which converts tyramine to octopamine. As a result, these flies build up an excess of tyramine and are unable to produce octopamine. We tethered a fly to a metal pin, and placed it an LED light arena, where we presented it with different moving stripe patterns. We placed an infrared light above the fly, and an infrared sensor below it. Infrared light was used because it is outside the visual range of the fly and would not interfere with our intended visual stimuli. The fly cast a shadow on the sensor, from which we computed the wingbeat frequency and amplitude. We used the left and right wingbeat amplitudes to determine the fly's torque, which indicates its turning response. We analyzed this turning response to measure the fly's ability to respond to the visual stimuli. Lastly, we compared the octopamine-null fly's response to wild type flies. These experiments will further our understanding of the role of octopamine in the optomotor response system of fruit flies.

**Laboratory Simulation of Cryogenites on Mars**

*Catherine Tang, Sophomore, Bioengineering*
*Mentor: David Catling, Earth Space and Sciences*
*Mentor: Bonnie Light, Applied Physics Laboratory: Polar Science Center*

A key factor involved in the exploration of Mars is the possibility that Mars may have harbored life early in its history. As the presence of liquid water is essential for life, NASA is pursuing the identification of aqueous salt minerals on the Martian surface. Examples of these minerals include magnesium sulfate of various hydration states (MgSO4-nH2O), Magnesium Chloride (MgCl2 nH2O), Calcium Sulfate (CaSO4), Magnesium Perchlorate (Mg(ClO4)2 nH2O),Potassium Perchlorate (KClO4 nH2O), and Sodium Perchlorate (NaClO4 n H2O). Therefore, Mars exploration emphasizes the origin of salts in Martian soils and what that could mean for past and current habitability of Mars. Recently, two NASA spacecrafts have returned imagery of mineral salt deposits on the Martian surface and it is hypothesized that these crystalline solids were formed when a salt solution cooled below its so-called eutectic temperature – the point at which everything becomes solidified. These cold salt deposit are known as "cryogenites".  These cryogenites can generally be crystallographically distinguished from "evaporates", which are crystals left behind after water has evaporated. It is possible to create laboratory simulations of these aqueous salt deposits that are believed to be in abundance on Mars to compare the morphologies and compositions of the different cryogenites. The temperature and concentration of the solution affect the number of water molecules attached to the resulting crystals and therefore the morphologies of the different crystals. We use multiple cooling methods including walk-in cold rooms, chest freezers, and standard refrigerators to cool our salt solutions below their respective eutectic temperatures (-0.2C to -68C). After cooling, some eutectic solids will contain ice that needs to be sublimated which requires the use of hydrophilic chemicals such as $CaCl_2$ to pull off the moisture and isolate the salt crystals. Another option is to desiccate the solid by freeze drying. After photographing the cryogenite crystals under a microscope, crystal morphologies are compared with that from the lander imagery. We expect our lab simulation photos to align very closely to the lander imagery, especially salts that are of abundance on Mars.

**Sensors, Soils, and the Search for the Driest Place on Earth**

*Connie Tang, Sophomore, Chemical Engineering*
*Mentor: Mark Claire, Earth and Space Sciences*

Yungai, located in the heart of the Atacama Desert, is currently recorded as the driest place on earth. These records are based only on experiments conducted through the use of rain gauges to measure rainfall. We are investigating the possibility of regions in the Atacama even drier than Yungai. However, in areas where less than 1mm of rain falls each year, it is almost impossible to measure rainfall by means of rain gauges. The goal of this project is to find a way to measure rainfall in areas with extremely low amounts of precipitation. To do this, we are looking at the correlation between the amount of rainfall and the salt distribution in a given region. Generally in non-arid regions, soluble salts such as nitrates and perchlorates wash away into groundwater and the ocean. In deserts, however, where salts are allowed to accumulate, occasional rainfall will dissolve these salts and moves them vertically through the soil column. If we can determine the amount of precipitation it takes to dissolve and move salts to certain depths, then we will be able to use a vertical soil profile as a means to determine how much rain has fallen in an area in a given period of time. The method will involve designing ion specific electrodes that can measure concentrations of nitrates and perchlorates in soil. These sensors will be used to run experiments in which known concentrations of salts are added to desert soils and subjected to simulated rainfall rates which will allow us to determine the maximum rainfall that correlates with various distributions of salts. Thus far, samples from KM 40, a region of the Atacama Desert, have shown a very irregular salt distribution, in the sense that it does not correlate with previously discovered trends. We anticipate that further tests on KM 40 will indicate that it is even drier than Yungai, the current driest place on earth.

**Correlating Aqueous Compositions and Surface Morphologies on Mars**

*Nancy Thomas, Sophomore, Astronomy and Physics*
*Mentor: Joshua Bandfield, Earth and Space Sciences*
*Mentor: Andrew Becker, Astronomy*

In order to gain evidence for the presence of liquid water throughout the history of Mars, we use spectroscopy, which provides the ability to analyze the surface composition of Mars from orbit. Spectral images from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) aboard the Mars Reconnaissance Orbiter (MRO) were used to identify a variety of minerals on Mars indicating the various processes that were present at the time of their formation. We identify minerals from their unique absorptions at specific wavelengths by examining CRISM surface reflectance data across 438 wavelengths that range 1.0 to 3.9 microns. Specifically, our global survey of hydrated mineralogy has targeted zeolite, sulfate, and hydrated silica deposits. Specifically, our surveys have targeted locations within Valles Marineris, Columbus Crater and Mawrth Vallis. By correlating CRISM spectral signatures within these regions with morphological features on the Martian surface pictured in MRO Context Camera (CTX) images, we are able to provide context for the surface mineralogy. Spatial association of minerals improves our understanding of the conditions present at the time of their formation. Our survey will continue to map the detailed distributions of zeolite, sulfate and hydrated silica deposits in order to compare with surface morphology. By combining the morphological and mineralogical information, we have stronger and more detailed evidence of the presence of liquid water on Mars that may indicate specific conditions conducive for the development of life.

