58th National Junior Sciences and Humanities Symposium:

Abstracts Catalog

The abstracts in this publication are from original scientific research conducted by participating students in the 58th National Junior Science and Humanities Symposium. JSHS is a collaborative effort between the research arm of the Department of Defense Tri-Services - U.S. Army, Navy, and Air Force and nationwide academic research institutes.

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National Junior Science and Humanities Symposium

Program Objectives

- Promote research and experimentation in sciences, technology, engineering, and mathematics (STEM) at the high school level.
- Recognize the significance of research in human affairs and the importance of humane and ethical principles in the application of research results.
- Identify talented youth and their teachers, recognize their accomplishments at symposia, and encourage their continued interest and participation in STEM.
- Expand the horizons of research-oriented students by exposing them to opportunities in STEM within the Department of Defense, academia, industry, and government.
- Increase the number of adults capable of conducting research and development.

NJSHS 2020 Oral Presenters

Environmental Science

Smrithi Balasubramanian
Krisangi Bhargava
Ella Dommert (3)
Jadyn Henry
Julia Kagiliery (1)
Mithra Karamchedu
Emma Kitchin
Lucas Ritzdorf
Hannah Rogers
Emma Romano
Safiya Sankari
Elise Scheuring (2)
Adyant Shankar
Lea Wang

Biomedical Sciences

Sarah Barksdale
Evelyn Bodoni (1)
Ishaan Brar (2)
Kevin Fan
Victoria Hwang
Kaeo Kekumano
Aditi Kumari
Anne Liang (3)
Ilhaam Mahoui
Arundathi Nair
Paulina Naydenkov
Sahasra Pokkunuri
Logan Ridenbaugh
Eden Winga
Keena Yin

Life Science

Ahmad Abdel-Azim
Audrey Anderson (1)
Sydney Assalita
Vaughn Hughes
Rincon Jagarlamudi
Sarah Katz
Alice Khomski
James Lao
John Lin
Amara Orth
Anya Razmi
Caroline Reed (2)
Anushka Sanyal
Emily Tianshi (3)

Medicine & Health/Behavioral Sciences

Rachel Brooks
Sarah Burkey (1)
Kasyap Chakravadhanula
Daniel Choi
Emmalyn Kartchner
Isabella Knott
Shan Lateef (2)
Rhea Malhotra
Irene Mamontov
Michaela McCormack
Viraj Mehta
Saraswati Sridhar
Grace Sun (3)
Dasia Taylor

Engineering & Technology

Yuvanshu Agarwal
Reese Artero
Joseph Clary
Bryce Goodin
Kelsey Krusen
Catherine Kung
Luke Millam
Eliza Moore
Axel S. Toro Vega (2)

Vetri Vel (3)
Ryan Westcott (1)

Mathematics & Computer Science

Sam Florin
Melody Guo
Anu Iyer
Kabir Jolly
Tarun Kumar Martheswaran (2)
Rachel Muppidi
Ryan Park (1)
Lillian Petersen
Jason Ping
Jacqueline Prawira
Michelle Tang (3)

Physical Sciences

Jared Lenn
Josie Long
Mina Mandic (1)
Aniket Pant
Alay Shah (2)
Owen Skriloff (3)

Chemistry

Anna Grondolsky (3)
Reagan Guerra (2)
Emma Steude (1)
Uyen Nhi Tran
Ethan Weisberg

Using Single-Cell RNA Sequencing Data to Study Plastid Differentiation Dynamics with Nucleus-Encoded Plastid Gene Expression in *Arabidopsis thaliana*

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Research Mentor:
Tessa Green
Department of Systems Biology
Harvard Medical School

Little is known on how cell differentiation dynamics are impacted by other biological systems, such as organelle development. The plant provides an interesting context to study this impact given its diverse array of cell and plastid types. Plastids are organelles that are unique to plant cells, synthesizing and storing critical chemical compounds and pigments. All plastids develop from undifferentiated proplastids in meristematic tissue; however, it is unknown how plastid development progresses relative to cell development, namely the extent to which plastid state is coupled with cell state. This coupling was explored via single cell RNA sequencing of the root of *Arabidopsis thaliana*. Cells and plastids were clustered based on distinct nucleus-encoded plastid genes and non-plastid-related genes, respectively, enabling independent assignment of plastid and cell types. A machine learning model was developed to classify cell types based solely on plastid gene expression profiles. The high accuracy of this model (>96%) suggests that each cell type houses a distinctive plastid type. A trajectory inference model was used to create a pseudotime axis between undifferentiated meristematic cells and mature endodermal cells, enabling the study of plastid development relative to cell development. Along this pseudotime axis, plastid state was found to be coupled with cell state. Our findings lead to advances in plastid engineering and may enable future biotechnological applications. Moreover, we offer a novel computational pipeline to actually study cell organelles at the single-cell level which opens the door for a wide variety of applications beyond plants.

Virtual Assistant application to optimize the usage of water and crop yield.

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Currently, agriculture wastes 1,500 trillion liters of water annually and to sustain a growing population, we must grow 70% more food by 2050. My voice technology based virtual assistant application predicts crops' water requirements and growth stage in languages like Hindi, French, Spanish, and English to optimize water and crop yield. The application extracts the required inputs using natural language processing. Based on the inputs it collects for different crops, the Python code mines for the PET (Potential Evapotranspiration) and the PPET (ratio of Precipitation to PET) from external APIs. The application utilizes an algorithm to compute the water requirements where if the weather forecast predicts no rain and PPET<1, then the water requirements (mm) is computed as PET-Precipitation. Similarly, the application determines the crops' growth stage by mining for each crops' accumulated GDD (Growing Degree Days) and mapping it to particular thresholds of growth stages. The results of the application were within an average error margin of 5-7% as compared to crop research. By relaying accurate water requirements and growth stages to small farmers around the world in multiple languages, the application can help farmers grow healthy crops and drive insightful irrigation decisions.

Resilin Distribution and Abundance in Apis mellifera Wing Joints across Biological Age Classes

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Research Mentor:
Dr. Fassbinder-Orth

This study investigated the variance of resilin between *Apis mellifera* biological age classes. The presence of resilin, an elastomeric protein, in insect vein joints provides the flexible, passive deformations that are crucial to *A. mellifera* flight and the role of the forager, the oldest *A. mellifera* biological age class. Foragers collect the pollen necessary to feed the colony and their disappearance jeopardizes colony health, contributing to the onset of Colony Collapse Disorder (CCD). As CCD and other stressors continue to impact *A. mellifera* populations, it is increasingly important to understand and establish physiological markers of *A. mellifera*health, allowing for early warning systems for apiarists to take preventative actions. Resilin is a potential novel and age-dependent indicator of health. Methodology included measuring the 1m-cu, 2m-cu, Cu-V, and Cu2-V joints on the forewing and the Cu- V joint of the hindwing using a fluorescence microscope equipped with an aniline blue filter. Quantitative fluorescence imaging analysis calculated Corrected Total Cell Fluorescence (CTCF). The 1m-cu and the Cu-V joints on the ventral forewing, and the Cu-V joint on the ventral hindwing varied significantly between age classes on the left and right sides of the wing. At the 1m-cu joint, CTCF continually decreased from the hatchling to forager age classes. At the Cu-V joints on the forewing and the hindwing, CTCF decreased from the hatchling to nurse age classes, and then increased between the nurse, guard, and forager age classes. The results of this study suggest that the CTCF of resilin is age-dependent.

Disaster Proof Design for Pacific Housing

Reese Artero
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U.S. Naval Hospital Base

Mentor: Paul Cuaresma

Typhoon damage is a growing point of concern for the people of the Pacific; destroying homes, causing water shortages, power outages, flooding, and even death in the most extreme cases, prompting the idea to create a design that could successfully withstand all natural disasters within the Pacific Region. With the creation of a contoured dome model structure, typhoon damages would be significantly decreased, limiting the amount of damage control that would need to be done afterwards, and limiting the amount of people that could possibly be harmed during typhoons as well. Through extensive wind tests using sugar and wind, it was found that a contoured dome model is more effective in comparison to a smooth model dome, with an almost 50% higher wind diversion rate. Ultimately, the design for a disaster proof home for the pacific, maintains a higher windload than most other residential structures, and would be able to withstand some of the most damaging winds in the case of a super typhoon in the pacific.

The Effect of Light Intensity on Planarian Regeneration: Using Planarian Regeneration Patterns as a Model for Human Regeneration Projects

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In a mere ten to twenty years, regeneration within human specimens may become common practice in the medical field. Considering this information, the impact of regeneration needs to be evaluated. The study of Brown Planarians, which is a freshwater model organism that has the ability to regenerate after amputation, can be used to further understand what regeneration may mean moving forward. In this study, these Planarians were cut and grown in different intensities and types of light to see the impact of this exposure on regeneration patterns. There were five types (correlating with different intensities) of light: total darkness, natural light, Incandescent Light, LED Light and CFL light. A randomized complete block design was used to set up the planarians on various trays. The Planarians were grown until full regeneration was observed, with a fully formed tapered tail, auricles, and eyespots. Between all trays, the ANOVA test for the time to regenerate had a P-value of <0.0001, and the Tukey HSD Test identified where the significance for all trays lie. Additionally, the Chi-Square test showed a distinct difference between the proportionality of Alive vs. Dead between all trays, also with a P-value of <0.0001. There was no statistical correlation between intensity and regeneration found.

Integrating Precision Agriculture through Automated Nutrient Analysis and Artificial Intelligence Crop Decision Modeling

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Teacher: Ms. Belinda Hafell
duPont Manual High School

To maximize crop production many farms utilize fertilizers that supplement the soil with nutrients, such as nitrogen, potassium, and phosphorus. However, many farms over apply the necessary amount of fertilizer in order to ensure high yields. To exacerbate the issue, fertilizer costs are now exponentially increasing, with sales exceeding $18 billion dollars annually just within the United States. Lamentably, the financial cost of applying extra fertilizer in a field is substantially lower than the potential yield loss as a result of an under-application of fertilizer. However, this over application of fertilizers is mainly due to the absence of a feasible method to quantify nutrient concentration in real-time. To combat this problem I created a two pronged solution. Firstly, I created a feasible and automated method of rapid and efficient nutrient quantification for the main nutrients. Secondly, I created a machine learning and artificial intelligence algorithmic program capable of predicting crop yields utilizing the nutrient values quantified from the former automated process, as well as an input of other variables, for rural farmers that have limited access to technology, allowing users to make timely and informed day-to-day decisions. By creating predictive crop models, small scale farmers will be able to make decisions for the amount of fertilizer necessary based on the outputs created by the algorithms, thus mitigating the issues created by the over and under application of fertilizers. This two pronged solution allows for a more efficient method of fertilizer application with far less detriments on the environment.

The effect of anti-PD1 and anti-PDL1 on the cytokine profile and immune system

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Teacher: Marion Zeiner

Programmed cell death -1 (PD-1) is an inhibitory receptor expressed on a variety of immune cells that provides a checkpoint against autoimmunity. The binding of PD-1 to its ligand, PD-L1, inhibits T cell function, proliferation, and cytokine production, and promotes apoptosis. Some cancer cells express high levels of PD-L1 and use this mechanism to evade attack. Immune checkpoint inhibitors, anti-PD1 and anti-PDL1, block this binding and allow T cells to attack cancer cells. However, these treatments have varying efficacy and more than 27% of patients experience adverse effects (Gong et al., 2018). This indicates that anti-PD1 and anti-PDL1 alter the healthy immune system. The goal of this study was to examine the effects of anti-PD1 and anti-PDL1 on the cytokine profile and immune system composition of healthy wild type mice to identify possible biomarkers for an adverse reaction to treatment. The cytokine profile of the serum and the immune landscape of the spleen of the mice treated with either anti-PD1, antiPDL1, or a control isotype were examined. These studies indicated that among the several cytokines tested, B Lymphocyte Chemoattractant (BLC), a chemotactic cytokine for B cells, and TIMP Metallopeptidase Inhibitor 1(TIMP-1), a signaling molecule that influences cell growth, apoptosis, and differentiation, were upregulated following anti-PD1 treatment. Additionally, immunophenotyping studies indicated that B cells and CD4+ and CD8+ Treg cells were up-regulated by treatment with both anti-PD1 and anti-PDL1. The adverse effects and varying efficacy of anti-PD1 and anti-PDL1 may be linked to these changes in the healthy immune system.

Reference List:

Gong, Jun, et al. “Development of PD-1 and PD-L1 Inhibitors as a Form of Cancer Immunotherapy: a Comprehensive Review of Registration Trials and Future Considerations.” *Journal for Immunotherapy of Cancer*, BioMed Central, 23 Jan. 2018. Accessed on June 5, 2019.

Impact of Hydraulic Fracturing on the Susquehanna and Delaware Watersheds

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Bryn Mawr, Pennsylvania

Mentor: Thomas McKeon MPH
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Chemical by-products from the hydraulic fracturing industry are known to contaminate bodies of water, often putting human health at risk. To prevent this issue, the Pennsylvania Department of Environmental Protection (PADEP) enacted a legislation, which required all hydraulic fracturing sites to be more than 1,000 feet away from a water body. However, during rain events, these chemicals can be washed downstream and travel more than 1,000 feet, finding their way into distant waterways. This chemical accumulation may negatively affect the environment and integrity of our public drinking water. ESRI’s ArcGIS, a computer software used for analyzing geographical and spatial data, was used to study this topic. Publicly available geographic layers from PASDA, PADOH, and OpenDataPhilly were used in this study. Locations of hydraulic fracturing wells in PA were geocoded over areal layers of the Delaware and Susquehanna watersheds, and county-level layer of the State of Pennsylvania. Spatial analyst tools such as Hydrology Fill and Flow Direction/Accumulation tools in ArcGIS were used to analyze elevation data and assess risk of chemical drainage into bodies of water via watersheds and tributaries. Key findings from this project were that forty-eight hydraulic fracturing sites are at risk for contaminating water with dangerous chemicals.

Please click this video link to review the presentation. Thanks!
Video Link: https://www.youtube.com/watch?v=JiiNRnQKEvk

Novel Preventative Strategies for Acute Kidney Injury & Chronic Kidney Disease

Greenwood Village, Colorado

Mentor: Dr. Nataliya Skrypnyk
University of Virginia

Acute Kidney Injury (AKI), a common complication in hospitalized patients, leads to Chronic Kidney Disease (CKD) and, eventually End-Stage Renal Disease (ESRD). Except dialysis and kidney transplant, there are no available therapies for these conditions, making kidney disease a pressing global health issue. Recent studies demonstrated that CpGs (short synthetic singlestranded DNA molecules containing unmethylated CpG dinucleotides in particular sequence contexts) stimulate B cells and reduce inflammation, having therefore beneficial effects on ischemic injuries in heart and brain tissues. In my study, I have hypothesized that CpGs may also have similar effects on AKI. Tissue samples (kidney) and plasma from murine models of ischemia reperfusion AKI (IR AKI) were utilized to assess renal function, the degree of kidney injury (and recovery), and post-injury fibrosis. Preconditioning with CpG A, CpG B or CpG C was performed before inducing IR AKI. Renal function was evaluated by serum creatinine; kidney injury was assessed via mRNA of NGAL (neutrophil gelatinase associated lipocalin) and mRNA of Kim 1 (Kidney Injury Model 1); and fibrosis was evaluated by mRNA of Collagen1, Collagen3, alpha Smooth Muscle Actin, and Sirius Red Staining. My results show that CpG C was most effective in both ameliorating the severity of AKI and reducing post-injury fibrosis; CpG A had some positive effect, while CpG B was mostly ineffective. Although further research on this topic is required, my study suggests that preconditioning with CpG C could be a promising approach to alleviate AKI and prevent its progression to CKD and ESRD.

Designing, Prototyping and Testing of a Multi-lumen Urinary Catheter with Sustained Unidirectional Biocide Flow

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Mentor: Harjeet Brar
Kidney Specialists of Kern County

Catheter associated urinary tract infections (CAUTI) are the most common healthcare-associated infections, resulting in 13,000 deaths annually. The underlying cause of CAUTI is the biofilm formed by bacteria within the catheter. The structure of Foley catheter has certain features which promote the biofilm formation and impede the biofilm removal. The novel catheter that I designed had features that reduce biofilm formation and promote biofilm removal. These features included multi-lumen catheter with instillation port for biocides, one-way valve to prevent back flow of biocide into the bladder, a mixing chamber and a sustained release pump for timed release of the biocides. To test the device, a 3D printed bladder was used. The alkaline fluid with pH of 11.5 was used as a biocide and instilled into multilumen catheter. A mildly acidic fluid with pH of 6.5 was instilled into bladder lumen. Alkaline pH of 11 was recorded in the discharge fluid that exited the catheter, but acidic pH was maintained in the bladder. Therefore, multilumen catheter worked as hypothesized. In future, the multi-lumen catheter will be tested for biofilm removal in a laboratory this model will be extended to other catheters like triple-lumen catheters and peripherally inserted central catheter (PICC) lines.

Increased Prevalence of Gastrointestinal, Cardiovascular, and Immunologic Conditions in Hospitalized Patients with Ehlers-Danlos Syndrome: A Case-Control Study

Rachel Brooks
Christian Heritage School

Mentor: Dr. James Grady
UConn Health, School of Medicine

This study investigated the prevalence of gastrointestinal, cardiovascular, and immunologic conditions in hospitalized patients with Ehlers-Danlos syndrome (EDS), a group of rare, inherited connective tissue disorders. Small studies have suggested a potential link between EDS and these conditions, but this is the first large case-control study to be performed to date. It was hypothesized that an EDS diagnosis would be associated with a higher prevalence of gastrointestinal symptoms, cardiovascular autonomic dysfunction, food allergies, and cardiovascular complications compared to the general population of hospitalized patients. It was also hypothesized that EDS patients would have higher odds of mortality and likelihood of having a longer than average length of hospital stay (> 4 days). Cases and controls (matched 1:2) were acquired from the 2016 Nationwide Inpatient Sample. The study population included 6021 individuals (n=2007 EDS). On multivariate logistic regression analysis adjusted for confounders, EDS patients had significantly higher odds of having GI symptoms (Odds Ratio [OR] = 3.53, Confidence Interval [CI]: 3.08-4.03, $P < 0.0001$), cardiovascular autonomic dysfunction (OR = 4.20, CI: 3.44-5.14, $P < 0.0001$), food allergies (OR = 3.92, CI: 2.57-5.98, $P < 0.0001$), and cardiovascular complications (OR = 5.76, CI: 4.17-7.96, $P < 0.0001$). EDS patients were also 76% more likely to have a longer than average length of hospital stay (OR = 1.76, CI: 1.54-2.02, $P < 0.0001$). These findings will enable physicians to exercise proper precautions in treating EDS patients and provide rationale for EDS to be considered in patients with unexplained GI, cardiovascular, and immunologic manifestations.

Developing A Urinalysis Immunoassay for Cortisol Detection Year 2

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Teacher: Scott Robinson
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In recent years, societal focus has shifted towards maintaining a balanced stress level. Stress is an issue that all people will face in their lifetime, however, few know the severity that results in chronic stress. Cortisol is the hormone that is known as the “biochemical marker of stress.” Numerous health problems occur as a result of increased cortisol and may cause a large range of side effects. Although interest in this field is increasing, tests available for measuring cortisol are limited. This project focuses on the development of a urinalysis immunoassay for cortisol detection. Similar to a pregnancy test, the results of this test show a number of lines depending on a person’s stress level. First, to create the test, a variety of glass fibers were tested for their absorbance ability. Next, a conjugate pad was created by mixing a solution of a purified cortisol antibody and gold nanoparticles. Then, the remainder of the cortisol antibody was mixed with fluorescent dyes and added to the strip. After, the components of the test strip were all put together to create a finalized test. A plastic cassette was designed using a 3D printer. Finally, numerous trials were completed to check accuracy using synthetic urine with altered amounts of cortisol. The results of the test found it to be 96% accurate, completing the original engineering goal. Because an excess of stress is common, the method created in this procedure will assist millions worldwide, allowing them to check their cortisol levels rapidly and inexpensively.

An Inexpensive Smartphone-Based Device for Rapid, Non-Invasive, and Point-of-Care Monitoring of Diabetes with Related Ocular and Cardiovascular Complications

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Supervising Mentor: Madhavi Chakravadhanula
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Diabetic retinopathy is the leading cause of blindness among working class adults, and cardiovascular disease is the leading cause of death worldwide. However, diagnosis is often too late to prevent irreversible damage caused by these linked conditions. The first goal of this project was to create an integrated test, automated and not requiring laboratory blood analysis, for diagnosis/screening of these conditions. First, a random forest model was developed by retrospectively analyzing the influence of various risk factors (obtained quickly and non- invasively) on cardiovascular risk. Next, a deep-learning model was developed for prediction of diabetic retinopathy from retinal fundus images by transfer learning the InceptionV3 model and pre-processing the images via automatic vessel segmentation. Then, a colorimetric sensor was developed to measure saliva acetone concentration to track diabetes, providing a "warning system" and enhancing early intervention for these conditions and many other complications. The models were integrated into a smartphone-based device, combined with the saliva acetone sensor and an inexpensive 3D-printed retinal imaging attachment. Accuracy scores, as well as the receiver operating characteristic curve, the learning curve, and other gauges, were promising. This test is much cheaper and faster, enabling continuous monitoring for diabetes and its complications. It has the potential to replace the manual methods of diagnosing both diabetic retinopathy and cardiovascular risk, which are time consuming and costly processes only done by medical professionals away from the point of care, and to prevent irreversible blindness and heart-related complications through faster, cheaper, and safer monitoring of diabetes.

Nicotinamide adenine dinucleotide (NAD^+) on H_2O_2-induced neuronal damage in Planarian

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Sponsor: Moonsuk Choi

Neurodegenerative diseases are characterized by a decline of motor and cognitive functions caused by the loss and degeneration of neurons. Nicotinamide adenine dinucleotide (NAD^+) plays an important role in axonal degeneration. Indeed, decreased NAD^+ levels were observed in Alzheimer's and Parkinson's diseases. Cell-based studies discovered that exogenous NAD^+ protected cells from death induced by oxidative stress. Planarian's nervous system is composed of cephalic ganglia, two ventral nerve cords, and many sensory neurons, and possesses neurotransmitters and associated receptors found in vertebrates. Thus, this study investigated the potential role of NAD^+ against neuronal damage using planarians as an animal model.

Planarian's cognitive ability and behavioral responses were measured by phototactic assays. The planarians were treated by Nicotinamide Riboside (NR), an NAD^+ precursor, after sustaining neuronal damage by H_2O_2 exposure. They moved rapidly away from the light reaching >0.8 of the escape index values (θ) in 1 min showing the same responses as the control group. These responses were significantly different than those of untreated planarians which showed 0.22 of θ value in 1 min. Consequently, the NR treatment restored the photophobic responses of the H_2O_2exposed planarians, by enhancing the NAD^+ level, thereby activating downstream factors such as NAD^+-dependent Sirtuins (SIRT), and eventually repairing neuronal damage. This was supported by the restored photophobic responses of Resveratrol (a SIRT1 activator)-treated planarians. This study provides the first insight into the protective role of NAD^+ and Sirtuin against neuronal damage in planarians and demonstrates that planarian can be a good animal model for neurodegenerative diseases.

Designing and 3D Printing a 3D Clinostat to Simulate Microgravity

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Mentor: Lynn Harrison Clary, Ph.D.
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Sending experiments to the International Space Station is expensive and very limiting, therefore 2D or 3D clinostats are used to simulate microgravity in research labs. Both machines are designed around the concept of continuously altering the specimen's orientation; however, the 3D clinostat utilizes rotation on two axes, while the 2D clinostat only rotates about one axis. The 3D clinostat provides the best simulation of microgravity for experiments using human cells, the majority of which grow attached to surfaces. However, 3D clinostats are $65-75,000 and cost prohibitive for many research labs. The aim of this project was to build a 3D clinostat that costs less than $1000. The 3D clinostat was designed in Fusion360 and its components were printed on a LulzBot TAZ 6 desktop 3D printer. The 3D clinostat has inner and outer rings mounted on a stand and each ring is turned independently by a motor. Both motors are operated by a program through a microcontroller, and a sample holder can accommodate 2 cell culture flasks inside the inner ring. The system was calibrated and tested using an accelerometer, temperature sensor, and Raspberry Pi Zero. After optimization, the clinostat was able to simulate 0.05G. After the testing phase, the impact of simulated microgravity was examined on damage to differentiated neuroblastoma cells, a model for human neuronal cells. Simulated microgravity caused a 20% reduction in DNA double strand breaks. Future experiments will probe whether increased DNA repair or decreased damage induction is the reason for the reduction in damage.

Oil Adsorption Capacities of Organic Materials

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Teacher: Steve Kuninsky

With over 4.9 million liters of raw petroleum being released into the oceans each year, a simple, cost-effective, and easily replicable method of oil removal must be found, both for the safety of our marine ecosystems and the economic impact lost oil has on industry. This experiment was conducted to determine which natural oleophilic material has the highest adsorption capacity for motor oil, a safer sand-in for raw petroleum. Out of 6 tested sorbents: cotton, kapok, duck feathers, peat-moss, wheat-straw, and rice-husk, the hypothesis predicted that raw cotton would have the highest adsorption capacity due to its waxy fiber structure. All tested sorbents were prepared by removing foreign contaminants and cutting the samples to a uniform size. To contain these sorbents, each pre-weighed sample was placed inside a nylon mesh bag. For each trial, the nylon mesh was placed into a plastic container containing 2L of saltwater and 150mL of oil. The sorbents, placed on the surface, were turned over after 2 hours and removed after 4 hours. Polypropylene pads cleaned the remaining oil from the containers. These pads were weighed and used to determine the mass of oil adsorbed by the sorbent. A control trial (no sorbent in the nylon bag) determined whether or not the nylon adsorbed a significant amount of oil. Next, 6 trials were performed for each sorbent. Graphing the data with SEM error bars suggested that a significant difference between the adsorption capacities of the different sorbents existed. T-tests determined that the adsorption capacity of the cotton, kapok, and duck feathers was significantly greater than the control value, with duck feathers having both the greatest adsorption capacity (12.08g/g) and the greatest significant difference from the control. Therefore, the hypothesis was refuted; the experiment suggests that duck feathers are the more efficient oleophilic sorbent.

Extracellular Vesicles as Biomarkers for Acute Respiratory Distress Syndrome

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Research Mentor:
Dr. Goodwin & Dr. Li
Medical University of South Carolina

Sepsis is defined as life-threatening organ dysfunction caused by a dysregulated host response to infection. Acute respiratory distress syndrome (ARDS) is a secondary disease that may follow sepsis and is characterized by inflammation, increased vascular permeability, and endothelial cell dysfunction. Currently, there are no approved pharmacological treatments. Extracellular vesicles (EVs) are membranous microvesicles secreted from the endosomal compartment or plasma membrane of cells. Recent evidence suggests that circulating EVs from septic patients are associated with inflammation and vascular permeability, so we investigated circulating EVs as potential biomarkers for sepsis-induced ARDS. To do this, we collected plasma samples from 85 ICU-administered septic patients, 21 of whom developed ARDS, as well as healthy controls. EVs were extracted from these samples and subsequently added to HMVECs. Transendothelial electrical resistance (TEER) assays were performed on the HMVECs, and the resulting data was used as an indication of vascular permeability. We found that EVs from ARDS patients (n=21) have a higher chance (81% vs 37.5%) to induce TEER compared to non-ARDS patients (n=64). These findings may eventually lead to a screening strategy to determine a patient's risk of ARDS development based on their EVs. We also wanted to explore potential explanations for this phenomenon. Previous studies suggest that EVs containing caspase-1 induce endothelial cell injury, so we determined caspase-1 activity in the EVs and discovered that EVs from septic patients contain significantly higher caspase-1 activity than healthy controls, and EVs from ARDS patients have higher caspase-1 activity than EVs from septic patients without ARDS.

Decoding Algorithms for Correction of X-Z and Spatially Correlated Errors in Topological Quantum Computing

Sam Florin
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Mentor: Andrew Bramante

Topological quantum error correction uses the topology of surfaces like the plane or torus to correct quantum errors, helping quantum computing to be successful. However, topological quantum error correction assumes that all errors occur independently. In this project, both spatial correlation and X-Z correlation are considered. In the error model used, staircase-shaped errors of fixed unknown length are considered, providing the spatial correlation. Also, instead of treating Pauli Y errors as a combination of X and Z errors, they are considered separately by having X, Y, and Z chains occur with equal probability. This forces the decoder to consider X-Z correlation. The decoder is a variation of the minimum-weight perfect matching (MWPM) algorithm. Instead of using the taxicab distance on the lattice as the weight of an edge, weight is defined using a combination of functions on distance and the overlap of chains. The distance function has a spike at the predicted staircase distance. The overlap function peaks at no overlap and maximum overlap to account for Y errors. This algorithm is applied twice; once for X syndromes and once for Z syndromes. This information is combined to give the most likely error chains. The traditional MWPM decoder has an error threshold at ~11%, beyond which the success rate dramatically declines. The revised decoder has a higher success rate and remains useful beyond this threshold, to as much as 17%. Both of the weight functions used in this research can be generalized to broader forms of spatial and X-Z correlation

Conserving Water Through the Filtration and Recyclation of Greywater in a Domestic System

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Bartlesville, Oklahoma

Supervisor/Teacher: Mrs. Henderson, AP Biology

This project aims to produce and test a prototype aid in water conservation within a domestic, consumer context. A specialized recirculating faucet system was built using direct filtration techniques: two carbon filters and an adapted Biosand Filter. The system was tested by filtering solutions of decreasing particulate sizes through the system and comparing the contamination after filtration to the initial contamination levels. The final goal of this project is to create a system that conserves water before it leaves the consumer. The system was made to be modular for easy installment and be able to filter sediments such as soil, graphite powder, vegetable oil, and soap content. E. coli was tested to assess the microbial-filtration ability of the system. The results for microbial-filtration suggested there were E. coli remnants after filtration and new methods will need to be applied to reach the desired function of the system. This will include an activated carbon and zeolite filter. One gallon of water was successfully recycled for an extended period of time within standard flow-rates for household faucets. This system, if implemented in the average American household, would save the consumer significant amounts of money in water costs and conserve up to 50 gallons daily in the American home with the potential for further conservation within commercial environments.

*This abstract has additional contributing author(s)

Building an Efficient Reversible Fuel Cell Stack for Use as a Backup Power Source

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Hawaii's energy costs are the highest in the nation. Hawaii is currently using solar and wind energy to try and combat these high prices. This project improves upon the current systems by replacing the battery backup storage with a reversible fuel cell (RFC). This project tests the effectiveness of using manganese sulfate as a catalyst, stainless steel as the electrode and ocean water as the electrolyte for an RFC. This project analyzed this RFC in parallel stacks of one, three, six, nine, and twelve. RFC stacks in parallel connections are utilized to increase the amperage of the system. This project also analyzed the effectiveness of manganese sulfate when added to the electrolyte. The twelve RFC stack with the catalyst produced the most power with 38.0 watts. This data was taken to create an observation buoy powered by solar energy and utilized a six RFC stack as backup power. The observation buoy included an anemometer, beacon, and rain collector for the solar panel and RFC stack to power. The solar energy powered the observation buoy for 12 hours and then was shut off to see the effectiveness of the RFC backup system. The RFC backup system was able to power the buoy for 24 hours, without the aid of solar energy. This will be tested further to create a backup system for home solar energy.

Evaluation of Isoheme: A Novel Replacement for Blood in Forensic Science

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Animal blood is used to create bloodstains for forensic science training and analysis. Blood is expensive, perishable and poses a safety hazard which limits its use by trainers and rules out its use by teachers. There is a need for a replacement that forms stains like blood without the issues of using blood. The purpose of this study was to

evaluate the properties of a novel blood replacement designed to meet forensic science needs. Isoheme was formulated with food grade ingredients to mimic the viscosity, density and surface tension of blood. When Isoheme ($0.25 for 50 mL) and porcine blood ($45 for 50 mL) drops were released from 60 cm and 100 cm and collected at 90° on cardstock, the diameters and numbers of spines/scallops of the Isoheme stains were not significantly different from the bloodstains. When the drops were released from 100 cm and collected on cardstock, foam core, ceramic tile and vinyl tile the diameters of the Isoheme stains at 90° and the calculated impact angles at 30° also were not significantly different. Tests confirmed Isoheme is stable for at least 24 weeks. When Isoheme and porcine blood spatter were

collected at 50 cm, the calculated distance to the point of origin was underestimated by 10% for Isoheme versus 24% for blood. Isoheme also worked well as a teaching tool for high school forensic science classes. This study confirmed that Isoheme is a safe, affordable, easy to use, stable blood substitute that meets forensic science needs.

Developing an Integral Equation Solution for the Incompressible Navier-Stokes Equations

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Computational modeling of viscous fluids has numerous industrial applications, and improving upon current fluid models, especially those for nonlinear fluids, while reducing computation time is of great interest. This project develops an algorithm to compute the "body force" volume integral derived from a Stokes boundary integral formulation of a general 3D axisymmetric fluid. To do so, the axi-symmetric volume integral is reformulated as the sum of a boundary integral and remainder volume integral, and a Galerkin approximation is then implemented for the integral equations. Simple numerical tests are used to verify the algorithm for the nonhomogeneous axi-symmetric Stokes equations.

An Investigation of the Effect of Various Yeasts and Water Sources on *Aedes albopictus* Oviposition and Egg Hatching

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Sponsors: Mrs. Sue Henry, Miss Kassie Henry

Mosquitoes represent a significant proportion of insect biodiversity, and yeasts fill important roles in food webs, decomposition of organic matter, and nutrient cycling in aquatic ecosystems, but potential mosquito-fungal interactions remain largely unknown. The purpose of this investigation was to evaluate the potential difference between mosquito oviposition rates and egg hatching when exposed to varied water sources and yeast isolates as compared to the control, oak leaf tea. Mosquito traps containing *Meyerozyma* red and white*, Tausonia,* and *Hannaella* were set to collect oviposition data. Six hundred seventy-five *Aedes albopictus* eggs were exposed to a variety of water sources and the same four yeast isolates to measure egg hatching. Water analysis was conducted to analyze correlation between egg hatching and water quality.

Oviposition data suggests that mosquitoes prefer *Hanaella* and Oak Leaf Tea, while *Meyerozyma* red and white and *Tausonia* had significantly less eggs deposited. Data from yeast bioassays showed *Meyerozyma* red had significantly less eggs hatch than the control, oak leaf tea. This preliminary data suggests that additional bioassays

are needed with *Meyerozyma* red to determine if it inhibits the growth and development of mosquito eggs. Zero eggs exposed to Mississippi River water hatched, while ditch water and oak leaf tea both had higher levels of egg hatching. Water quality tests revealed high levels of conductivity in the ditch water and the oak leaf tea. Further testing using water sources for both oviposition and egg hatching will also be conducted to determine correlation with water quality.

Using Environmental Enhancements to Increase Vitamin-C Production in *Spinacia oleracea* in Varied Agricultural Environments

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Vertical Farming (VF) has emerged to feed Earth's growing population. VF grows crops indoors without sunlight or soil. VF produce has less vitamin C and is less nutritious than conventionally-farmed produce because abiotic stress is removed to achieve faster growth times and higher yields. The top twenty vitamin-C producing crops have one thing in common; harsh growing conditions. The ascorbate-glutathione cycle is a plant metabolic pathway that produces vitamin C as a reaction to increased $H_2 O 2$; a result of plant stress. It was hypothesized that adding abiotic stress to the VF environment would stimulate the enzymatic pathway, resulting in increased vitamin-C production. Stress in the form of wind, heat and drought was applied to *Spinacia oleracea* in a VF environment and vitamin C was measured by titration. Thirty samples were taken from each of three plant groups (outdoor farming, VF and VF+stress). The VF groups had statistically significantly lower vitamin-C levels than the outdoor produce ($p<0.01$) . The three stress groups had statistically significantly higher vitamin-C levels than the traditional VF groups but lower levels than the outdoor group ($p<0.01$) . The vitamin-C levels of an interaction group combining wind and heat stress were higher than those of the other stress groups ($p<0.01$) and were statistically equal to the outdoor group. The addition of abiotic stress to the VF environment can increase vitamin-C levels and, with the addition of both wind and heat stress together, vitamin-C levels can be equal to that of conventionally-farmed produce.

Dismantling Malignant Brain Tumor Protections: The novel role of POLK in protecting GBM-derived cells

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Glial cells provide structure and metabolic support for neurons. Glioblastomas (GBM) are malignant tumors of glial cells. To improve their survival, cancerous cells have elevated levels of proteins that resolve replication stress and repair DNA damage. Studies found that human DNA polymerase kappa (hpol κ) was overexpressed in glioblastomas; this increase is thought to play a role in tumor survival because the mechanism bypasses DNA lesions and protects tumor cells from DNA breakage and replication catastrophe (RC). In order to study the role of hpol κ in replication dynamics, glioblastoma-derived T98G cells without a functional Polk gene (GBM-POLKKO) were compared to wild-type cells. To study cells under stress, all cells were treated with an inhibitor of the Kinase Rad3-related (ATR) kinase, a regulator of replication stress response (RSR). ATR inhibition is known to induce RC in cells experiencing stress. To determine if hpol κ prevents RC, the changes in RSR proteins, replication fork dynamics, and markers of RC were measured using immunofluorescence microscopy and DNA fiber spreading.

Between 13.7% more cells entered RC after being treated with ATR inhibitor and hydroxyurea (HU) in either GBM-POLKKO or GBM-WT cells compared to untreated control cells. New origins and stalled forks increased meaning that the cell was more likely in RC in GBM-POLKKO or in cells treated with ARTi. The results of this study suggests that inhibiting ATR and decreasing hpol κ function could be new potential treatments for patients.

Automated User Request Operator and Responsive Application (AURORA): A Novel Approach Implementing A Deep Learning Convolutional Neural Network Framework to Detect Choroidal Neovascularization, Diabetic Macular Edema, and Macular Degeneration

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Over 1.3 billion people worldwide suffer from either vision impairment or blinding retinal diseases, and approximately $139 billion is the estimated economic burden due to these retinal diseases (Rein & Wittenborn, 2013). Machine learning approaches are increasingly helpful in successful image-based diagnosis, disease prognosis, and risk assessment. Retinal optical coherence tomography (OCT) is an imaging technique used to capture high-resolution cross-sections of the retinas of patients (Swanson & Fujimoto, 2017). Though it has been demonstrated that an early diagnosis can significantly reduce eyesight difficulties later in life, screenings for retinal diseases are inaccessible to a majority of the world because of their cost ($100-$1000 screening) and the need for specialized scientific equipment. As none of the current models provide a diagnostic accuracy higher than 90%, AURORA was conceptualized. The purpose of this project was to create AURORA, the Automated User Request Operator and Responsive Application, a diagnostic tool based on a deep-learning framework for the screening of patients with common blinding retinal diseases. This framework utilizes transfer learning (in both training and testing programs), which trains a neural network with a fraction of the data of conventional approaches. AURORA was trained on the dataset of greyscale OCT images repository at the open-source dataset platform, Kaggle. AURORA may ultimately aid in accelerating the diagnosis of these retinal diseases, thereby facilitating earlier treatment, resulting in improved clinical outcomes.

Utilization of a Novel Method of RNA Interference in Caenorhabditis elegans to Conduct a Phenotypic Analysis of the daf-2 and daf-16 Longevity Genes

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The daf-2 and daf-16 genes have been highlighted for their reciprocal activity in altering longevity in the model organism *Caenorhabditis elegans*. Both daf-2 and daf-16 present orthologs in the human genome that maintain similar function. The most straightforward method for analyzing the impacts of these genes on worm phenotype is through RNA interference. This can be accomplished by feeding *Escherichia coli* containing double stranded RNA intended to make the target gene inoperative in the nematodes. However, as the worms age, consumed E. coli can colonize the gut, resulting in a pathogenic infection. As part of the following research, a novel procedure for RNA interference with *Bacillus subtilis* was tested and developed. With this novel system, RNA interference with daf-2 and daf-16 were analyzed and compared with the results yielded through RNA interference with *E. coli.* The results from the study indicate reduced bending and maneuverability among daf-2 mutants suggesting that successful interference is achieved. This study demonstrates that using *B. subtilis* as a feeding vector is the superior course of action for RNAi in *C. elegans*.

EyeSpy Diagnosis: Developing a Smartphone-Based Non-Invasive Intelligent System for Detecting Eye Fundus Anomalies via Machine Learning

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Diabetic retinopathy (DR) is the leading cause of preventable blindness in the world. Due to the necessity of expensive ophthalmoscopic equipment and a trained professional, the screening process is inaccessible to millions of people. The goal of this work was to develop an end-to-end solution for triaging DR in an accessible, non-invasive, timely, and affordable manner. First, a machine learning (ML) model was developed for image analysis using convolutional neural networks and feature extraction with the Keras framework in Python. The model was trained on the EyePACS open-source, annotated dataset to ensure its validity over a wide range of fundus images. Second, programs were created to segment blood vessels and extract microaneurysms from the image. Third, a smartphone application was programmed to take images and house the ML model. Finally, a versatile smartphone lens attachment was 3D printed to seamlessly integrate with the application and provide testable DR classification results within minutes. The ML model was validated on the EyePACS testing dataset and obtained statistically comparable results to those of an ophthalmologist in a clinical setting. The applications of this project are twofold: first, this presents a novel solution to grading the severity of DR and identifying fundus anomalies, and second, this approach can be easily adapted to diagnose other retina-related conditions. The project was deemed successful as the system is an intuitive and affordable tool for accurately diagnosing DR and has the potential to mitigate the vision impairment issues currently faced by 18% of the global population.