**Determining the Cause of Period Shift in Radio Emissions from Saturn**

*Kazuo Thow, Junior, Mathematics and Applied and Computational Mathematical Sciences*
*Mentor: Erika Harnett, Earth and Space Sciences*

Measuring the rotation rate of a gas giant planet can be very difficult; in the absence of a solid surface, rotation must be measured indirectly. Jupiter and Saturn's rotation rates have been estimated from periodicities in radio emissions from their magnetic poles. At Saturn these radio emissions are called Saturn kilometric radiation (SKR), and the Cassini spacecraft surprised us by measuring a significantly different period in SKR compared to what Voyager 1 measured 30 years previously. Simulations of the space around Saturn show persistent "fingers" of relatively cool plasma rotating around the planet and distinct plasmoids (coherent structures of plasma and magnetic fields) forming at semi-regular time intervals and moving downstream along the direction of the solar wind. We suspect that the period shift of SKR is related to the behavior of plasmoids and plasma fingers. We will examine simulations of Saturn for patterns in this magnetospheric behavior. Finding the nature of their relationship will help in understanding SKR data, determining the rotational period of Saturn itself, and may also bear implications on the search for extra-solar planets.

**A Comparison of Trait Size Among Magellanic Penguin Colonies**

*Johannah Verhulst, Junior, Ecology, Evolution, and Conservation Biology*
*Mentor: Dee Boersma, Biology*
*Mentor: Ginger Rebstock, Biology*

Magellanic penguin size (weight and structural traits) is likely to influence the survival and reproductive success of an individual. Although Magellanic penguin colonies are not genetically differentiated, there may be significant trait size differences among colonies. The goal of my project was to use the Boersma lab's substantial Magellanic Penguin Project database to compare the size of various traits (weight, bill length, bill depth, flipper and foot) among Magellanic penguin colonies in Argentina, Chile, and the Falkland/Malvinas Islands. We expected structural traits and weights to differ among colonies reflecting adaptation to the local environment. To investigate that possibility, we matched the years, months and approximate gender ratio of the measurements collected from other colonies with a randomly selected sample of penguins from Punta Tombo for comparison. We had twelve colonies with a total of 792 penguins with measurements that we also divided by gender to control for variation in gender ratios among colonies. We performed an ANOVA on these data using Stata, a statistical analysis program. When ANOVAs were significant, we performed pairwise comparisons (Tukey HSD) among the colonies. All traits varied among colonies except flipper length for females. Average female flipper length was 14.6 cm. and was similar in size among colonies suggesting that surface area may be critical for foraging success and for survival. Bill length decreased with latitude for both males and females ($R^2$ = 0 .73 for males, $R^2$ = 0.58 for females). Exploring the interactions between latitude and trait size suggests selection is favoring penguins with longer bills at lower latitudes. Why? How does diet change with latitude? Do penguins with longer bills have higher reproductive success and survival at lower latitudes than penguins with shorter beaks? Further research may explore the relationship between differences in penguin morphology and these potential environmental factors.

**Evaluating Used Helmet Standards and Utility**

*Tyler Wickstrom, Senior, Mechanical Engineering*
*Mentor: Randal P. Ching, Mechanical Engineering*
*Mentor: Irving Scher, Guidance Engineering*

Helmets have been trusted to provide protection against head impacts for millennia and have become a universally promoted piece of safety equipment. Current helmet standards such as NOCSAE, SNELL, and ASTM specify the requirements for critical impacts under varying conditions such as; temperature, impact location, and impact energy. However, most standards only minimally account for the effects of sub-critical collisions and the natural fatiguing processes experienced by a helmet during its use. Intuition suggests that these seasonal cycles and minor impacts attenuate the utility of protective headgear; however, a scientific inquiry into such effects could illuminate or invalidate this assumption. The working hypothesis of the research team under Professor Randal Ching and Irv Scher was that sub-critical impacts and seasonal cycling would diminish a helmet’s protective abilities (as measured by metrics such as peak linear acceleration and severity indices), and the goal was to illustrate that current standards and refurbishing methods need to account for these various effects of age and use. Accordingly, my research group designed a helmet drop tower to test a variety of different helmets (football, motorcycle, and ski) according to SNELL and NOCSAE standards, and used helmets were compared to their new counterparts. Direct comparisons between used and new helmets were used to evaluate the effects of age and minor impacts on helmets, the effectiveness of current standards at predicting the utility of helmets, and the expected lifetime of helmets under given conditions. As the first independent study of helmet performance in the state of Washington, this study could give vital feedback to helmet manufacturers, helmet standard foundations, and helmet users alike.