A Dual Sensor Machine Learning Approach to Sulfur Quantification of Lignite Coal

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Coal accounts for 38% of global power production. Sulfur appears in coal in two forms; elemental form and pyritic form. Pyrite is an iron sulfur compound (FeS2) which is not homogenous throughout coal. In combustion, coal forms sulfur dioxide (SO2) which is released into the air where it becomes sulfuric acid (H2SO4). This alters the pH of ecosystems. Mines use dry combustion analysis (expensive and time consuming lab analysis) to quantify sulfur. The goal of this study was to create different models to predict sulfur content in lignite coal, using optical color

sensing and portable X-ray fluorescence (PXRF). For the study, 249 lignite samples were collected from four mines in North Dakota. Each sample was ground, dried, and subject to dry combustion analysis. Samples were scanned using color sensing and PXRF. Machine learning algorithms were used to create 15 different prediction models. 75% of samples were used to calibrate the model, while 25% of samples were used to validate it. The R squared values of models for individual mines A, B, C, and D using a combination sensor approach were 0.81, 0.19, 0.34, and 0.46 respectively. Comparatively, when all mines and sensors were used to generate a model, the R squared value was 0.85, meaning the model accurately predicted the sulfur content of the lignite with mg/kg resolution 85% of the time. This is preferable to traditional analysis because it is a faster, more cost efficient approach to sulfur quantification with minimal lab preparation.

Glacier Melting Risk: A predictive model of glacial melting by correlating timeseries geoglacial data with fractal-analysis of remote-sensed images

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Glacier recession and thermal expansion account for 75% of observed sea level rise. The importance of studying glacial melting is amplified by number of unmonitored glaciers in the world and complicated by the feasibility of exhaustive field monitoring. Remote sensing techniques such as multiyear satellite imaging provide a valuable dataset for such comprehensive surveillance. Current techniques using remote sensed data involve volume-area scaling analysis that rely on active field measurements. This study demonstrates the potential utility of fractal analysis of multi-year glacier landsat images to serve as a predictive indicator of glacial melt. Specifically, it investigated how annual changes in the observed surface geometry of glaciers correlate with the 1) mass balance of the glacier, 2) observed temperature around the glacier. The results show that the fractal dimension changes in the landsat images are predictive of the glaciers' mass balance ($p=0.0008$), and mean temperatures ($p<0.0005$). This study suggests that it is possible to rely on readily available remote sensing techniques to rapidly and continuously monitor the world's glaciers and identify critical glacial regions undergoing melting.

Intra- and Inter-racial Cross-modal Biometric Matching

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Have you ever envisioned what face belongs to the voice at the other end of the phone? Or search the crowd for the person who looks like the voice you just heard? This study investigates into this seemingly impossible task of accurately matching stranger's faces to voices through the angle of another phenomenon; the cross-race effect, or the tendency to be less likely able to distinguish between other-race faces due to less-robust neural encoding. This experiment tests the accuracy by which people can match same-race and other-race voices to the corresponding faces, to demonstrate how levels of experience influence our assumptions. In the current study, 104 American and

Japanese participants listened to the voices of twelve Americans and sequentially matched them to one of the twelve faces shown, and then repeated with Japanese faces. Comparison of the accuracy of each nationality group as well as participant familiarity level produced some results indicating that a higher familiarity level may lead to enhanced ability to perform cross-modal biometric (face and voice) associations, though incongruencies with other results lead to intriguing conclusions such as the presence of a threshold of experience for making accurate cross-modal associations with unfamiliar stimuli. This study not only aids our understanding of the phenomenon we experience in everyday life, but also creates a gateway for future research on cross-modal associations by applying it to a larger demographic, with the potential to lessen the perceptual illusion of the "other-race effect" with regards to racial discrimination.

Re-administration of Different Doses of Tetracycline and Ciprofloxacin in Combination Therapy to Pre-treated Escherichia coli to Determine if Antimicrobial Resistance Transfers to New Colony

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Antimicrobial resistance is a serious problem in global public health and has not shown signs of slowing or stopping despite scientific advances. With lack of new antibiotics being produced and an absence of research regarding resistance patterns of bacteria over time, resistance continues to grow. This experiment sought to determine if bacteria (already treated with antibiotics in combination therapy) is more or less resistant when the same antibiotic combination is readministered. By comparing the zones of inhibition (ZOIs) from the baseline and recolonized bacteria, an increase in resistance was observed. It was concluded that the ZOIs of the recolonized (RC) bacteria were smaller than the ZOIs from the baseline (B) bacteria. An ANOVA test revealed a calculated *p* value of *p*=.013. This suggests that if a bacterial colony has already shown resistance to an antibiotic combination, re-administering the antibiotic combination in hopes of increased susceptibility will prove ineffective. Further research is required to effectively control antibiotic resistance and potentially reduce the severity in global public health today.

Sea Cucumber Extracts (*H. cinerascens* and *H. impatiens'* Cuvierian Tubules) Decrease Cancer Cell Viability

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Colon cancer is a leading cause of death worldwide. Sea cucumbers are a potential source of medicinal compounds and have been consumed in traditional Chinese medicine. Thus, it was hypothesized that extracts of *Holothuria cinerascens* and *Holothuria impatiens'* cuvierian tubules would be effective in treating HCT-116 colon cancer cells. These two species have not been investigated in cancer research before. It was discovered that the *H. cinerascens* body wall must be cryogenically homogenized before being extracted in a MeOH solvent to induce significant

viability reduction in HCT-116 cells ($p<0.05$). *H. impateins'* cuvierian tubules MeOH extract consistently showed significant HCT-116 cell viability reduction, despite not being cryogenically homogenized. Liquid Chromatography–Mass Spectrometry (LC-MS) identified several triterpene glycosides in both the *H. cinerascens* and cuvierian tubule MeOH extracts. Using SRB and XTT assays, dilutions from both extracts showed significant HCT-116 cell viability reduction ($p<0.05$); however, at lower dilutions, no significant effect on HEK293 cell viability (a non-cancerous cell line) were shown. Additionally, at serial dilutions of 10% and 1%, the *H. cinerascens* extracts have shown to significantly inhibit the migration of HCT-116 cells across a scratch. At 10% and 1% dilutions, both extracts have also shown to significantly suppress HCT-116 colony formation, which implies that the extracts may reduce HCT-116 cells' reproductive viability and survival rate. This study demonstrates that MeOH extracts of *H. cinerascens* body walls and *H. impatiens'* cuverian tubules inhibit cell proliferation and colony formation, suppress cell migration, and reduce cell viability and adhesion of HCT-116 colon cancer cells.

Investigating the Impact of Serum on the Growth of TM7x and Host XH001

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Nanosynbacter lyticus strain TM7x is an ultra-small, parasitic bacterium that lives on the surface of host, *Actinomyces odontolyticus* strain XH001. Studies have reported a considerable increase in TM7x abundance in patients with periodontal disease, an association that warrants further study. Interestingly, gingival crevicular fluid (GCF) flow also increases during periodontitis. The prevalence of TM7x during periodontal disease may thus result from attraction to GCF. However, GCF is not commercially available for testing. Since its composition is similar to that of fetal bovine serum (FBS), FBS was tested instead. The objectives of this project are to determine whether FBS promotes the growth of TM7x and XH001 and to develop the optimal culture medium for analysis of these microbes. TM7x/XH001 co-culture and XH001 monoculture were separately cultivated in media (RPMI and FMC) supplemented with FBS. Cultures grown in the same, non-supplemented media served as control samples. Serial dilutions were performed and spotted onto plates at several time points, and samples were quantified in colony-forming units (CFU)/mL. 2% FBS FMC induced a significant increase in the growth of culture samples, as compared to control FMC ($p = 0.0140$ and $p = 0.0424$ for the co-culture and monoculture, respectively). Furthermore, microscopy revealed a heightened presence of TM7x in FBS-supplemented media in comparison to control media. These findings signify that FBS is an effective supplement to RPMI and FMC, both of which support TM7x/XH001 growth. Overall, the utilization of these media with FBS can ensure optimal cultivation of TM7x for investigation of its potential pathogenicity.

Mycofiltration of Microplastics Within a Simulated Waste Water Treatment Chamber

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Mycofiltration of Microplastics Within a Simulated Waste Water Treatment Chamber As the world hurtles into a new age of technology and synthetics, the once forward facing focus begins to turn back towards the ever-growing build-up of discarded non-biodegradable material. In a repeated study, sediment from 4 deep sea locations from 1176 to 4383 meters was analyzed for microplastics. An average abundance of about 1 microplastic per 25cm^3

was observed (*Cauwenberghe, 2*). In a related study, microplastic concentration was measured in waste water treatment plant effluent at nine rivers in Illinois, United States. The mean microplastic flux was 1,338,757 pieces per day with a minimum of 15,520 per day, and a maximum of 4,721,709 per day (*Mccormick, 1*). There have been several studies detailing how to measure the amounts of microplastics and how to remove them from natural bodies of water; however, would it not be more effective to remove and dispose of these pollutants whilst they are in a man-made, controlled environment?

Evaluating Mental Health Factors in Veterinary Medicine Students

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Current research by the Center for Disease Control documents an increased risk of suicidal ideation and completion in practicing veterinarians in the U.S. (Nett et al. and Tomasi et al.). The research goal of this study was to examine whether symptoms of mental distress (depression, anxiety, suicidal ideation) were present in future veterinarians prior to entering practice, specifically, within the veterinary student population. A sample of 832 veterinary students, from three different U.S. veterinary colleges, participated in the study. Research participants completed an online survey, resulting in a 53% response rate. The sample population was largely female (85.3%), Caucasian (88.2%), 18-34 years old (97.6%), with no dependents (83.9%). Significant correlations were discovered between mental health amongst veterinary students and several factors: gender, the ability to pay for vet school, perceived competitiveness of vet school, role conflict, coping style, perfectionism, empathy, life satisfaction, spirituality, social support, awareness of and perceived ability to pay for counseling services on campus. Mirroring the veterinarian population, vet students have significantly higher rates of depression, anxiety, and suicidal ideation when compared to the U.S. population. Suggestions for veterinary colleges to decrease mental distress amongst their students are discussed.

Shakey Wakey: A Portable Innovation To Wake The Deaf, Hearing Impaired, Elderly, And Children

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Phase one of the Shakey Wakey Project was to test how long it took children under 14 to wake up to smoke alarms. Phase One, also referred to as 'Alarming Study', tested the hypothesis: if a smoke detector goes off after 1 hour of sleep, then a child will wake up around 1 minute after a smoke detector starts beeping.

Phase two of the Shakey Wakey Project was to test can people aged 60 years and older hear the frequency of smoke detectors. Phase two, also referred to as 'Be Alarmed' tested the hypothesis: if participants are played a tone at a frequency of 3100 Hz, then 75% of the participants will not be able to hear the tone.

Phase three: The Shakey Wakey is a portable biomedical innovation to wake the deaf, hearing impaired, elderly, and children during a fire. This innovation was created to combat the problem, people don't wake up to the average smoke detector frequency of 3,100 to 4,100 Hz. A Raspberry Pi was programmed using Raspbian to write code in Python coding language. The code utilized audio op, pyaudio, time, and os modules to tell the Raspberry Pi to recognize the frequencies of smoke detectors and to then use the GPIO pins to turn on a vibrating device. In order for the code to function properly, the callback order of the programs priorly listed must be formatted so that

the Raspberry Pi can support the code. The prototype built during this project is a proof of concept; to make the Shakey Wakey marketable, it must be shrunk in size while still waking the user within 5 seconds. Future work will be to incorporate the idea of waking people into smartphones and smartwatches by reaching out to corporations such as Google, Amazon, and Apple.

Investigating the Role of Thrombospondin-2 in Extracellular Matrix Formation and Fibroblast Migration in Diabetes

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One of the major complications of diabetes mellitus is poor wound healing, which leads to increased morbidities and mortalities. Thrombospondin-2 (TSP2), is a component of the extracellular matrix (ECM), and is expressed in the proliferating and remodeling phases of wound healing. As a matricellular protein, TSP2 influences cell matrix interactions and is implicated in different wound healing processes. However, there is little information regarding the effect of TSP2 on ECM remodeling and cell functions, specifically the migration of fibroblasts in wound healing. The ultimate goal of this study was to test the hypothesis that TSP2 alters the components of the ECM and function of diabetic cells and that this contributes to poor wound healing. Three types of fibroblast cells were used in this study: wild type, diabetic, and diabetic with TSP2 knockout. The experiments were divided into three components; the first part examined the effect of TSP2 on the migration of fibroblasts, while the second studied the effect of TSP2 on the structures of cell-derived ECM. The third part studied the migration of fibroblasts through the cell-derived ECM. My findings confirmed that TSP2 affects the formation of ECM by increasing the size of fibers, but the results do not indicate differing protein deposition. Additionally, experiments showed that diabetic cells migrate slower and secrete ECM that retards the migration of WT cells. These defects are rescued when diabetic cells are depleted of TSP2. Taken together, these observations provide insights into the role of excess TSP2 in diabetic wound healing.

Bio-Inspired Flexible Multi-Sensory Artificial Skin

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Artificial skin is a synthetic membrane structure that mimics the flexibility and sensory functions of biological skin. Similar to receptors in biological skin sending signals to neurons in the brain, an artificial skin needs sensors capable of converting information into electrical signals and transmitting them. Recently, artificial skin has received a lot of attention for various applications, such as prosthetics, soft robotics, virtual reality, wearable devices, and emerging medical applications. In particular, it can potentially help reduce the number of amputations due to foot ulcers found in 25% of diabetic individuals. This project aims to create a synthetic artificial skin that is flexible and capable of sensing temperature and pressure/touch.

To do so, thin and flexible films were realized using pectin, a natural substance found in many fruits and vegetables. Low-methoxyl citrus and apple-based pectins were compared. The properties of pectin films were optimized by systematically adjusting the pectin concentration and thickness during jellification. After drying, the pectin was used as a temperature sensing artificial skin. A change in electrical current of nearly 10,000% was achieved when the temperature was varied between 24 and ~80 °C. The magnitude of the current change was a

direct function of the amount of temperature change. Flexible pressure/touch sensing devices were realized using silvercoated microbeads and polydimethylsiloxane flexible membranes. Electrical responses due to both continuous and instantaneous pressure stimuli on the device surface were successfully detected, with the magnitude of current change being a function of the amount of pressure applied.

SE Sensory Neuron cGAL Driver in Caenorhabditis Elegans

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cGAL, a bipartite GAL4-UAS system, was recently developed for cell-specific modulation of gene expression in *Caenorhabditis elegans*. The cGAL system consists of a "driver" construct and an "effector" construct. The driver construct uses a cell-specific promoter to express the GAL4 protein in designated cells, and the effector construct places upstream activating sequence (UAS) sites upstream of the gene of interest. If two separate transgenic cell lines containing a driver and an effector individually are crossed, the expressed GAL4 protein will bind to the UAS sites and drive the expression of downstream genes. By leveraging the specificity and bipartite nature of the cGAL system, researchers can manipulate gene expression and interrogate gene functions. In this study, we constructed a novel cGAL driver using part of the promoter region of *gcy-5* due to its highly-specific expression in ASE neurons, which are responsible for the detection of chemical repellants and water-soluble attractants. The driver plasmid was constructed through two rounds of polymerase chain reactions and injected into the 15xUAS::GFP (green fluorescent protein) effector strain of *C. elegans*. Microscopy confirmed ASE neuron-specific GFP expression. The results demonstrate that the promotor in our driver construct can dictate the expression of GAL4 protein specifically in ASE neurons, which binds to the UAS site and drives the expression of the downstream GFP gene. This novel cGAL driver construct can be used by the scientific community to precisely control the expression of genes of interest in ASE neurons and to understand the genetic basis for neuron biological activity.

Using *Drosophila melanogaster* as an Integrated Model to Elucidate the Cellular and Genetic Mechanisms Underlying Traumatic Brain Injury (TBI)

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Background: Traumatic brain injury (TBI) is a leading international cause of morbidity and mortality and its outcome is significantly influenced by poorly understood cellular and molecular responses to the initial impact. This project's objectives were: 1) To assess apoptosis levels in brains of *Drosophila* subjected to TBI, 2) To define the immune system's response to brain injury, and 3) To detect intestinal barrier dysfunction in *Drosophila* following TBI. Methods: A "high-impact trauma" (HIT) device was used to inflict brain injury. An antibody to *cleaved-Caspase-3* was used as an *apoptotic* marker in *whole Drosophila brains*. Immune response was assessed by quantifying Anti-Microbial Peptides (AMP) gene expression, using qRT-PCR. Intestinal barrier dysfunction was detected by the presence of a non-absorbable blue food dye outside of the digestive tract after feeding. Results: Increased apoptosis was detected in *Drosophila* brains subjected to TBI, by measuring cleaved caspase. This was especially evident in the mushroom bodies known to play a role in olfactory learning and memory.

TBI flies showed an enhanced innate immune response as measured by increased gene expression of the anti-microbial peptide, Diptericin B. More flies with TBI had the "Smurf" phenotype, compared with controls, demonstrating that impaired gut permeability is a non-neuronal effect of severe TBI. **Conclusion:** TBI causes distinct biochemical and physiological alterations. An improved understanding of these secondary sub-cellular mechanisms of TBI is a vital prerequisite for developing effective interventions.

Engineering a DNA Aptamer Nanomachine Platform for T Cell Detection Based on Cancer Metabolites

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Supervising Scientist:
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Aptamers, oligonucleotides evolved to be specific against a target ligand, are promising as selective drug delivery agents for cancer cells that express unique biomarkers on their surfaces. However, cell surface antigens do not always differentiate among cells as specifically as desired. The altered metabolism of cancer cells results in pronounced changes to their microenvironment, particularly through altered metabolite concentrations. In this study these metabolite markers of tumor cells are leveraged to rationally engineer a two-stage aptamer nanomachine, in which activates the aptamer cell binding domain is activated only once its metabolite domain has been bound. This nanomachine recognizes ATP as its metabolite, and binds to T Cells when activated. For this reason, I termed the aptamer ART, for ATP-Regulated T1C. We demonstrate that aptamer binding activity is controllable by the conformational status of an intramolecular domain via helix destabilization. Furthermore, it is shown that cancer indicative metabolites can be used to regulate binding of this nanomachine to cancerous T Leukocytes. In this way, we have developed a new platform for specific cancer recognition and drug delivery, which relies not only on cell-specific antigens but also on the conditions surrounding the cells. This technology will enable higher dosages of chemotherapeutic agents to be used with reduced side effects to healthy cells, enabling a safer and more effective form of chemotherapy

Grape Polyphenols Inhibit Dental Bacteria and Pro-Inflammatory Signaling

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Teacher: Ms. Keri Polevchak
duPont Manual High School

Mentor: Ms. Juili Shivde
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Periodontitis is one of the most prevalent inflammatory diseases, with an annual expense of 14 billion dollars on disease therapy. It is the leading cause of tooth loss among adults and is associated with various systemic diseases. Periodontitis is instigated by a number of microbial pathogens and caused by pathogen-induced inflammation and

collateral tissue damage. Among all periodontitis pathogens, *Porphyromonas gingivalis* stands as a primary contributor to pathology and has been used in various animal models for periodontitis. *P. gingivalis* is able to signal through various signaling pathways for inflammation induction. One pathway that plays a major role in periodontitis is the NF-κB pathway, an important mediator for both bone resorption and inflammation.

The beneficial effects of grapes and grape products on human health have been widely investigated, yet leave many questions unanswered. Reports have shown that grape components, including (pro)anthocyanidins and flavonols, have the ability to down regulate inflammation. Therefore, it is highly plausible to ameliorate periodontitis by grape consumption through inhibiting oral pathogen growth and down-regulating infection-induced inflammation and bone loss. Grape powder was tested on its ability to inhibit periodontitis in mice. Grape powder extract was investigated for its effects on inflammation and osteoclastogenesis (the development of bone resorbing cells). Grape phenolic compounds were tested on their ability to inhibit the NF-κB signaling pathway and the growth of *P. gingivalis*. Grape components were shown to suppress periodontitis through the inhibition of NF-κB activation, oral bacteria growth, inflammation, and bone loss.

Role of Protective Species in Inhibiting Virulence Factor in *Streptococcus mutans*

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Boston Latin School

Mentor: Dr. Megan Pugach
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Affecting over 2.4 billion people, dental caries is the most prevalent, global disease. Caries is caused by *Streptococcus mutans*, a bacteria that produces lactic acid, creating lesions in the enamel. Because of the cost and ineffectiveness of current treatments, there is a great need for more specific preventative methods against caries.

The study aims to harness the oral microbiome to prevent caries by 1) elucidating the interactions between potentially "protective" bacteria and *S. mutans* and by 2) assessing the feasibility of *ex vivo* models for translational experimentation. It was hypothesized that protective species inhibit acid production in *S. mutans* thereby hindering caries development. Cocultures of *S. mutans* and protective bacteria were incubated in plates with phenol red as a pH indicator. Acid production on the plates was analyzed with a microelectrode and ImageJ. To determine biofilm feasibility on teeth, monocultures of both species were incubated in artificial saliva with third molars. SEM imaging was utilized to observe biofilm development on teeth.

In the end, the study characterized a novel interaction between the protective species and *S.mutans* in that protective species significantly lower acid production in *S. mutans*. SEM imaging revealed that protective species formed biofilm in *ex vivo* models. These findings open the doors to various applications. The discovery that protective species form biofilms allows for translational studies to measure the impact of protective species on enamel dissolution. Clinically, the mechanism behind acid inhibition could be developed into a drug, leading to a more effective preventative measure against caries.

Calculated distance to a pulsar using DM

Josie Long
Wheeling Park High School

Teacher: Debbie Mckay

In my first year I analyzed the difference between radio frequency interference and pulsar detection. My research for the American Astronomical Society Conference centered on tracking pulsars using the 20 meter telescope at Greenbank to analyze the change in spin rate in both topocentric and barycentric measurements.

This year I chose to center my focus on dispersion measure and distance to the pulsar in kiloparsecs. Dispersion measure is the density of electrons and the medium in which waves travel through them. I wanted to calculate how far away a pulsar is by using dispersion measure which is better known as DM. I used the right ascension and declination to determine the position of the pulsar in the sky. Right ascension is comparable to the longitude of the sky and declination is the latitude of the sky.

I selected known pulsars using the ATNF catalog, I analyzed 48 known pulsars. Using my permitted access to the pulsar search collaboratory website, I calculated the distance to each pulsar with their tools. My hypothesis was that the higher the DM the further the pulsar would be from Earth. There would be more electrons in space for the waves to travel.

In conclusion I found that the pulsars along the galactic plane fit my original prediction. My graph shows a positive trend with increasing dispersion measure.

Quantifying Myelin Maturation in Healthy Babies

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Mentors: Scott Persohn
Chang Ho
Paul R. Territo

In the first years of life, a baby's brain undergoes rapid growth. A major component of this growth is myelin maturation. Myelination is the process by which Schwann cells form a non-conductive fatty sheath around axons, which accelerates the electrical impulses from cell to cell. This sheath in the pediatric brain increases the degree of myelination with age. To assess the degree of myelination, a unique MRI scan is required to measure the changes in tissue proton relaxivity (T1). The goal of this project is to assess the T1 relaxation rate in the white and grey matter of the brain where the density of axons are highest. The T1 relaxation rates correlate with the degree of myelination at a given age, and as the brain matures the T1 decrease. A cross-sectional study measuring T1 relaxation rates in 146 brain regions (white and grey matter) were conducted for 122 MRI patient ranging from birth to 19 years old, and were grouped into the following: 0-6, 7-12, 13-24, and 25 months to adults. Summary statistics were generated for all age ranges and regions, and estimates of population variances were computed to describe the effective myelination rate as a function of age. In addition, test-retest analysis was performed to assess the degree of reproducibility. The degree of correlation for white ($r = 0.88$) and grey ($r = 0.95$) matter was very high showing high reproducibility across 25 randomly selected subjects. Analysis of average T1 relaxation rates for 56 and 90 regions of white and grey matter, respectively, show an age dependent decrease in T1 values of 0.19 and 0.27ms per month. These data will serve as a normal pediatric atlas to permit comparisons of the expected myelination levels with age and regions, thus improving the diagnosis for abnormalities during brain growth and development.

Dissecting the Functional Heterogeneity of Pearson Syndrome via Single Cell Sequencing

Rhea Malhotra

Mentors: Mr. Caleb Lareau
Computational Biologist, Harvard University
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Pearson Syndrome is a rare, multisystemic genetic condition caused by large deletions of mitochondrial DNA (mtDNA), typically resulting in sideroblastic anemia and exocrine pancreatic dysfunction. While some of the phenotypic characterizations of Pearson have been defined, there is little to no understanding of the specific genetic or molecular basis underlying disease pathogenesis. Here, we hypothesized that utilizing a single cell genomics approach would facilitate the inference of the etiology of this condition. In particular, by leveraging the naturally-occurring heteroplasmic variation between cells, we sought to identify molecular mediators of Pearson Syndrome . By analyzing single-cell ATAC-seq and RNA-seq data of various patient-derived cell lines, we identified a set of 10 genes associated with Pearson Syndrome pathogenesis across sample sets. Further, more comprehensive associations further defined molecular pathways potentially involved in Pearson Syndrome development, including angiogenesis, extracellular adhesion, and protein binding. Overall, this work demonstrates the utility of single-cell genomics approaches to understand rare, Mendelian disorders in uncovering a molecular basis of disease. Further, our results show how synthesizing multiple modes of information across multiple single-cell technologies and analytical tools can potentially enhance diagnostics and therapeutics for rare diseases like Pearson Syndrome.

The Variability Hypothesis and Distribution of Standardized Test Scores

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The current study uses the SAT® test scores distributions for the years of 2012, 2013, 2014, and 2015 to explore the greater male variability hypothesis, which postulates that, due to the greater variability in cognitive aptitude, males are expected to outnumber females at both the lower and upper tails of the standardized test scores distribution. While the SAT® test scores indeed show male-to-female ratios greater than one at the lower and upper tails of the score distributions, the current study demonstrates that the customarily employed assumption of the normal distribution of the test scores overestimates the male-to-female ratio at the upper tail. Furthermore, extrapolation of the normal score distribution model beyond the upper test score cutoff predicts a large male-to-female ratio for the individuals of the very high cognitive aptitude that cannot be assessed by the standardized tests. However, a modified model comprising two normal distribution components, which provides an accurate description of the actual score distributions at the tails, predicts an approximately 1:1 male-to-female representation up to 4.5 standard deviations above the mean cognitive aptitude. Thus, the results of the current study caution against the use of the customarily employed assumption of the normal distribution of the test scores for validating the greater male variability hypothesis and comparing the cognitive aptitude of males and females, especially near and beyond the upper score cutoff.

Exploring the Wonders of the Early Universe: Green Pea Galaxies and Light Flux

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St. Paul Academy and Summit School
St. Paul, Minnesota

Teacher: Karissa Baker
St. Paul Academy and Summit School

Mentor: Claudia Scaralata
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Green Peas are a unique set of galaxies characterized by low mass, low density, and high star formation rate. These properties are shared with Lyman alpha emitters, one of the first types of galaxies that existed in the early universe and played a role in reionization, a phase in the early evolution of the universe that is not well understood. Investigating the properties of Green Peas would help understand the Lyman alpha emitters and their contribution to reionization. This project examines the light flux distribution emitted by Green Peas, separating the light from the stars and the surrounding gas. Python code was used to extract images of 80 galaxies from the Sloan Digital Sky Survey database and to create images of the components produced by stars and by oxygen gas. These images were used to make plots of Flux vs Distance from the center of each galaxy to show the regions from which the two components were emitted. The results show that the stars and the oxygen gas emit light from the same locations within the galaxy.

An Enhanced Early Detection Model of Dengue Fever Outbreaks Using SEIR Infectious Disease Epidemiological Compartments, Generalized Linear Regression Relationships, and Statistical Computing

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Teacher: Mr. James Harris

Dengue Fever is a debilitating viral disease, with more than 25,000 deaths annually. To date, no vaccine has been developed for Dengue Fever due to the existence of four virus serotypes. This project aims to innovate a novel approach to detect outbreaks of Dengue disease, and one that is adaptable to several different regions of the world. The SEIR model was applied to track the population dynamics of transmission between mosquitoes (vectors) and humans. Using outbreak data collected from Singapore's Health Database, a regression relationship was found between climatic variables and the Density of Infectious Mosquitos. The collected variables were Temperature, Precipitation, and Humidity, which have been shown to relate to increased mosquito breeding rates in entomological studies. Simulations were then performed with varying the parameter of Density of Infectious Mosquitoes in the SEIR model, based on generalized linear regression relationships with the climate variables. The model was then tested using this relationship on actual 2013 to 2019 Singapore Dengue Outbreaks, 2019 Honduras Dengue Outbreak and 2019 Cambodia Dengue Outbreak with successful results. Statistical testing using cross-correlation showed a significant relationship between the test data and reported Dengue case count. With this early detection model, the authorities can effectively plan and put measures in place to fight the outbreak with enough lead time. This tool will be the only viable measure until a promising vaccine is developed to control and curb this century-long disease that, to date, has killed more than 5 million humans worldwide.

Sleep's Effect on Cognitive Capability

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Teacher: Ms. Shawn Lowe
TC Williams High School

Sleep deprivation among adolescents is common due to academic studies and athletic participation, causing a potential decrease in academic performance. This study determines if cognitive abilities, more specifically learning and memory, are affected by sleep in both humans and in a *Drosophila melanogaster* model. Human subjects

complete a demographics survey, wear a fitbit for seven nights and take two cognitive tests: a concussion baseline test measuring reaction time and short term memory and a balance test assessing spatial awareness and long-term memory. Wingless *D. melanogaster* were given two cognitive tests: an olfactory avoidance test for short term memory and a spatial orientational test for long term memory. Comparisons will be drawn between the short-term and long-term memory results in both subjects. Experimentation is in progress. In the human study, 32 people have participated, and regression analyses were run for participants with usable data. In the Drosophila study, prototyping is complete for the cognitive test apparatuses, but after completing the procedure twice, it was determined further prototyping is necessary for the sleep deprivation method. The next steps are to continue human trials when it is safe to do so, continue prototyping the *Drosophila* methodology, and to test my hypothesis.

GLIA-Deep: Glioblastoma Image Analysis using Deep Learning Convolutional Neural Networks to Accurately Classify Gene Methylation and Predict Drug Effectiveness

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Mentor: Seema Mehta

Glioblastoma Multiforme is a deadly brain tumor, with a median patient survival time of 18-24 months, despite aggressive treatments. This limited success is due to aggressive tumor behavior and resistance to therapy. Temozolomide is a commercially approved alkylating agent used to treat glioblastoma, but around 50% of Temozolomide-treated patients do not respond to it due to the over-expression of O^6-methylguanine methyltransferase (MGMT). MGMT is a DNA repair enzyme that rescues tumor cells from alkylating agent-induced damage, leading to resistance to chemotherapy drugs. Epigenetic silencing of the MGMT gene by promoter methylation results in decreased MGMT protein expression, reduced DNA repair activity, increased sensitivity to TMZ, and longer survival time. Thus, it is paramount that clinicians determine the methylation status of patients to provide a personalized therapeutic recommendation. However, current methods for determining this through invasive biopsies or manually curated features from MRI scans are time- and cost- intensive, and have a very low accuracy.

The author presents a novel approach of using convolutional neural networks to analyze brain MRI scans from TCIA and genomic data from TCGA to predict MGMT methylation status. The author developed a web-app www.GLIA-Deep.com to perform tumor identification using a U-Net architecture and predict methylation status using Resnet-50. This real-time analysis gives results within seconds, eliminating huge time and cost investment of invasive biopsies. Using computational modelling, the analysis further recommends microRNAs that modulate MGMT gene expression by translational repression to make glioma cells TMZ sensitive, thereby improving the survival of glioma patients with “unmethylated MGMT”.

Hemp Reinforced Ice Bridge design for HS20 Design Load

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Teacher: Mr. Christopher Benshoof
Lathrop High School

Mentor: Mr. Jason Millam

Ice bridges are important in Alaska and are required to move large amounts of materials across rivers. Currently ice bridges are built by finding the minimum ice thickness to safely transport the designated load. Twenty Seven ice beams reinforced with hemp were tested to failure in a three point bending test. Nine of the beams contained hemp rope on the tensile side. A Finite Element Analysis (FEA) model was constructed to determine the forces and stresses of an ice sheet on an elastic (water) foundation loaded with an HS-20 design load. Testing of the ice beams showed that the ice reinforced with hemp fibers has a much higher bending capacity than unreinforced ice. This bending capacity was further increased with the addition of hemp rope. The results of the FEA model and ice beam tests were used to design a sample ice bridge reinforced with hemp fibers that supports an HS-20 design load. This design shows that a reinforced ice thickness of 1'-6" could support an HS-20 load with a factor of safety (FS) > 2. Whereas a design with unreinforced ice would require an ice thickness of 2'-6" under the same design assumptions.

Using "Echolocation" to Create a Better Cane for the Blind

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Teacher: Ms. Marsha McCauley

The goal of this project was to create a cane that uses an ultrasonic sensor to measure a distance, the code changes the distance to a tone, and the tone frequency is then sent out through a speaker. The hypothesis was that if this cane were created, it would allow users to feel safer while walking by sending out tones frequently in a way that the cane sounds like a metal detector when being used. The code was created in arduino and used an arduino board to run the sensor and speaker. To test this, 4 subjects were blindfolded. Holding the sensor in their hand, subjects were asked to walk towards a wall starting 150 centimeters away. Subjects were asked to say when they could hear a distinct change in the tone of the speaker to help measure how often the change was notable for distances. The conclusion from this test was that in 150 centimeters, subjects were able to detect between 8-9 changes, each about 15.68 centimeters away. The overall conclusion was that the cane was effective in helping the visually impaired by using "echolocation" from the ultrasonic sensor to help.

Investigating Visual System Neurons in *Drosophila melanogaster* through Machine Learning

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Mentor: Dr. Michael Reiser
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The visual system is the component of the nervous system that processes visual information. Scientists understand that all neuron types in the human visual system work together to analyze visual information, which leads to an approach or escape from a visual stimulus. However, they have a limited understanding as to how each individual neuron type affects behavior. The human visual system is complex, as it contains over 140 million neurons that aid in visual processing. The fruit fly, *Drosophila melanogaster* , is therefore a model organism to study the visual system, since its compact genome shares 60% of genes with that of humans and can be easily manipulated.

Genetic driver lines were used to silence lobula plate visual system neuron groups H2 and HS in flies. These flies were placed in a fly arena and were subject to 18 moving light stimuli. Each fly experiment was recorded, and a Mixture Density Network algorithm was used to track the flies' head movements in response to the stimuli. The output was then uploaded onto MATLAB to calculate for the angle between the flies' head and body. The movements of the wild type flies and flies that have silenced H2 and HS neurons was compared.

Flies that had silenced H2 and HS neurons had slower reaction times to the stimuli, and more staggered head movements. The data also show that the H2 neuron affects clockwise head motion more than counterclockwise movements. These results are novel and are being confirmed with fly body movement data.

iBraille: A Text Converter Device For The Deaf-Blind

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Mentor: Raghu Kumar, National Center for Atmospheric Research

Less than 10% of the 1.3 million people who are blind in the United States are literate in Braille. Approximately 50,000 of these people are part of the deaf-blind community. More than 70% of blind community are unemployed, with about 50% of children dropping out of high school. This project aims at designing a device, "iBraille", that will be able to convert text to Braille, which will facilitate people in the deaf-blind community to read, communicate, and be more involved in their surroundings. The prototype constructed is simple, affordable, and can successfully translate English written text to Braille. Using simple hardware including a camera, Raspberry Pi processor, solenoid pins, batteries, and text recognition software, "iBraille" costs roughly $160. The camera can be used in a given environment and the processor, within seconds, can interpret any English language statements in front of the camera. The English text is then converted to Braille, which is expressed physically by six mechanical solenoid push-pull pins, which the user can then read in Braille. While the prototype tested one-character output at a time with English text conversion, it can be developed to an array of characters in other languages.

Hierarchically Engineered Nanotheranostic for Ovarian Cancer

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Mentors: Dr. Achraf Noureddine PhD
Dr. Jimin Guo PhD
University of New Mexico

Ovarian cancer is the deadliest cancer among women. Less than one-half of patients survive for more than five years after diagnosis. After mutilating surgery women still have cancer cells left and sometimes the drugs are too weak to fight with the remaining cells. This project hypothesizes that when chemotherapeutics with different activation sites are used in co-therapy it will decrease cell viability. In addendum this study focused on hydrophobic drugs who have low bioavailability which makes it hard for them to get into the cell. This causes a lot of the chemotherapeutic to be wasted as the body will filter it out through the kidneys and liver damaging them in the process. To increase the efficiency of the hydrophobic drugs they were loaded onto nanoparticles. The nanoparticles increased the bioavailability of all the hydrophobic chemotherapeutics, decreased cell viability, and increased the co-therapy effect of hydrophobic combinations containing Afatinib. Using this treatment more women can be cured from ovarian cancer and less drug can be used to do it.

The secret sounds of bees: honeybee vibro-acoustic patterns are influenced by environmental and colony health-related factors

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Mentor: Dr. Carol Fassbinder-Orth
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Honeybees are an essential part of global food production and revenue. However, pollinators around the world are declining at a rate faster than ever recorded due to pesticides, diseases and pests, and habitat loss. Obtaining a better understanding of the relationships among environmental and health factors with measurable bee behavior and physiology may help predict or combat major colony loss. Vibroacoustics are sounds and vibrations that are emitted by bees in response to stimuli and may be essential to understand more about honeybee behavior and health. In this study, 18 hives in two different beeyards in Iowa were analyzed for their vibroacoustics, colony temperature, size, and overall colony health over the course of three winter months. The results of this study indicate that: cluster temperature is a predictor of colony size, thermal imaging is not a reliable tool for estimating colony size, aggressive colonies with suspected Africanized backgrounds exhibit unique spectral outputs, and dying hives also exhibit several unique spectral outputs. This is the first study to report vibroacoustic output of honey bee colonies during the winter months and indicates that a connection exists between honeybee colony size, health, behavior, temperature, and the presence of more unique vibroacoustic frequencies. The use of vibroacoustic monitoring in the winter months may be useful to determine the health state of a colony and could be used by beekeepers to determine when interventional strategies many be necessary to save a colony.

Plasmonic and dielectric nanostructures: Distinguishing size, material, and dielectric environment via machine learning

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Mentor:
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To further the development of optical nanosensing technologies, nanostructures with more desirable optical features must be developed. This entails optimizing the greatest performance-to-cost ratio for optoelectronic use. Using machine-learning of nanostructure optical spectra, we demonstrate the use of linear and nonlinear dimensionality reduction techniques for the analysis and assessment of optical properties for optimal nanostructure design in optoelectronic applications. First, we use linear (Principal Component Analysis) and nonlinear (t-Distributed Stochastic Neighbor Embeddings) dimensionality reduction techniques for studying analytically calculated optical spectra. Second, we couple this lowerdimensional study with an XGBoost-based multi-output regressor to map optical spectra to our 3D dimensionally reduced maps. For experimental validation, we generate spectra using a 3D full-field electromagnetic simulation and evaluate these in the presented model. We find that, given optical spectra calculated analytically, we can effectively separate experimentally simulated nanostructures based on intrinsic material properties. The explored machine learning techniques can be broadly applied to the efficient design of nanostructures for a wide range of optoelectronic technologies.

*This abstract has additional contributing author(s)

X-Net: A Deep Convolutional Neural Model For X-Ray Threat Detection

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Teacher: Dr. Arrigoni

This research proposes X-Net, a novel deep learning architecture that enhances airport security through the detection of threats in X-ray luggage scans. Scanning of luggage is a critical part of aviation safety but is alarmingly unreliable due to human error, endangering the safety of millions of airline passengers. To address this error, this study introduces several deep learning innovations engineered for baggage scan analysis and packages them into one model, called X-Net. X-Net employs a network of deep convolutional lateral stacks that combine vertical residual transpose blocks with inter-layer connections. This combination allows for multi-directional gradient flow, resulting in richer and more robust internal feature representations. These innovations enable X-Net to perform exceptionally well on real-world baggage scans, significantly enhancing public safety and potentially saving thousands of lives:

X-Net detects luggage threats 400% more accurately and 91 times faster than a TSA officer. Moreover, this proposed approach provides novel and empirically useful deep learning tools that can strengthen other fields of computer vision, such as autonomous driving, medical imaging analysis, and biometric security.

Activity-by-Contact Model to Predict Enhancer-Gene Connections: A Tool to Increase our Understanding of Cancer

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Los Alamos NM

Mentor: Graham McVicker

Gene expression is regulated by proteins known as transcription factors, which bind to specific DNA sequences called enhancers. Enhancers activate nearby genes, but there is still a limited understanding of these mechanisms. I created an Activity-by-Contact (ABC) model to predict enhancer-gene connections based on the three-dimensional structure of the genome. This is important because it can identify mutant transcription factors causing the up-regulation of oncogenes. First, I conducted a validation in the K562 cell line and found that the ABC model predicted enhancer-gene connections significantly better than the previous method of using linear distance. Next, the model was applied to study 24 B-Cell Leukemia patients. The samples were first grouped into subtypes by comparing principal component analysis of their gene expression data to 2,000 previously identified samples. Differential enhancers, differential genes, and those with high ABC scores to each other were identified within each subtype. In these cases, the differential enhancer likely regulates the differential oncogene. I was able to identify specific enhancers that regulate known leukemia oncogenes such as FOXO4 and HUWE1. This can allow for the development of novel drugs to target these mutant transcription factors and thereby treat the cancer. This model builds a better understanding of the mechanisms of gene regulation and supports the theory that genes are regulated by enhancer activity and enhancer-promoter contact frequency. The ABC model has the ability to illuminate pathways of oncogene activation, identify mutant transcription factors, and lead to the development of new drugs for targeted treatment of cancer.

Enabling Personalized Medicine: A Novel Deep Learning Tool for Classifying Genetic Mutations Using Text from Clinical Evidence

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Mentor: Donna Leonardi
Bergen County Academy

The understanding of genetic mutations and their effects is the foundation of personalized medicine. Currently, this interpretation is time-consuming, costly, and susceptible to bias, involving the manual reviewing of thousands of scientific texts on individual mutations. To address these issues, a deep-learning natural language processing tool was developed to automatically classify genetic variants and their effects. Opensource data on genetic variants and related clinical literature was utilized to engineer features that represent the relationship between variations and their impacts. Text-mining algorithms such as term frequency-inverse document frequency, coupled with high dimensional vector representations, were performed on the text corpus to embed the relationships between terms. Additionally, physicochemical properties of the substituted amino acids and their respective Grantham scores were used to map the severity of the changes and the amino acid evolutionary distances. The machine-learning system is the concatenation of a Multi-Layer Perceptron and a bidirectional Long Short-Term Memory Network that incorporates dimensionality reduction to capture principle features and mitigate noise. After training, the predictor achieved a high accuracy of 92.3% and an F1-score of 85.5. The tool was validated based on feature prioritization and previously annotated mutations through cross-validation. The deep learning predictor was then applied to currently unclassified genetic variations and identified 13 as novel oncogenic mutations. Ultimately, this study not only helps solve one of precision medicine's primary limitations, but also presents industry viability, significantly streamlining the research process and potentially leading to the development of new therapies.

A Comprehensive Solution to Sleep Apnea: A Mini C.P.A.P. Machine using a Piezoelectric blower and a Real Time Adjustable Smart Pillow with Audio Sensors

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Old Bridge High School
Old Bridge, New Jersey Teacher:

Puvalowski Kimberly

Mentor/Sponsor: Sateesh Pokkunuri

Obstructive sleep apnea is a common and serious disorder in which breathing repeatedly stops due to the throat collapsing and closing the airway. It can happen from 5 to 30 times each hour each night, which impairs one's ability to achieve restful sleep. According to the National Sleep Foundation, about 18 million Americans suffer from sleep apnea, and 90 million Americans snore or have snoring problems costing about $149.6 billion per year. The gold standard remedy for treating apnea is a C.P.A.P. machine, but those have been proven to be invasive, bulky, loud, and a cause of headaches. Research has been explored to reduce apnea incidents by miniaturizing and developing a soundless C.P.A.P. machine using small piezo-electric blowers and also examined the possibility of snore reduction by taking pressure off the airway during sleep with an autonomous head-tilting pillow equipped with audio sensors. These two devices have been proven to be successful when the mini-C.P.A.P. caused a 100% reduction in the number of apnea incidents, whereas SmartPillow resulted in a 92% reduction of snoring incidents. A Chi-square test is administered to validate ways mini-C.P.A.P. and SmartPillow responded to apnea and snoring incidents.

Ocean.Bioplas: The Plasticity of Marine Exoskeleton-Inspired Materials and Their Degradability in the Environment

Jacqueline Prawira

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Mountain House, CA

Teacher: Ms. Gary

Objective/Goals: Shell waste contains useful compounds: chitin, calcium carbonate, and protein which influence its physical properties. Yet unlike plastics, they can naturally degrade in the environment. Inspired by the concept of marine exoskeleton composition, I developed alternative materials to combat the short-lived/single-use plastic problem.

Methods/Materials: Project development took place in 4 stages: Preliminary, Experimental, Degradation testing in 5 different settings for 12 weeks, and Enhancement. Using permutations, I formulated the ratios/combinations and derived mathematical inequalities that define intervals where formation was achieved.

Results: The physical properties range from thin, flexible films to more rigid, composite-like structures. Chitosan (chitin derivative) and CaCO3 have positive correlations to tensile strength while diminishing flexibility. Each gram of Chitosan increases tensile strength by 15%-154% depending on the ratios/combinations, while each gram of CaCO3 increases tensile strength by 5%-13%. The addition of protein improves tensile strength up to 5 times. Biodegradation in organic soil occurs faster than photodegradation in saltwater. Melanin in squid ink slightly accelerates the degradation process, with minimal effect on tensile strength and flexibility.

Conclusion/Discussion: The ratios/combinations of compound derived from shell waste determine the qualities and applications. Some Ocean.Bioplas successfully biodegraded in 12 weeks in organic soil, which meets ASTM D6400 for 60% conversion in industrial composting facilities in 180 days and has the potential to photodegrade in saltwater up to 54% based on linear projection. Ocean.Bioplas has comparable tensile strength up to 32.5 N/mm^2 surpassing some regular plastics, including polystyrene and LDPE, according to ASTM D638. Prototypes were successfully created.

Impact of Haltere Removal on Gravitational Perception and Takeoff in Dipteran Insects

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Mentor: Jessica Fox
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Animal movement requires the input of sensory information. In particular, flies use sensors known as halteres, a type of mechanosensory organ located on the metathorax, to aid in flight. However, the precise function of halteres beyond their canonical role during flying has yet to be determined. In this study, three major conditions were examined—free fall, tarsal reflex, and takeoff—to better understand the behavioral significance of halteres outside of flight stabilization. First, flies were subjected to free fall; specifically, flesh flies (Sarcophagidae), which oscillate halteres while walking, and long-legged flies (Dolichopodidae), which do not oscillate halteres while walking, were observed. The behavior of intact flies was compared to behavior of flies with their halteres removed. Each fly was placed in a clear plastic container suspended 2 cm above a surface and filmed using a high-speed videography camera as the container fell. For both flesh flies and long-legged flies, there was no significant difference in median body velocity during the fall between intact and haltereless flies. Secondly, to examine tarsal reflex, the speed at which flesh flies initiated wing flapping when tethered to a pin and pulled away from a contact surface was observed; intact and haltereless flies did not behave significantly differently when subjected to these conditions. Finally, takeoff of intact crane flies was recorded; it was noted that flies began oscillating halteres before the movement of the wings. Taken together, these data suggest that any sensory information from

oscillating halteres during shifts in gravity is only supplemental as opposed to necessary for behavioral adaption, and that halteres likely do not play a role in tarsal reflex, but may provide sensory input during takeoff.

North Atlantic Minke Whales Exhibit Spatially Varied Vocal Responses to Ambient Noise and a Novel Paradigm for Passive Acoustics Research

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Teachers: Angelo Piccirillo
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Mortality of the North Atlantic minke whale increased during the past two decades, and a lack of knowledge of its behavior inhibits conservation efforts. Despite growth of passive acoustics monitoring, cetacean surveillance remains limited because ambient noise masks some frequency bands of many vocalizations, making these difficult to classify. To classify vocalizations partly obscured by ambient noise, this study developed a novel signal processing algorithm adapted from human speech-recognition software. The algorithm divided audio input into frequency-delimited subbands before analysis, successfully classifying all minke whale calltypes (precision= 93.5%, recall= 92.4%, F1= 91.5%). Minke whale vocal behavior in the Northeast Atlantic Ocean was investigated using 32,352 audio files collected by bottom-mounted recorders in Martinique and Blake's Plateau. Minke whale vocal behavior was analyzed in relation to vessel noise and humpback whale song. Minke whales vocalized consistently during winter at both sites, indicating widespread occurrence during this period. Minke whales in Martinique exhibited no reaction to vessel noise, whereas individuals in Blake's Plateau vocalized significantly less when vessel noise was present ($r= -.363$, $p<.0001$). Minke whale vocalization in the Caribbean Sea was negatively correlated with humpback whale song ($r= -.339$, $p< .0001$), suggesting partitioning of a shared acoustic niche. This research provides insight into how minke whale vocal behavior varies geographically, seasonally, and with varying ambient noise environments. Moreover, the signal processing algorithm establishes a novel paradigm for automation in bioacoustics research that can be applied to the study of any vocal species.

Effect of Storage Time and Temperature on Norovirus Positive Stool Specimens Collected on Whatman Flinders Technology Associates Elute Cards

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Traveler's diarrhea (TD) remains a significant burden to operational readiness during military deployment and overseas travel. Pathogen detection is limited to Polymerase Chain Reaction (PCR) detection in advanced laboratories and requires immediate processing or cold-chain management of stool samples. In this study, the researcher investigated the performance of Whatman Flinders Technology Associates Elute cards (FTA cards) in

stabilizing Norovirus (NoV) positive stool samples for PCR detection at room temperature and 37° C for 1 week, 1 month, and 2 months. Detection rates and cycle thresholds (C_t) were compared between frozen and FTA card stored samples using NoV-specific PCR. Overall, the researcher did not detect a significant difference in positivity rates between frozen and FTA card stored samples. When comparing C_t values, prolonged 37° C exposure for 2 months caused C_t values to increase, notably a significant difference was observed between room temperature (RT) 1-month and 37° C 2-month storage conditions. The findings support the use of FTA cards for storage of stool samples and advancing the usage for molecular based pathogen detection.

A Stochastic Computational Model for Dreissenid Mussel Invasion Risk in Montana's Waterways

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Mentor:
Tom Ritzdorf

Zebra mussels, first detected in Montana in 2016, are known to cause severe economic and environmental damage when they colonize an area. To combat their spread, an accurate computer model would allow decontamination resources to be placed so that water bodies most at risk of contamination could be most effectively protected, while indicating certain lakes in which mussels would not survive and could thus be prioritized below others. This study has created a computational model to determine ideal locations for watercraft inspection stations such that as many contaminated boats are intercepted as possible, and that vulnerable lakes are effectively protected. The models developed in this study will be able to assist in determining the most efficient way to prevent mussel infestation, both from the state's interior and its exterior. The primary model described herein is a gravity model, which computes boat traffic within a given area based on the locations of nearby lakes. It also incorporates GIS data describing precise boat travel routes and stochastic procedures within a repetitive Monte Carlo framework, allowing the full range of possible outcomes to be determined, while also making clear the most probable ones.

In general, it appears that major highways tend to carry the most contaminated boat traffic, and the model is equipped to identify sections of these highways over which the most boats travel. Watercraft inspection and decontamination stations placed on these sections of road would intercept the greatest numbers of boats, reducing contamination and curbing infestation spread

Application-Based Integration of Motile Near-Infrared and Electrochemical Sensors with Realtime, In-Situ Indication of Nitrate-Induced Crop Stress

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Mentor: Chris Reeves

Researchers in precision agriculture are exploring efficient methods of monitoring nitrogen content in crop systems to manage resources, increase crop yields, and prevent environmental degradation from fertilizers. Conventional methods of monitoring nitrogen are inaccessible, expensive, and unrepresentative of spatial and temporal changes. Given that nitrogen levels are extremely variable, it is key to have an efficient system that monitors dynamic nitrogen levels in both the soil and crop canopy throughout the growing season. This study aimed to create a system that connects optical near-infrared (NIR) sensors and nitrate sensors, due to their

strong biological association, via python script, an autonomous soil collector, and an interactive app with geospatial mapping, allowing for realtime analysis of crop health.

To create a functional module, several sensors were interfaced using a Raspberry Pi (RPi), Python, and Google Firebase (GF). An integrated program was successfully designed and tested to receive, process, and upload data from a NIR sensor, GPS receiver, and nitrate ion selective electrode (ISE). A soil collection mechanism was designed, built, and controlled remotely with the Python script for in-situ soil analysis. Data from each sensor was uploaded realtime to a database, overlaid on a map, and presented in an IOS app. This study takes a novel approach to in-situ nitrogen monitoring for the prospect of more sustainable farming and resource management: a system that collects data pertaining to crop health and the soil, equates field conditions, and displays geospatial data.

Shut Off the Runoff

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Mentor: Stephen Howard

This project's question was - Is there a simple cost effective way to reduce agricultural runoff? A hole was cut at base level of a tin foil pan, placing 45 oz inside and compacting the dirt, and shaping the dirt to form an upward slope in relation to the hole. The dirt was then moved to fit the specifications of the trial : a control group, terracing away from the waterway, building a mound at base level of the slope, and contour lines. Two teaspoons of red dye - to represent fertilizer would then be spread evenly across the surface area. 0.48 L of water would be applied gently to the surface area to represent the watering of fields in increments of 0.06L, 0.12 L, 0.18 L x1 0.12 Lx2, 0.24 L. This would allow the determination of which trial is the most effective for heavy rains, light rains and rain overall. A bowl is placed beforehand directly underneath the hole with 0.12 L of water to collect dye. This allows the substance to be diluted to give a better representation of what shade it produces in comparison to the 9 point scale that was used to evaluate. Every 15 minutes the water shade was evaluated and replaced. Once 45 minutes has passed, 0.12 L of water was added to simulate rain. Building a mound was the most effective, terracing away from the water (hypothesized as the most effective) came in second and parallel lines allowing more runoff than the control.

Using Novel Soil Microbes as a Neonicotinoid Alternative on Popillia japonica Newman Infestations as a Method of Pollinator Protection

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Neonicotinoids are a family of insecticides that have gained worldwide popularity. By 2009, the global Neonicotinoid market was worth $2.63 billion. Recently, their usage has come under question as studies have shown a correlation between Neonicotinoids and a degradation of behaviors necessary for honeybee survival. This is alarming as one third of total crop production is dependent upon insect pollination. This research is focused on determining if novel soil microbes could be a viable alternative to Neonicotinoids. The effectiveness of Imidacloprid (a type of Neonicotinoid), GrubGone G (commercial microbe) and 2 experimental microbes were tested using the model organism *Popillia japonica*. 40 beetles were sectioned off for each trial and caged in cylinders, where they then either remained untreated or underwent treatment from the respective product

tested. 4 trials were replicated for each product. The number of larvae present in each plot was recorded on September 19th, 2019. The Imidacloprid was the most effective of the products, with a mean of .3 larvae. The first Experimental Microbe was more effective than the second Experimental Microbe in the July 18th trials, but less effective in the August 15th. Overall, the two microbes appear to supply similar levels of control. While not as effective as the Imidiacloprid, the experimental microbes did prove to be effective in reducing the number of larvae present in comparison to the control and GrubGone G. In the future, different ratios of the microbes could be tested for effectiveness.

Exploring the Role of the G-protein Signaling Pathway Interaction with nAChR α 7 in D. melanogaster Alzheimer's Models

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Schmahl Science Workshops

As a current treatment for Alzheimer's Disease (AD), acetylcholinesterase inhibitors prevent the impairment of neuronal signaling pathways by retaining acetylcholine, a neurotransmitter involved in memory retention. Unfortunately, this therapy is temporary. I researched a different route for maintaining such pathways via the nAChR subunit α7/G-protein Signaling Pathway, one of the most under-studied pathways impacted in AD pathogenesis. I tested how a lack of the pathway affects learning, memory retention, locomotion, and longevity using model organism D. melanogaster . I tested nAChR- (silenced Dα7 allele PΔEY6) and GAP-43- (a key G-protein through silenced Igloo allele Igl) lacking mutants, along with AD models, double crosses Igl x PΔEY6 & Igl x AD models, and Wild-Type (WT & W118) fruit flies. The Wild-Types' success rates were ~80% for locomotion and learning/memory retention. The mutants' (all but Wild-Type) success rates were ~60% and ~45% for the same. Additionally, the mutants displayed decreased longevity by 25% compared to Wild-Types. Hence, a lack of the D. melanogaster -nAChR and GAP-43 causes learning, memory retention, locomotion, and longevity impairments, similar to those observed in AD models, suggesting that these two reside in the same pathway. This interaction should be further studied as a potential therapeutic target in AD.

The Application of Advanced Oxidation Using an Isopropyl Alcohol and β-Cyclodextrin Enhanced Fenton Reaction to Remove Pharmaceuticals From Synthetic Wastewater

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Mentors: Dr. Dominic Brose, Dr. Matavos-Aramyan, Dr. Joseph Pignatello

Pharmaceutical contamination of ground and surface water is a growing issue and wastewater has been identified as the main route of entry. Because they are bioactive, pharmaceuticals do not solubilize easily or evaporate at normal temperatures and pressures. Some water treatment methods have been found to effectively remove pharmaceuticals from wastewater, however, many of them are expensive and therefore not feasible for application on a larger scale. The goal of this experiment was to determine a more feasible method for removing five specific pharmaceuticals from water including diphenhydramine (Benadryl), acetaminophen (Tylenol), ibuprofen (Advil), naproxen (Aleve), and caffeine. The Fenton reaction is an advanced oxidation reaction performed when H_2O_2 in the presence of iron (Fe) creates hydroxyl radicals that can degrade pollutants. It was hypothesized that the Fenton reaction enhanced with β-cyclodextrin and isopropyl alcohol would effectively

degrade pharmaceuticals. The statistically significant data (caffeine ANOVA p-value 0.00019, ibuprofen ANOVA p-value 0.0011, naproxen ANOVA p-value 0.022, and diphenhydramine ANOVA p-value 0.0038) suggests the probability that the null hypothesis is incorrectly rejected is 2% or less for caffeine, ibuprofen, naproxen, and diphenhydramine. Based on this data, implementation of the Fenton reaction for the removal of pharmaceuticals shows promise for municipal water reclamation facilities.

Computational Eye-Tracking Biomarker for Improved Neuropsychological Evaluation via Deep Learning

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Neuropsychological evaluation proves exceedingly valuable in applications that require a complex understanding of human behavioral interactions and mental processes, such as in the diagnosis of cognitive disorders. Current standards of neuropsychological assessments pose serious inaccuracies and difficulties in accessibility due to a degree of subjectivity present in monitoring behavior. This project uses computer vision and deep learning to tap into the oculomotor biomarker (eye movements) to create a non-invasive, low-cost, and effective approach to quantifying brain functions. The developed tool uses pupil-tracking and gaze-estimation algorithms to accurately assess the neurological and psychological deficiencies of patients. An infrared camera sensor (a) tracks eye movements and (b) estimates gaze points; in both cases, pattern recognition is employed to identify abnormal eye sequences in response to visual stimuli. Clinical testing on ADHD patients found that the tool was able to localize behavioral abnormalities within a 75-second test, including areas of inattention, poor reaction, and indecisiveness. The pattern recognition engine also classified neuromotor issues, such as a lagged movement of the eyes, rapid deviations of gaze, and eye tremors. With multiple unique patterns identified, the biomarker yields a 95% sensitivity rate and a 99% specificity rate for ADHD detection, proving this tool's capability in understanding human behavior, intent, and actions in cognitive disorders. The data suggests that the developed eye-tracking tool accurately classifies neuropsychological and motor issues, and the easily implementable nature increases viability in other applications that require an analysis of human interactions with their surroundings.

Photocatalytic Oxidation Utilizing Doped Titanium Dioxide for Air Purification

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Air pollution has become the deadliest environmental problem, leading to more than seven million deaths per year. People are forced to wear masks in China to protect themselves from the heavy smog in the area. In the U.S. alone, $500 million are spent yearly on air purifiers to increase indoor air quality. Current effective air purifiers are extremely expensive (up to thousands of dollars) and cannot filter many dangerous pollutants such as volatile organic compounds (VOCs). In order to mitigate these issues, a filter using photocatalytic oxidation by doping titanium dioxide was created and tested. By using a sol-gel process, titanium dioxide nanoparticles were doped with various dopants such as silver nitrate and coated on a paper filter. This doping process reduced the band-gap energy, therefore; increasing the air purification efficiency. The screen was tested by passing polluted air through the filter and analyzing the outgoing air using air quality monitors. Through this research, a new dopant called PANI was found to be the most effective in reducing air pollutants. The PANI-doped titanium dioxide brought down the amount of VOCs by 99% after 2 hours. This data was also supported with the methylene blue degradation process seen through the ultraviolet-visible spectroscopy data. Furthermore, the samples destroyed 70% of bacteria in 15 minutes of exposure, proving PANI-doped titanium dioxide to be the most efficient solution toward air purification. A materials cost of $0.90 proved that using PANI-doped titanium dioxide is more efficient and affordable than other current air purification solutions.

An in vitro evaluation of the relationship between stress and mineralization through the use of a piezoelectric barium titanate composite

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Mentor: Dr. Santiago Orrego
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In the United States, 55% of people over the age of 50 have either osteoporosis or low bone mass, both of which result from the human body's failure to produce bone-strengthening minerals. Currently, these diseases are treated with hormonal therapy drugs that slow the loss of
minerals, but at the expense of detrimental side effects. This study utilized a composite combining piezoelectric barium titanate nanoparticles (BTO), which turn stress into electricity,
with a commercial resin used in both bone grafts and dental sealants for the potential of remineralizing bones. The calcium phosphate mineralization potential of the composite, resulting from the produced charges of the barium titanate, was quantifiably measured in relation to stress. The BTO composite successfully promoted mineralization in-vitro, and quantifiable amounts of mineral deposition were found. Finally, equations were fitted to data points in order to model the stress and mineralization relationship from 0-6.65 MPa of stress, and up to 30% surface coverage and 9 µm of mineral height. Therefore, the mineral deposits of the BTO composite were successfully quantified for specified stress values. Using the methods described in this study, piezoelectric materials can be used to provide targeted therapy for the millions with bone mineralization problems.

Assessment of sensorimotor deterioration caused by Mild Cognitive Impairment or early Alzheimer's Disease using a novel deep neural network algorithm

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Cognitive deterioration caused by Mild Cognitive Impairment (MCI), which is often a transition between regular aging and neurodegenerative disease (Alzheimer's disease), is displayed before symptoms are. Timely detection of cognitive deterioration is currently inaccessible. A Brain-Computer Interface based on a sensorimotor paradigm (auditory, olfactory, movement, and motor-imagery) that employs a subject-agnostic Bidirectional Long Short-Term Memory (BLSTM) Network was developed to assess cognitive deterioration and identify its relationship with brain signal features, hypothesized to consistently indicate cognitive decline.

Testing occurred with healthy subjects of age 20-40, 40-60, and >60, and MCI patients. Auditory and olfactory stimuli were presented, and the subjects imagined and conducted movement of each arm. The application trains a deep BLSTM Neural Network with Principal Component features from evoked signals and assesses their corresponding pathways. Wavelet analysis was conducted to decompose evoked signals, and calculate the band power of component frequency bands.

This BCI system performs better than conventional deep neural networks in detecting MCI. Most features studied peaked at age range 40-60 and was lower for the MCI group than for any other group tested. Detection accuracy of left-hand motor imagery signals best indicated cognitive aging ($p=0.0012$); here, the mean classification accuracy per age group declined from 82.31% to 79.63%, and was 76.86% for MCI subjects. Motor-imagery-evoked band power, particularly in gamma bands, best indicated ($p=0.007$) cognitive aging. Although classification accuracy of the potentials effectively distinguished cognitive aging from MCI ($p<0.05$), band power did not. This application can be conducive in developing effective diagnostic tools for dementia.

Synthesis of a Tau Aggregation Inhibitor in Relation to Alzheimer's Disease

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Teacher: Dr. Timothy Anglin

A multitargeted approach is suggested to be most effective in inhibiting the formation of tau aggregates in Alzheimer's disease. Two promising targets for treatment of Alzheimer's are the initial hyperphosphorylation of tau, which is caused by an overexpression of the GSK-3beta protein, and early tau aggregation itself. To improve drug effectiveness, the structure of a known inhibitor molecule targeting both of these stages of tau aggregation was adjusted to increase binding affinity with the GSK-3beta enzyme. These adjusted molecules were screened using Molegro. The candidate molecules with the highest calculated binding affinities were further evaluated. One of these novel compounds was then synthesized and assayed for its ability to inhibit the GSK-3beta protein, resulting in a comparable efficacy to the original known molecule's multitargeted structure. The novel molecule has promising GSK-3beta inhibition results and maintained structural features to attack early tau aggregation. This indicates possible effectiveness in inhibiting the future stages of tau aggregation indicative of Alzheimer's disease.

The Potential Role of Trophoblast Slc20a2 Mutations in Vascular Calcification of the Placenta

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Any dysfunction of the placenta can negatively impact maternal-fetal health and cause placental insufficiency, which can lead to issues such as stillbirth and congenital heart defects. One particularly harmful complication is vascular calcification. Sodium-dependent phosphate transporter 2 (PiT-2), which is encoded by the Slc20a2 gene,

lead to novel therapeutic treatments for vascular calcification. To determine the cell type that expresses Slc20a2 and to discern the location of calcification in the placenta, fluorescence in situ hybridization (FISH), Alizarin Red staining, and immunofluorescence staining were performed on wild-type and Slc20a2 knockout mouse placental tissues. Alizarin Red staining showed that Slc20a2 knockout mice had significantly greater areas of calcification than wildtype mice. The calcium deposits were located within the intracellular space and extracellular matrix of the chorionic plate and labyrinth regions of the mouse placenta. Similarly, immunofluorescence staining combined with FISH revealed that Slc20a2 mRNA was found in the trophoblasts of vascular spaces within the chorionic plate and labyrinth. This indicates anatomical co-localization of regions of calcification and Slc20a2 mRNA expression in the placenta. The findings suggest that deleterious mutations of the Slc20a2 gene may result in vascular calcification of the placenta. Furthermore, Slc20a2 gene expression in the trophoblasts of the labyrinth and chorionic plate may play a major role in preventing or mitigating placental vascular calcification.

Deep Multimodal Learning for the Diagnosis of Autism Spectrum Disorder

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Recent medical imaging technologies, specifically functional magnetic resonance imaging (fMRI), have advanced the diagnosis of neurological and neurodevelopmental disorders by allowing scientists and physicians to observe the activity within and between different regions of the brain. Deep learning methods have frequently been implemented to analyze images produced by such technologies and perform disease classification tasks; however, state-of-the-art computer vision algorithms do not make use of all the information offered by fMRI scans. In this paper, we propose to use two functional imaging modalities in the construction of an automated end-to-end autism diagnosis system, which we believe will offer a more comprehensive picture of the neural activity, and thus allow for more accurate diagnoses. We propose a deep multimodal model that learns a joint representation from two types of connectomic data offered by fMRI scans; specifically, functional images can be expressed through two different activation maps, i.e. correlation matrices, computed from the original fMRI image volume. The model consists of two subnetworks, a multilayer perceptron and a residual network, which work in tandem to extract features from the two imaging modalities. The final multimodal model achieved a classification accuracy of 74% and a recall of 95%, as well as an F1 score of 0.805, and its overall performance was superior to using only one type of functional data. Through our study, we have demonstrated that taking advantage of the information offered by the two different data types allows for more accurate predictions and a more powerful computer-assisted diagnosis system.

A Novel Suture Additive: Use of Beet Extract to Assess for Surgical Wound Infection

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The *A Novel Suture Additive: Use of Beet Extract to Assess for Surgical Wound Infection* experiment, has developed a suture that can change color when it comes into contact with an infected wound. A wound that is infected has a basic pH which is different than an uninfected wound. The goal of this experiment was to develop a suture that could indicate if a wound is infected. In developing countries, people might not have the ability to see a doctor but if they knew that a color change in a suture could indicate infection, they would know to seek medical attention. This was accomplished by discovering a natural indicator (beet juice) that is also antibacterial. Through many trials, it became evident that 50%-50% Polyester-Cotton string fit the criteria of my ideal suture. From experimentation, a suture with high absorbency and a noticeable color change at a pH of 6 to 8 was deemed as an optimal suture. Since the initial findings, the string was tested on K12 E Coli treated Petri dishes and early experimentation suggests that the beet juice suture is indeed antibacterial. Meaning, the K12 E Coli did not grow where the beet juice was added to the petri dish. This is an inexpensive, effective suture that is able to detect infections.

Atmospheric Moisture Harvesting Device: Biomimicking Torrey Pine Needles

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Mentor: Dr. Michael Brady
3D Systems

By 2025, two-thirds of people could be living with freshwater scarcity. Harvesting atmospheric moisture is an innovative method to alleviate this crisis. Torrey Pine tree needles are well known for their atmospheric moisture harvesting abilities. This study is focused on learning their surface structures and properties at a microscopic level and identifying the characteristics that contribute to efficient harvesting. A fog harvesting device with a surface treatment is being developed that biomimicks Torrey Pine needles for drought-stricken areas. My work can be concluded in the following three areas:

Torrey Pine needle surfaces were observed microscopically to contain alternating rows of hydrophobic stomata and hydrophilic ridges, creating a hydrophilic/hydrophobic micro-pattern. Their harvesting process was videoed on the microscopic level. Image processing in MATLAB revealed w ater droplets condense first on the ridges, shift over when enough water condenses, and roll down the valleys. Additionally, foliar water uptake was observed.

Controlled harvesting testing and theoretical analysis concluded that micro-patterns increase water droplet mobility and improve the moisture harvesting rate compared to homogeneous hydrophilic surfaces. Water droplet mobility tests were conducted to explain why the micro-pattern improved the wa ter harvesting rate.

I found three features that can be biomimicked: alternating hydrophilic/hydrophobic micro-pattern, ridge/valley structure, and needle tip-up orientation. Many CAD designs and mock-ups were created to maximize the total surface area, enable large airflow, and balance the condensation and transportation rate. An optimized portable device can potentially be as efficient as a 14m^2 fog net.

Guiding Device for the Visually Impaired using Artificial Intelligence Category: Engineering and Technology

Axel S. Toro Vega (2nd Place Engineering & Technology)
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Aguada, Puerto Rico

Teacher:

Yamitza Rosas

Blindness is the third most common disability in the world, around 36 million people are blind (Bourne RRA et al, 2017), ranging from total blindness to 20/200 visual acuity. The investigation's engineering goal is the development of a device for assisting the visually impaired in having a healthier, safer, and more enjoyable lifestyle, using Artificial Intelligence and Ultrasonic technology to identify and classify obstacles in a safe and interactive way. A Raspberry Pi Microcomputer uses a camera to capture what is in front of the user, then uses a C+ + program to send the images to an AI Cloud Service, where it passes though segmentation, characteristics extraction and final image classification. The AI returns a JSON response, containing the image classification labels and a percentage of certainty. The user is notified of the object classification using text-to-speech technology. The device measures distance using ultrasonic sensors, notifying the user of nearby obstacles using text-to-speech. 3D-printed supports secure the components on some glasses, maintaining the best position for obstacle detection. During the various tests conducted, the device correctly identified and classified obstacles in front of the user, with the most accurate classifications being in the top three labels, while notifying the user in a time of less than 5 seconds per image. The research's current phase includes incorporating a voice user interface for an interactive experience, as well as integrating process management and forking to assure efficient and fail-safe operation of the device.

AFM-based Nanoindentation Technique: A Novel Approach to Determine the Nanoscale Degradation of PET

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The purpose of this experiment was to investigate the impact of water type, movement, and sand on the degradation of polyethylene terephthalate (PET). It was hypothesized that if PET was exposed to distilled, spring, and ocean water, then atomic force microscopy (AFM) will be able to investigate the nanoscale degradation of PET using the novel technique of lithographybased nanoindentation. Two square 1 cm pieces of PET were treated in distilled, spring, and ocean water, along with shaking treatments for each water type with or without sand. The samples were individually placed in a 50 mL Erlenmeyer flask and treated for 19 days in the still (control) and shaking conditions. Force-distances produced by nanoindentation were obtained for each surface to investigate surface abrasion resistance of different water types on PET. Surface roughness from topography scans were used to determine the impact of shaking and sand. The alternative hypothesis, that at least one of the amounts of surface roughness was different from the others, was accepted. The p-value of ≤0.002 was statistically significant at the 5% significance level, indicating that the mean surface roughness of PET treated with all three types of water, sand, and shaking were not equal. Abrasion resistance values were calculated using depths obtained from topography scans after nanoindentation was performed, which indicated that when untreated PET (25.378 nN/nm) was exposed to each different water type, spring water treated PET (29.716 nN/nm) was the most susceptible to degradation in comparison to distilled (43.715 nN/nm) and ocean water (52.173 nN/nm).

Embedded System for the Real-Time Fall Detection of Elderly Individuals using Thermal Imaging and Deep Learning

Vetri Vel (3rd Place Engineering & Technology)

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Teacher: Dr. Barbara Stewart
Bangor High School

Mentor: Mr. Cary James
Retired Bangor High School Science Department Head

Falls are the leading cause of fatal injury among older adults with over 12 million falls in the United States annually. For elderly people living alone, quick assistance after a fall is critical and can reduce hospitalization rate by 26% and death rate by 80%. While there are wearable medical alert systems, many elderly individuals prefer not to wear them or may be unable to call for help if injured after a fall. The research goal of this study was to develop an unobtrusive embedded system for real-time fall detection. A Raspberry Pi and a Forward-Looking Infrared (FLIR) thermal camera were utilized. Thermal imaging preserves privacy while detecting heat signatures of humans. Deep learning was used to analyze and classify images due to its effectiveness for complex pattern recognition. The system developed uses a set of thermal images to train a convolutional neural network to identify images of fallen individuals. The effects of factors including image resolution and number of training images on the accuracy of the created neural networks were investigated. An average accuracy of 99.2% (SD 0.62%) was achieved even in the presence of non-human heat sources such as pets. A functioning wall-mounted system has been developed to detect falls and immediately call for help, potentially increasing the safety and independence of elderly people living alone at home or in assisted living facilities. The embedded system can also be used for other applications such as monitoring the night-time activity and sleep patterns of autistic children, enhancing their safety.

Effective repeated filtration of antibiotics from wastewater using activated charcoal filters

Lea Wang
Council Rock High School South
Holland, PA

Mentor - Professor Jeffrey Field, Ph.D.
University of Pennsylvania Perelman School of Medicine Department of Pharmacology

The CDC reports that 2.8 million Americans are affected by antibiotic resistance and that 35,000 die each year as a result. Recent studies indicate that bacterial infections secondary to the novel coronavirus (a viral infection itself) have been fatal to those with antibiotic resistance. Antibiotics from human and animal consumption have polluted drinking water, enabling bacteria and fungi to develop resistance and hindering the treatment of many bacterial and fungal diseases. Many wastewater treatment facilities cannot employ expensive existing filtration technologies, so an effective, economical filtration option is needed. This study investigated the repeated use of inexpensive, scalable activated charcoal in filtering amoxicillin, a penicillin-class antibiotic, from water.

The first phase of the study established an amoxicillin-in-water solution concentration vs. absorbance standard curve using a UV-vis spectrophotometer. Amoxicillin filtration was then studied over five rounds with filters containing varying ratios of charcoal to solution. The percent removal rates were determined by the standard curve. A bacteria test was conducted to visually display the effects of filtration by applying various amoxicillin solutions to E. coli colonies and conducting survival counts. A limited attempt at regenerating used charcoal thermally was conducted.

A 1:10 ratio of charcoal to solution consistently removed >99.9% of amoxicillin and a 1:20 ratio filter displayed removal rates between 94.0% and 99.9%. The quantitative results of the reusability study, further validated by the bacterial study, indicated the potential of activated charcoal to filter amoxicillin and possibly other antibiotics

effectively and economically. The charcoal regeneration study had limited success. Potential future work includes investigating ways to restore used charcoal and researching ways to apply these findings in treatment plants to help reduce the population affected by antibiotic resistance.

Development of a Peptoid-peptide Macrocycle Inhibitor of CDK2-cyclin A as a Cancer Therapeutic

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New York, New York

Supervising Scientist:
Kent Kirshenbaum
NYU Biomedical Chemistry Institute

Cyclin-dependent kinases (CDKs) are critically important targets for cancer therapy, as their overactivity is often associated with tumorigenesis. The traditional approach to targeting CDKs has been the development of small molecules, which are ATP competitive as they competitively inhibit the enzyme at the ATP-binding site. This approach, however, is not ideal because of the conservation of the ATP-binding site structure among CDKs and kinases more broadly. Thus, the development of allosteric inhibitors specific to tumorigenic CDKs and CDK function is ideal. I have sought to develop a non-ATP competitive inhibitor of CDK2-cyclin A by targeting the cyclin-binding groove. The CDK2-cyclin A complex is involved in the phosphorylation of transcription factor E2F1 necessary to terminate E2F1 activity and allow the cell to enter the G2 phase and continue through the cell cycle. This function is mediated by the cyclin-binding groove (CBG), as the E2F1 substrate must bind there in order to be recognized and phosphorylated. Therefore, peptides that bind selectively to this site cause inappropriate persistence of E2F1 activity in cells with deregulated E2F1, resulting in tumor-specific E2F1-induced apoptosis. Unfortunately, peptides have weak pharmacokinetic properties because of their susceptibility to proteolytic cleavage. Therefore, I have used N-substituted glycines to build a macrocycle to target the CBG, as these macrocycles, termed peptoids, have been previously shown to have folding capabilities complementary to the protein surface, as well as pharmacokinetic properties superior to those of peptides. Here, I report the successful synthesis of the peptoid macrocycle, the synthesis of a positive control, and Rosetta docking simulations to validate the design of the macrocycle.

Development of a Fully Reusable and Autonomously Landing Suborbital Launch Vehicle

Ryan Westcott (1st Place Engineering & Technology)
Oregon Episcopal School
Portland, OR

Teacher: Rob Orr
Oregon Episcopal School
Portland, OR

Throughout the past decade, significant aerospace research has focused on bending the cost curve of space exploration through the development of reusable boosters. However, the investments in reusable technology have been primarily directed towards the development of cost savings for large, orbital class boosters. This has left the smaller, lower-powered launch market without reusable technology which has resulted in relatively high launch prices. The development of technology capable of returning and landing smaller rockets could dramatically reduce launch costs. To achieve this goal, I worked towards developing hardware and software that enables a small booster to propulsively land, ready to be reused. The launch vehicle (rocket) that I have engineered utilizes Thrust Vector Control (TVC) to stabilize and slow itself on descent. The TVC propulsion system is accurately controlled by a custom-developed flight computer which runs on a 180 MHz ARM Cortex-M4 processor and contains all

necessary sensors and control interfaces. Flight control software was developed to utilize Proportional Integral Derivative (PID) control loops to stabilize and control the vehicle. The PID coefficients were determined through the development of a mathematical model to simulate the vehicle's flight with six degrees-of-freedom. Rigorous ground testing was conducted before attempting real-world landing tests of the system. Additional hardware was also designed, built, and tested to support the landing and reusability of the rocket. My project analysis indicates that the successful development of this system shows significant potential to save costs for smaller launch vehicles by enabling them to propulsively land and be reused.

X-ray Protein Crystallography and Kinetic Analysis of *Salmonella* Fumarase C

Eden Winga
La Crosse Central High School
La Crosse, WI

Mentor: Dr. Basudeb Bhattacharyya
University of Wisconsin-La Crosse

During the tricarboxylic acid (TCA) cycle of cell metabolism, the enzyme fumarase catalyzes the reversible hydration of fumarate to S-malate. Fumarase has also emerged as a key factor in DNA damage response and tumor suppression. Although the biochemical properties of class II *E. coli* fumarase has been studied extensively, no investigations on class II *Salmonella enterica* Fumarase C (Se FumC) have been conducted. In this study, the gene for Se FumC was cloned into a protein expression plasmid, expressed, purified, and characterized using biochemical techniques. Protein crystals were obtained to determine the three-dimensional structure of Se FumC, and initial X-ray diffraction data was collected. Biophysical and kinetic analyses were also done, thus providing a more comprehensive understanding of the role of Fumarase C in the essential process of life.

Evaluating the Effectiveness of a Combination Treatment of Antibodies to Blood Vessel Receptors to Reduce Angiogenesis Around Tumor Cells

Keena Yin
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Great Neck, New York

Research Mentor: Shun Li
Memorial Sloan Kettering Cancer Center

As cancer is becoming more widespread, immunology is looked at as safer than chemotherapy, which is harmful to healthy cells, and its goal is to manipulate the human body's antibodies against dangerous invaders. It is of interest to program antibodies to target the blood vessels that supply nutrients to starve the tumor. An antibody that targets growth receptors in blood vessels surrounding a tumor previously developed by the Li Lab called 4T-Trap thins the volume of blood vessels. In response, Vascular Endothelial Growth Factor (VEGF) is released by the tumor and angiogenesis is even more rapid. An antibody, VEGF-Trap was developed specifically to be used in combination with 4T-Trap. It that blocks the VEGF receptors in the blood vessels to avoid angiogenesis caused by 4T-Trap.

This summer, I helped to create and implement VEGF-Trap and 4T-Trap and I took measurements and analyzed the results that the antibodies had on the tumor itself. VEGF-Trap was developed by my mentor through plasmids that contained the VEGF gene. After I conducted protein purification, VEGF-Trap was mixed with 4T-Trap and injected into the mice by my mentor. These Mus Musculus Molossinus mice were treated to develop melamona tumors 20 days prior. Three groups of 30 mice were formed: just 4T-Trap, and both 4T-Trap and VEGF-Trap. Tumor size and cell death were measured within the tumor over a span of two weeks. The tumor size for mice that were treated

with both 4T-Trap and VEGF-Trap was 30% less than mice that were only treated with 4T-Trap. Between the 4T-Trap and control groups, there was no significant difference. The cell death area for the combined group, determined by fluorescence spectroscopy, a machine that evaluates cell death percentages, was larger at 14 days, at 24% more than 4T trap alone. There was a significant difference between the combined group and the two other groups, but no significant difference between control and 4T-Trap. The combination of 4T-Trap and VEGF-Trap might lead to a promising treatment to reduce the growth and size of cancer tumors.

NJSHS 2020 Poster Presenters

Environmental Science

Esha Agarwal (PP)
Eric Armstrong
Yeji Cho
Brittany Del Valle
Diya Desai (1)
Tori Hemstreet
Sourish Jasti
Tori Jones
Willow Lewis
Kayla Livesay
Sonja Michaluk (2)
Luke Mo
Parth Patel
Katherine Pommerening (3)
Isabel Portner
Elena Prichard
Cambria Spangler
Ella Wang
Phoebe Xu
Ethan Zhao

Biomedical Sciences

Perisa Ashar
Veronica Brooks
Halla Clausi (3)
Neil Dogra
Brittany Del Valle Gonzalez
Ishraq Haque (PP)
Alexandra Hoffman
Quentin Hughes
Arjun Jain
Margaret Kennedy (2)
Abby Liu
Stanley Liu
Nikhil Mantena
Nathan Mu
Dhruv Pai
Kannammai Pichappan
Ritvik Pulya
Shruthi Ravichandran (1)
Ericka Van Alstine
Kevin Yang

Life Science

Siona Beaudoin (3)
Ava Chae
Catherine Chen
Emily Davis
Jacob Egelberg
Emily Goodwin
Everlee Harvey
Pooja Kasiviswanathan (1; PP)
Aravind Krishnan
Jake Miller (2)
Nikhita Mudium
Gianna Nilvo

Medicine & Health/Behavioral Sciences

Samuel Aberman (1)
Ruchi Agashe
Haarika Ayyadevara
David Ban
Harper Chambers
Simran Chambers
Jason Cui
Caitlin Cunningham
Rachael George
Rishab Jain (2)
Abihith Kothapalli (3)
Ansel LaPier
Emily Liu
Daphne Liu
Zadan Mason
Tanya Mehta
Taylor Moniz (PP)
Anushka Naiknaware
Beier Nelson
Kenneth Roedl
Sid Thakker

Engineering & Technology

Alexander Bell

James Clinton
Brendan Crotty (1)
Arnav Jain
Xingyu Ji
Jasmine Li
Irelyn Meckley (3)
Lauren Morris
Nhan Ngo
Berkan Ottlik (PP)
Crystal Pan
Rachel Pizzolato (2)
Wolfgang Ploch
Michelle Wang
Zehao Yang
Tom Zhang

Mathematics & Computer Science

Janelle Bachman
Kenneth Choi
Milidu Jayaweera
Sadhana Lolla (1)
Isabel Melendez
Isha Narang (2)
Rithika Narayan
AnaMaria Perez (3)
Micah Pietraho
Helen Shao
Brea Swartwood
Sarah Tang
Samanthak Thiagarajan
Alexander Wan
Charlotte White
Jonathan Williams
Benjamin Yan (PP)

Physical Sciences

Maya Beleznay
Ashley Granquist (1)
Harper Learmonth
Ethan Mandojana (3)
Ashini Modi
Zoe Rutkovsky
Paxson Swierc (PP)
Eric Zhong (2)

Chemistry

Arsonlove Abney
Vikram Ailiani (PP)
Weston Henning
William Huang
Natalie Martin
Nadine Meister (3)
Kavita Parikh
Khushi Pola
Emma Price (1)
Joshua Yi
Lisa Zhang (2)

NJSHS 2020 Poster Presenter Abstracts

Facilitation of an orthogonal IL-2 system for CAR T cell therapy through the novel knockout of the human IL-2 gene

Samuel Aberman (1st Place Medicine & Health/Behavioral Sciences)
Byram Hills High School
Armonk, NY

Teacher: Dr. Caroline Matthew

Mentor: Dr. Michael Milone
Milone Lab, University of Pennsylvania

Chimeric antigen receptor (CAR) T cell therapy is a novel immunotherapy that engineers a patient's own T cells with an artificial receptor to recognize and attack cancer. While this approach has been successful in treating hematologic malignancies, it has struggled in solid tumors. Adjuvant interleukin-2 (IL-2) can increase T cell expansion, survival, and function, potentially improving CAR T cell therapy. However, when administered at high levels, IL-2 therapy induces severe toxicity due to the overactivation of T cells throughout the body. Furthermore, IL-2 stimulates regulatory T cells (Tregs) which are immunosuppressive. To overcome these issues, an orthogonal cytokine system was created using a mutated cytokinecytokine receptor pair that functions like the endogenous IL-2 pair but makes use of a unique binding site. This approach ensures that orthogonal IL-2 will specifically interact with CAR T cells engineered with the orthogonal receptor. Unfortunately, upon activation CAR T cells still produce endogenous IL-2, which promotes immunosuppressive Tregs. Therefore, this study tested six CRISPR-Cas9 gene editing molecules designed to disrupt the endogenous IL-2 gene, preventing endogenous IL-2 secretion.
Here, we show the feasibility of a CRISPR-Cas9 knockout of IL-2 production in human T cells. T cells transfected with one of six guide RNAs targeting the IL-2 gene were able to achieve a 97.3% reduction of IL-2 secretion compared to control cells. Data from this study supports the use of this orthogonal IL-2 system, which will hopefully allow for CAR T cell therapy to serve as a successful cancer treatment with remarkable persistence.

Testing The Effect of Different Salt/ Salt Alternatives on Conductivity Using Soil Columns

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duPont Manual High School
Louisville, KY

Teacher Keri Polevchak

The first year this project was done while taking water quality samples - from Broad Run (forested watershed) and Chenoweth Run (urban watershed). The data showed that Chenoweth Run had very high conductivity, it ranged from 150 microsiemens per centimeter (uS/cm) higher to 800 us/cm higher than Broad Run. Because of this, it was decided to go upstream of Chenoweth Run to see what was making the conductivity in this urban watershed so much higher than its forested counterpart. When testing twelve different sites upstream of Chenoweth Run it was found out conductivity was higher in urban areas, with impervious surfaces, especially during the winter season. However further data analysis gathered that these urban sites have high conductivity year-round, due to high amounts of salt in groundwater released year-round.

Originally data was obtained from four different water quality tests, statistics providing rainfall, an online program providing the percentage of impervious surfaces in the watershed. This year data was obtained using soil columns, a conductivity meter, and a lab analysis of samples. To determine which salt alternative prevented the most damage to watersheds, concerning conductivity the different salt alternatives were tested. It was hypothesized that if the road salt alternative used contains less sodium chloride than road salt, conductivity will be lower. After organizing the data obtained and looking at the trends present it showed that the salt alternatives with low levels of NaCl and high levels of CaMg were better for watersheds.

Measuring Ammonia and Phosphate Uptake Efficacy for Two Species of Seaweed to Reduce Eutrophication

Esha Agarwal (Poster Peer Awardee)
Enloe High School
Raleigh, NC

Teacher: Mr. Brian Wood

Nitrogen and Phosphorus are essential nutrients for photosynthetic plants and are used in fertilizers. Runoff from agrarian and urban areas contain large amounts of nitrogen and phosphorus; such contaminants entering water bodies leads to Harmful Algal Blooms and eutrophication due to excess nutrients. The creation of a natural barrier using freshwater seaweed can prevent nitrogen and phosphorus in runoff water from entering a body of water. In this experiment, the change in ammonia and phosphate concentrations by two seaweed species was investigated through a controlled simulation. Three different concentrations and a control were studied in *Chara* and *Aegagropila linnaei* (Marimo Moss). Nutrient concentrations were referenced from Jordan Lake/NC runoff water data. Water samples were monitored eight weeks; three trials were done to ensure accuracy of the results. Both *Chara* and Marimo Moss were found effective in reducing ammonia and phosphate concentrations, respectively, with statistical significance. *Chara* immediately removed ammonia from the water over all three concentrations and results were also significant for the days studied. Marimo Moss removed phosphate from the water over all concentrations studied but the data was not significant over a period of time. *Chara* was found not as effective in the absorption of phosphate as Marimo Moss, Marimo Moss was not as efficient at removing ammonia as quickly as *Chara*. Results remained consistent after three trials. The freshwater seaweed *Chara* and Marimo Moss provide a potential solution to eutrophication when used as a natural barrier for water bodies and can be an excellent example of bioremediation.

Identification of Treatments for Hemophilic Joint Disease Through Evaluation of Vascular Defects via Optimization of Imaging Techniques

Ruchi Agashe
Canyon Crest Academy
San Diego, CA

Teacher: Ariel Haas

Hemophilia A (FVIII deficiency) is characterized by spontaneous bleeding in weight-bearing joints, resulting in hemophilic arthropathy (HA). Bleeding causes inflammation and hypoxia, inducing angiogenesis. Despite advances in treatment, HA still develops. The project goal was to identify treatment and treatment targets for hemophilia that prevent vascular abnormalities.

The goal was approached by gaining insight into abnormal blood vessel formation through developing a 3D visualization of joint vessels, optimizing a cryomethod for immunofluorescent analysis of hard joint tissue (allowing for detection of angiogenic markers expressed in FVIII KO models), and testing the efficacy of the most promising anti-angiogenic treatment candidate targeting Vascular Endothelial Growth Factor (VEGF).

It was determined that anti-VEGF significantly reduced aSMA positive vessels at week 2, abnormal blood vessels are specific to hemophilia as compared to other joint diseases, new vessel formation and vascular remodeling was increased in FVIII KO mice after bleeding but not to the same extent in WT mice subjected to joint bleeding, and lack of hemostasis drives excessive vascular changes. Furthermore, a microCT based 3D model was developed for the visualization of blood vessels and immunofluorescent staining was optimized to allow for the identification of angiogenic targets in mouse hemophilic joints after bleeding.

X-ray Crystallography and Biochemical Analysis of Fumarase C Variant H129N

Vikram R Ailiani (Poster Peer Awardee)
Onalaska High School
Onalaska, WI

Mentor: Basudeb Bhattacharyya
University of Wisconsin-La Crosse

Crystallographic studies of the structures of proteins help explain how those proteins function as enzymes. The field of crystallography has advanced in the past decade, mainly in terms of the energy that can be achieved by a beam in X-ray crystallography. However, current crystallography data on the structure of the H129N mutated variant of the enzyme fumarase has a significantly lower resolution than modern structures of the regular wild type. In this study, we used purification techniques such as Ni^{2+} metal-chelate chromatography to create crystals of the H129N variant with hanging drop vapor diffusion so we could solve its structure with X-ray crystallography, eventually obtaining a resolution of approximately 1.41 angstroms, near that of modern structures for the wild type. We also began experiments with circular dichroism and Michaelis-Menten kinetics to determine thermodynamic quantities for folding in wild type fumarase C and the H129N variant as well as kinetic quantities for the catalysis of both enzymes in the dehydration of *S* -malate to fumarate, with the goal of understanding how the solved structure affects the function of the variant.

The Effect of *Pseudomonas, Piriformospora indica* and *Laccaria bicolor* on the Growth of *Gossypium hirsutum*

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Oak Ridge, TN

Teacher: Dr. Sharon Thomas
Oak Ridge High School

Mentor: Dan McDonald
Phenotype Screening Corp.

It has been shown in the literature that certain species of mycorrhizal fungi and bacteria can stimulate hormone production in food-bearing crops resulting in enhanced growth and yields. This study is the first to evaluate a unique combination of bacteria and fungi developed by the Oak Ridge National Laboratory on the growth of cotton

plants. The results indicated that the inoculated plants went through three stages of growth. In the first stage, the microbes were dormant, and the two populations grew at the same rate. In the second stage, the microbes grew at the expense of the plants as they competed for nutrients. In the final stage, hormones produced by the microbes accelerated the growth of the inoculated plants. The inoculated population had 350% more lateral roots than the control population. They also had a higher density of roots deeper in the growing medium. The more significant number of lateral roots and gravitropism are both key indicators of high levels of auxin in the roots, which could only come from *P. fluroscens* and *L. bicolor.* The increased flowering observed in the inoculated plants is an indication of the presence of gibberellin produced by the *P. indica.* The increased flowering resulting from the increased hormones led to a 14% increase in yield, the highest ever reported for cotton.

Development of a Novel Biomarker and Stage-Classifier Panel for Treatment and Rapid Identification of Lung Cancer by Blood Tests Utilizing Next-Generation Sequencing, Computational, and In-Vitro Analyses

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Maggie L. Walker Governor's School
Richmond, Virginia

Mentor: Dr. Michela Saviana
Virginia Commonwealth University-Institute of Molecular Medicine

Lung cancer is the leading cause of cancer death worldwide. Diagnostic methods including CT-scans are expensive and time-consuming. miRNAs participate in gene-silencing, and can be dysregulated in cancer. Extracellular vesicles (EVs) circulate our bloodstream and participate in cell-cell communication within tumor microenvironments during metastasis. This project developed a novel EV miRNA biomarker panel for various lung cancer histologies and stages, for point-of-care testing. Small RNA libraries of patients' plasma were quantified by qRT-PCR, underwent next-generation sequencing, and pre-processed. Novel miRNAs with their default parameters and their abundance changes were identified. A heat-map (biomarker panel) displayed the expression of miRNAs with p-values <0.05 and fold-changes >1.5, for Stages I-III of SCC, LUAD, and SCLC. miR-374a-5p, and miR-374b-5p were selected for qRT-PCR validation of the biomarker panel in LUAD EVs. PCR confirmed that miR-374a-5p and miR-374b-5p were downregulated in advanced stages of patient plasma samples. Hundreds of LUAD patient data were extracted from TCGA. miR-374a and miR-374b were downregulated in LUAD tissue samples, while miR-1306 was upregulated. Low levels of miR-374a-5p and miR-374b-5p and high levels of miR-1306-5p resulted in LUAD patients having a lower probability surviving over a period of time. Deep-learning neural networks were trained develop automated diagnosis of lung cancer based on histopathological images from available online datasets, with an accuracy rate greater than 95%. Discovery of these novel plasma and tumor miRNAs via potential simple blood extraction tests can be used in conjunction with automated deep-learning diagnosis for effective and rapid detection of lung cancer.

The Effect of Therapeutic Agents on the Installation of GLUT1

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Little Rock, Arkansas

Supervising Scientist:
Dr. Steven Barger
University of Arkansas for Medical Science

Glucose is the main source of energy for the brain and the presence of glucose transporters, such as GLUT1, is very critical for brain function. Glucose utilization in the human brain of an Alzheimer's (AD) patient is very low, and recent evidence indicates that this may result in poor installation of GLUT1 i n the plasma membrane of certain brain cells called astrocytes. Modeling this phenomenon with a strocytes in cell cultures will allow the screening of potential drugs that might restore GLUT1 m embrane installation. As an initial step in developing such a model, we tested the effects on GLUT1 installation in the astrocyte membrane affected by tunicamycin, an inhibitor of the proper trafficking of membrane proteins through the secretory pathway. Primary cultures of astrocytes were treated with tunicamycin, fixed, and stained for GLUT1 by immunocytochemistry. Some cultures were permeabilized with detergent and others were not, so the latter should restrict detection to the GLUT1 on the cell surface. Glial fibrillary acidic protein (GFAP), an i ntracellular protein was detected as a control for permeabilization. This approach revealed d ecreased levels if GLUT1 in the presence of tunicamycin; there was no significant difference in GFAP. These findings indicate that this m ethodology will be useful in testing various agents f or the ability to increase or decrease G LUT1 installation in the plasma membrane of astrocytes. We validated this method with a novel drug developed in lab PNR962 (patent pending) which n ot only reduced ER stress but also improved GLUT1 installation on the astrocyte membrane.

Alteration of Dopaminergic Neurocircuit Pathways: Cannabis Addiction in Adolescents

Janelle Bachman
Academia María Reina
San Juan, Puerto Rico

Mentor: Rubén A. García-Reyes
Scientific Caribbean Foundation (SCF)

Cannabis addiction is described as a chronically relapsing disorder marked by compulsive drug seeking and intake, loss of control in limiting intake, and the emergence of a negative emotional state when access to the drug is prevented. Repetitive cannabis intake may lead to long-term effects such as cardiac, digestive, and pulmonary conditions. In addition to physical problems, a growing number of studies indicate that marijuana exposure during development can possibly cause permanent adverse changes in the brain. Such exposure mainly stimulates the reward system, where neurocircuits found in dopaminergic areas such as the limbic system and the prefrontal cortex become dangerously imbalanced. These imbalances can lead to other psychiatric disorders related to compulsive and impulsive behaviors especially if the patient began using cannabis at an early age. Furthermore, we used the program SIMBRAIN to build, run and analyze a visual representation of the neurocircuits found in the dopamine pathways. This simulation consists of neurocircuits found in dopaminergic pathways of a young cannabis addict and a non-addicted adolescent where we observed the differences in both neurocircuits. Additionally, the results were analyzed by plots in way of a time series that reflected differences in the fluctuation of electrophysiological charges. As a result, our graphs indicate that the electrophysiological charges in an addicted teen remain static, while the control subject experienced expected depolarization. Moreover, the dopamine levels found in the reward pathways of a cannabis addict are lower compared to a non-addict. These alterations in the neurocircuitry of a cannabis addicted adolescent negatively stimulate the reward system.

Predicting Protein-Ligand Binding Using Deep Learning with Spatial Transformations

David Ban
North Allegheny Senior High School

Wexford, PA

Mentor: Dr. David Koes
School of Medicine, University of Pittsburgh

There is a pressing need for new technologies that can accelerate the drug discovery process, which is currently laborious, time-consuming and costly due to the initial pre-screening of thousands of compounds. Because most drugs bind to proteins to produce their effects, more efficient and accurate selection of drug candidates that bind to specific proteins will save time and money. Computer-aided drug discovery and deep learning convolutional neural networks (CNNs) have been applied for virtual drug screening, however, they are limited by their ability to analyze complex 3D structures of proteins and ligands. Spatial Transformer Convolution Neural Networks (STNs) can recognize spatially transformed structures, and has yet to be tested for drug discovery. In this study, novel deep learning models incorporating STNs were built to predict protein-ligand binding by recognizing inherent relationships between proteins and ligands. Models were constructed in either Caffe or PyTorch framework and were trained and tested using the refined dataset from PDBbind database. The accuracy of the model was determined by calculating the loss and Pearson's R coefficient for each model. Results show that in both Caffe and PyTorch models, the STNs are able to converge following translational and rotational perturbations of the ligand with higher accuracy predicting translational perturbations than rotational perturbations. Between the two models, the Caffe model has better accuracy, and PyTorch model has much shorter run time. This is the first study using STNs to predict ligand-protein binding, and demonstrates the potential of STNs models to become efficient tools for drug screening.

Public Perceptions of Wild Berry Crops and an Invasive Species Pest Threat in Rural Michigan

Siona Beaudoin (3rd Place Life Sciences)
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Lake Linden, MI

Mentor: Dr. Tara Bal
Michigan Technological University

The Upper Peninsula of Michigan (UP) is a region heavily dependent upon agritourism. The population has a high percentage of Native Americans and Finnish Americans, and a median household income that is below the Michigan average. During the summer of 2019, a study was conducted in the western UP concerning local knowledge of berries a new invasive fruit fly, Spotted Wing Drosophila (SWD, *Drosophila suzukii*). SWD infests fruit before it is ripe, meaning that it is already inside the berries when they are harvested, and can make it ripen faster. Sampled berries from the UP contained SWD larvae. A demographic survey was used to determine public knowledge of SWD and local berry practices. Out of 45 completed surveys, only one reported that they did not pick berries. Over 75% of respondents began picking berries in their youth and have continued throughout their life. This shows that berries are ingrained into the local culture. Furthermore, the surveys confirmed that many people pick berries as an costsaving way to obtain healthy food.

Determining the distance to the close binary star AL Sculptoris

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Pine Crest School
Fort Lauderdale, Florida

Supervising Scientist:
Walter V. Hamme

Florida International University

This paper presents the light curves in the *uvby* bands of the Strömgren photometric system, and the velocity curve for the close binary star AL Sculptoris (AL Scl). Models for light and velocity curves were fitted using the Wilson-Devinney light curve and differential corrections programs, which use the method of least squares to fit the periodically varying light and velocity data for the system. Four different parameter computations, obtained from each of the combinations of three light bands, yielded a mean distance of 235±0.6 pc. This distance is well within the standard error of the distance of 234.4±7.0 pc found by the Gaia satellite, information that was publicly released in the mission's second data release date in May 2018. These findings allow AL Scl to be used as a standard candle for distance determination, and they strengthen the viability of using light and velocity curve modeling as a method of distance determination for distant stellar objects.

Finding the Optimal Funnel Configuration to Enhance Gas Sensor Readings

Alexander Bell
Kealakehe High School
Kailua-Kona, HI

Teacher: Mr. Justin Brown

This research was conducted with the intent of designing and testing a gas funneling system for use in a non-invasive blood alcohol content detection system. The design goal was to identify the optimal method for gas transfer between a user's finger and the MiCS-5524 gas sensor embedded within the steering wheel. After initial prototyping with designs from vortex-funnels to proximity based arrays, a venturi funnel was identified as a candidate for further exploration. By altering two variables, length and closing diameter, a set of nine venturi funnels were created ranging from 30-60mm in length and 16-28mm in diameter. To provide airflow, a 27mm fan was installed for testing. The MiCS-5524 gas sensor was placed ¾ of an inch away from the rear opening to detect gas concentration levels. For each test, a cotton swab soaked in a 91% isopropyl alcohol solution was applied to a 5mm hole at the smallest cross-sectional area of the funnel. After multiple repetitions, a correlation between longer funnels with midsized closing diameters and high concentration readings became apparent. To add validity to these results, two more tests were done to examine the qualities of funnels <30mm in length and the effect of enclosing the sensor. Both of these trials supported the idea of a "goldi-locks zone" near the 60x22mm configuration. This research has the potential to be applied to numerous industry applications utilizing the venturi effect, including everything from jet pumps, to fuel injectors, and passive flow control valves in liquid propellant rocket engines.

The Antidiabetic Effects of Resveratrol Alone or in Combination with Piperine in Type 2 Diabetic Wild-Type *Drosophila melanogaster* as a Basis for a Novel Treatment

Veronica Brooks
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Oak Park, IL

Supervisor: Mrs. Allison Hennings, R.N., B.S.N., M.A.T.

Mentors: Dr. Laura Musselman
Professor Richard Carthew, Ph.D.
Ms. Pamela Agbu, Doctoral Candidate

More than 30 million Americans have diabetes. The most prevalent is type 2 diabetes mellitus, which is characterized by insulin resistance. Resveratrol, an organic compound, has the potential to be antidiabetic due to its antioxidant effects. However, it is quickly removed from the body by glucuronidation, resulting in low bioavailability. Piperine, another potentially antidiabetic organic compound, is believed to improve the oral bioavailability of resveratrol by blocking glucuronidation. This study investigated the efficacy of resveratrol as an antidiabetic agent alone and in combination with piperine. Type 2 diabetes mellitus was induced in *Drosophila melanogaster* through a high sugar diet. After exposing the control and high sugar diet groups to resveratrol and/or piperine, mass, physical activity, developmental time, and circulating glucose concentration were tested. It was concluded that both resveratrol and piperine were antidiabetic, particularly when administered in combination. Based on ANOVAs, resveratrol and piperine together significantly increased physical activity (p=1.19×10^{-19}) and decreased developmental time (p=0.0003) compared to the untreated diabetic flies. The combination treatment was also more effective compared to groups treated with only one compound. This suggests that a combination resveratrol-and-piperine treatment has the potential to be prescribed alone or in tandem with other treatments as a novel therapeutic treatment.

Examining the Association between Adolescents' Characteristics and Their Involvement with Vaping

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Sponsor: Janet Stark
Gifted Counselor, MHS

Vaping in the United States has increased in the past decade especially among teens and young adults, causing a rise in public concern for their health. What is relatively scarce in the previous research and the current discussion is the question about what groups of adolescents may be more vulnerable to vaping. This research investigates this very issue by analyzing the associations between vaping use and adolescents' individual characteristics using a national survey of drug use among U.S. adolescents ("Monitoring the Future: A Continuing Study of American Youth (12th-Grade Survey), 2018"). The findings for logistic regression show that students who struggle with academics and skip school are more vulnerable to vaping than other students. In addition, there is a greater chance of vaping with those students going out more often than others. The amount of money students earn from a job and other work may also be increasing the chance for vaping. This study also provides initial evidence about religion and political preference, and their association with vaping. The findings can be valuable elements in designing a program of effective prevention and intervention of vaping in the U.S.

Look Me in the Eye: The Perception of Adults and Children with Autism Spectrum Disorder

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Supervising Scientist:
Dr. Leslie Templeton
Hendrix College

People with ASD faced heavy stigma, preventing families from searching for a diagnosis, receiving accommodations, participating fully in their communities, and enjoying the same quality of life as their neighbors. The degradation of people with ASD urged families to isolate themselves and, in turn, created more misunderstandings and hatred because people are unable to correct misconceptions and teach about ASD. This

observational study aimed to identify the subgroups within the autistic community who face the heaviest amount of stigma and determine the groups harboring more negative attitudes towards ASD. Participants, found using an online survey platform, read a scenario depicting adults and children with ASD experience high and low levels of support. To determine stigma, participants were asked about their comfort level, willingness to work with, and attitudes about the behaviors presented. The results indicated people with ASD experiencing low levels of support suffered from increased stigma, and adults with ASD suffered from increased stigma. Additionally, people were less inclined to associate with the autistic community in social environments than educational and vocations settings, proliferating social stratification. Lastly, while economic background showed no significant difference in attitudes towards ASD, women, older generations, and people close to the special needs community expressed more positive attitudes towards ASD. To destigmatize ASD, advocacy organizations must focus on introducing the autistic community to groups holding more negative attitudes towards ASD.

The Novel Application of Coenzyme Q10 and Nitric Oxide as a Treatment for Simulated High Altitude Pulmonary Edema in *Caenorhabditis Elegans* as Expressed Through Hypoxia

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Supervisor: Mrs. Allison Hennings R.N., B.S.N., M.A.T

Mentors: Dr. Lorenz Fenk & Dr. Lihsia Chen

High altitude pulmonary edema (HAPE) is a moderately prevalent disease that effects both individuals travelling to high altitude and those who preside at high altitude. Currently, the available treatments (nifedipine and dexamethasone) are both expensive and difficult to access. This studied aimed to provide a novel pharmacological treatment for HAPE as experienced through hypoxia that is both easier to access and less expensive. It was determined that the combination of Coenzyme Q10 (CoQ10) and nitric oxide are a plausible treatment due to being over the counter and drastically more affordable than the current treatments. This experiment was designed using the model organism *Caenorhabditis elegans* (*C. elegans*) due to their response to hypoxic conditions and oxygen transport system. In order to induce HAPE, a novel altitude simulator was created by assembling a vacuum system that lowered the air pressure to 65.8 kPa (the air pressure at 4,00m). The hypothesis that if *C. elegans* were exposed to HAPE conditions and then provided with novel treatment using CoQ10 and nitric oxide, it would diminish the effect that the hypoxic conditions had by: increasing activity level and producing no change in behavior compared to a control, was supported. It was found that there was convincing evidence to reject the null hypothesis with a p value of 1.33×10^{-7}. Therefore suggesting that the combination of CoQ10 with inhaled nitric oxide proves to be a plausible treatment for HAPE, but must first go through more testing.

Metagenomic Analysis of Thawing Permafrost Soils in Alaska

Catherine Chen
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The Arctic region is the most sensitive region on earth to the effects of climate change. Temperature changes in the Arctic region are increasing at the speed as twice as the global average rate, leading to drastic changes in the landscape including melting of permafrost, changes in precipitation patterns, and changes in vegetation and microbial communities. As the permafrost melts, microorganisms become more active and begin to decompose huge carbon reserves. The proportion of carbon in the permafrost soils accounts for about 5-10% of the entire carbon on earth. Due to the melting of the permafrost as a result of rising global temperatures, this carbon storage is easily decomposed. High-throughput sequencing analysis helps to reveal the diversity and composition of

microorganisms in various soil ecosystems, and provides a valuable biomarker for climate change. This project shows that many microbial communities begin to change during the transition from frozen to thawed permafrost soils. The microbial communities that live in these permafrost soils have some common members, including Actinomyces, which account for a significant proportion of microbes in permafrost soils, but Eukaryotic and viral populations differ in their degree of representation. These results will help us understand climate change in the microbial ecosystem of permafrost soils in response to global climate change.

Optimization of a Photosynthetic Microbial Fuel Cell

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Rolling Hills Estates, CA

Mentor: Dr. Andres Carrillo
Cabrillo Marine Aquarium

Photosynthetic microbial fuel cells (PMFCs) present a relevant and new focal area in the field of renewable energy. In PMFCs, electrons produced by anaerobic bacteria are transferred via conductive electrodes to algae, creating an electrical current. Chemical mediators, such as methylene blue (MB), are necessary to transport electrons between bacterial/algal cells and electrodes, but are costly and unsustainable.

Flavins are naturally-produced molecules, which correspond to greater external electron transport. The purpose of this experiment was to evaluate the novel use of riboflavin as a supplemented mediator. Riboflavin was chosen because of recent development of its mass- production through biosynthesis. It was hypothesized that if riboflavin was added to PMFCs as a mediator, then it would lead to better energy production than MB or mediator-less PMFCs.

PMFCs were constructed with *Spirulina platensis* algae and anaerobic bacteria. Then, three sets of trials were conducted, comparing (1) riboflavin to a mediator-less PMFC, (2) riboflavin to MB, and (3) a riboflavin-coated carbon-cloth electrode to a typical PMFC. It was found that PMFCs with riboflavin were superior to both mediator-less and MB. This project holds important implications for the future by making PMFCs far more accessible, and presents a novel method of increasing PMFC energy production.

Towards Privacy-Preserving Intelligence: Differential Privacy in Machine Learning

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Mentor: Dr. Xiaodi Wang
Western Connecticut State University

Although scary, data collection is inevitable. Our society needs data to improve. But, unlike popular opinion, data collection does not necessarily entail privacy loss. For decades, data-holding organizations have anonymized public datasets, removing identifying information such as names. However, hackers can now link two public datasets containing the same person and find who that person is—thus compromising privacy. Differential privacy prevents these linkage attacks by using computer mechanisms to obscure data with randomized numbers (noise). Mechanisms add just enough noise to datasets to make individuals undetectable. However, current mechanisms are not complex enough: they neglect next-generation hacking techniques and data reconstruction through noise averaging. Overly-secure mechanisms, on the other hand, add too much noise, preventing analysts from learning

from the data. To fix these issues, I create three differentially private mechanisms that first use the discrete M-band wavelet transform, which preserves the energy of the data. The mechanisms LS and LS+ then use a "Laplace-Sigmoid" distribution that multiplies Laplace-distributed values with the sigmoid function, creating a doubly random distribution to draw noise from. The third mechanism utilizes pseudo-quantum steganography, which simulates qubit encryption, to embed noise into data. I then test the mechanisms in five machine learning environments. The mechanisms achieve more than 94% classification accuracy for all privacy values tested, proving that they successfully retain both differential privacy and statistical learnability. As data privacy becomes exigent and quantum computing emerges, my research links the two branches and portrays what data privacy could look like in the future.

A Photonic Crystal-based, Non-Invasive, Color-Changing Sensor for Detection of Salivary SOD2, for Diagnosis of Hepatocellular Carcinoma

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Greenwich, CT

Teacher:
Andrew Bramante

Hepatocellular carcinoma (HCC) is the most common type of liver cancer and is regarded as one of the most aggressive cancers. Over 800,000 people contract HCC each year and around 700,000 die, making HCC the 3rd leading cause of cancer death in the world despite only being the 6th most common.

Currently, the most common means of diagnosing HCC are through costly imaging tests, such as CT and MRI, as well as potentially traumatizing and invasive blood tests and liver biopsies, all which require trained personnel. As such, an easily readable sensor that could measure superoxide dismutase 2 (SOD2) levels in saliva in a low-cost, noninvasive way is highly desirable, and is the focus of this research. To begin, a photonic crystal microchip with opal structure was created through the spin-coating of monodispersed latex spheres (P-(St-MMA-AA)) onto a PDMS glass substrate. This microchip was then dipped in an aqueous prepolymer solution containing the salivary biomarker, SOD2, pulled out, and cleansed under 100 W UV, acetic acid, sodium dodecyl sulfate solution, and deionized water. It has been found that the PC microchips exhibit a change in intensity when exposed to SOD2 with a ratio of 0.14 (clean SOD2 chip) to 0.34 (chip with SOD2), which was measured through a UV-Vis spectrometer and SEM.

Spudfinder 6500: Creating a radar-based system for pre-harvest potato yield mapping, year two

James Clinton
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Golden Valley, MN

Mentors: Dr. Ce Yang Dr.
Peter Marchetto
University of Minnesota
Engineering and Technology (Devices)

Potatoes require heavy watering and intensive fertilization, which negatively impacts the environment. A system designed to mitigate these environmental impacts and improve farming efficiency would be beneficial for farmers. Precision agriculture techniques accomplish this by documenting spatial variability across and within

fields. One key precision agriculture technique is yield mapping. Mapping yields throughout a field allows farmers to determine how various factors like water and fertilizer usage influence farming efficiency, leading to informed decisions about how much water and fertilizer are necessary to apply to the field.

Current potato yield mapping methods occur during harvest. This means that farmers can't use their data during the growing season, instead having to wait until future years to benefit. To mitigate current yield mapping problems, last year we built a robot that detects individual underground potatoes, known as a phenocart. This phenocart uses ground-penetrating radar and machine learning for data collection and processing, allowing for non-invasive, pre-harvest detection of underground potatoes.

This year, we improved our cart's drive system by designing a chain drive using a self-designed sprocket, improved our radar's casing by mitigating interference, tested our radar system with clusters of potatoes rather than single potatoes, and used new machine learning models to analyze the radar data and estimate the mass of buried potatoes. This work suggests methods for using radar and machine learning to estimate the mass of underground potatoes and has the potential to help farmers save money and reduce the environmental impacts of potato farming.

Clean Machining A Comparative Analysis of Cooling Systems in Subtractive Manufacturing Using Biphasic CO_2 as a Safe and Environmentally Sustainable Alternative

Brendan Crotty (1st Place Engineering & Technology)
Homeschool
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Teacher: Jennifer Crotty

Mentor: Richard Twigg
Retired Metallurgical Engineer

The goal of this research was to demonstrate that Biphasic CO_2 is a viable alternative to liquid coolants used in subtractive manufacturing, in all ways: health, environmentally, and functionality.

The investigation started by reviewing MWFs (Metal Working Fluids) used in subtractive manufacturing (milling, drilling, turning, etc.) and their respective limitations. A test matrix for controlled milling and drilling was configured so as to provide data for a comparative analysis of: cutting tool wear, part surface finish, chip size, and exposure. Biphasic CO_2, liquid MWF, and Air Blast was used on three different alloy steels. The functionality data collected consisted of: cutting tool wear as measured by changes in cutter weight and optical inspection, resultant test block surface finish in Ra measured using a profilometer, and chip size determined by visual comparative analysis. The analyses of the health and environmental differences were more subjective, as no quantitative data was garnered.

When compared to CO_2, the MWF netted 11x more end mill wear, and air blast 3x, as measured by weight loss. The surface finish with the CO_2 was 16.30% smoother than MWF and 2.61% smoother than Air Blast. The drilling was inconclusive.

The research proved that Biphasic CO_2 is a functional alternative to industry standard MWF coolants currently being used in subtractive manufacturing. As no airborne MWF mist is produced either within the machining center

or workspace environment, it is speculated that the health hazards should be mitigated. As Biphasic CO_2 nets dry chips higher metal unit recyclability is possible.

Sodium benzoate, a common preservative, inhibits growth, shortens lifespan and accelerates neurodegeneration

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Mentor: Dong Tian

Sodium benzoate is one of the most commonly used preservatives in the food industry. Although the compound is recognized as safe by the FDA, the effects of sodium benzoate on human health have been of interest to both the public and the scientific community. The nematode *Caenorhabditis elegans (C. elegans)* is an ideal model organism to study the health effects of sodium benzoate because of its simplicity and its well established genetic toolkit. In this study, I found that sodium benzoate restricts *C. elegans* growth, shortens its lifespan, induces premature aging, and accelerates neurodegeneration. Sodium benzoate functions in parallel with the insulin/IGF-1 pathway to decrease lifespan. Using an Alzheimer's disease model that expresses human beta amyloid peptides, sodium benzoate was revealed to also significantly accelerate neurodegeneration. Sodium benzoate induced age-pigments in young worms through accumulating age-pigments in lysosome-related organelles (LROs), contributing to premature aging and neurodegeneration. Using GFP marker strains and quantitative RT-PCR assays, I uncovered the role of sodium benzoate in suppressing the *irg-1* innate immunity gene expression. The compromised innate immunity response is another underlying mechanism for the phenotypes described above. Overall, these results reveal the long term detrimental effects of sodium benzoate on animal health and it may have similar consequences on human health.

The Effect of Rapid Serial Visual Presentation Technology on Reading Recall and Comprehension

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Mentor: Dr. Michael Atkinson, PhD
School Psychologist

Many companies today promote speed-reading technology, the goal of which is to allow users to absorb more information in less time. However, before adopting such technology, it is important to know whether an increase in speed comes with a decrease in understanding of the material. The goal of this study was to determine whether a certain speed-reading technology, *rapid serial visual presentation* (RSVP), can increase one's reading speed without sacrificing one's ability to recall and comprehend the information read. Subjects in this study read an 811-word passage either in traditional paragraph form or using RSVP, which presents words one at a time on a computer screen at a predetermined rate. The subjects then answered questions relating to the passage to measure recall and comprehension.

Analysis of the data determined that RSVP readers performed better than the control group on both recall and comprehension questions, with a statistically significant difference of 10 percentage points in average scores for recall questions ($p=0.01496$). Although further research should be done, both with increased reading speeds and

different genres and lengths of passages, the implications of this study are that RSVP technology can in fact be used as an alternative to traditional reading, without sacrificing users' ability to recall the information.

The Effects of Gibberellic Acid on Plant Growth

Emily Davis
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Inwood, WV

Mentor: Cindy Raines

Just like humans, plants also have hormones. One of these hormones, gibberellin, plays a key role in plant growth. Humans have found they are able to add or remove this hormone, gibberellic acid, from plants. The question still remains, how does gibberellic acid effect plant growth? My hypothesis was if a higher concentration of gibberellic acid was sprayed on the plant, the plant would grow taller. Rosette-Dwarf Fast Plants, a plant that produces less gibberellic acid than regular Fast Plants, were used for the experiment. The gibberellic acid was diluted to 25, 50, 100, and 200 parts per million, or ppm. A quad with four plants was sprayed with each level of acid, along with a control quad that received no acid. The acid was only sprayed once. After they were sprayed, the pants were placed in a greenhouse on a water reservoir. Every plant that received the acid grew to a height taller than the controls, but the plant that grew the tallest only received 100 ppm. This plant grew to a height of 140 mm, while the controls had a maximum height of 15 mm. The plants soon died due to their quick lifecycle, and in the end, my hypothesis was proven incorrect. The plants that received the most gibberellic acid didn't grow the tallest. The controls still grew the shortest, but the 100 ppm plants grew the tallest, with the 200 ppm behind them.

Abundance of Macro Plastic Debris and the Beach Profiles of Puerto Rico

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Teacher: Prof. Luz Burgos
Radians School of Math, Science and Technology

Mentor: Tiffany Del Valle

Worldwide, plastic is a material used globally. The main problem is that it is slowly accumulating in the marine environment because this material does not degrade completely. The beach profiles are an accurate measure of the inclination and width of the shoreline. The accumulation of macro debris items is a major threat to the marine ecosystem. For this reason, the main purpose for this investigation was to conduct a research of the abundance of macro plastics and see if there was a relation with the beach profiles. To conduct this project, seven beaches were identified, macro debris items were counted, beach profile was measured, and One Simple ANOVA statistic test was conducted. Based on the results, there was no significant difference between study sites but, there was a significant difference among macro debris. The items more abundant were plastic pieces, cigarettes and straws. The steeper beach was Carolina, and Cabo Rojo was the study site with the less slope. On conclusion, even though the hypothesis was rejected and there was no relation found between the amount of debris and the beach profiles, the impact of the debris on the study sites was clearly noticed and future practical applications were suggested.

The Efficacy of Graphene Oxide Coated Sand in the Filtration of Major Heavy Metal Contaminants to Solve the Global Water Crisis

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Caddo Parish Magnet High School
Shreveport, Louisiana

Mentor: Dr. Ruipu Mu
Centenary College of Louisiana

Over forty percent of the world population lack access to clean water, equating to roughly seven hundred million people. 80% of illnesses in developing countries can be attributed to poor water conditions; this has resulted in a global water crisis. A chief concern is the prevalence of heavy metal contaminants in water, which can result from industrial or natural causes. Heavy metal contamination can lead to nervous system diseases, cancers, and other fatal diseases. Graphene oxide has been hailed as a revolutionary material with potential in water filtration. If this material is coated around sand, a more traditional material used in filtration, it is expected that the concentration of major heavy metals (lead and mercury) will decrease.

Graphene oxide coated sand was synthesized from graphite powder using a modified Hummers method. The heavy metal solutions were filtered through regular and graphene oxide coated sand, with samples of the filtrate taken every five minutes. An elemental analysis was performed on the two sand samples, showing a greater proportion of carbon in the graphene oxide coated sand, signifying that graphene oxide was in fact synthesized. The filtration technique using the graphene oxide coated sand showed a significant decrease in the concentration of both heavy metal solutions. A one-tailed, paired t-test was performed on the last five samples of both eluents, and the resulting pvalues, which were less than 0.05, implied significance. As a result, the potential of graphene oxide coated sand in the filtration of heavy metal contaminants is evident.

Acute Effects of Vaping on Human Endothelial Cells

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Supervising Scientist:
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University of Arkansas for Medical Sciences

Human Endothelial Cells (HUVECs) were exposed to concentrations of Acrolein and Propylene Oxide (PO). Both chemicals were chosen because they're products of chemicals after vaporization. Acrolein and PO are products of glycerol and propylene glycol respectively. Because new chemicals are introduced into the body after vaporization, many effects are unknown. In this study, two experiments were conducted. Experiment 1 contained a 1-to-10 serial dilution and exposed Acrolein/PO to HUVECs in 4 trials, comparing results to media, and HUVECs exposed to media. Concentrations increased by 10 and went from 0.001 µg/ml to 100 µg/ml. Experiment 2 contained a 1-to-3 serial dilution and exposed chemicals to HUVECs in 4 trials, but Acrolein concentrations started at 1 µg/ml and increased to 243 µg/ml, and PO started at 100 µg/ml and increased to 24300 µg/ml. Results from Experiment 1 showed Acrolein cell death between 1-to-10 µg/ml. PO didn't cause any deaths. Results from Experiment 2 showed Acrolein causing cell death at beyond 3 µg/ml. PO reacted at beyond 8100 µg/ml. To find a lethal range for both chemicals, further experimentation is needed. These results show changes in morphology, supporting the hypothesis, Acrolein and PO can damage endothelial cells even at nonlethal doses. This study has far-reaching applications as scientists hope to learn more about the dangers of vaping and communicate findings to the public. This study shows both chemicals could be responsible for morphological changes in HUVECs and Acrolein contributing to cell death.

Flagella-Mediated Antibiotic Persistence: A Scientific Enigma

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Supervising Scientist:
Michael Gates
Northeastern University

Persister cells are mutli-drug tolerant bacterial subpopulations likely responsible for the recalcitrance of chronic infections. It is unclear what population heterogeneities encourage individual cells to become persistent or which molecular pathways confer tolerance. The current study addressed the latter by elucidating the relationship between flagellar gene expression and persister formation. A variety of Escherichia coli deletion mutants constructed via P1 phage transductions, as well as transformants containing an inducible ycgR expression vector, were subjected to persister assays. It was found that any inhibition of cellular motility significantly reduced persister formation, whether facilitated by the knockout of genes necessary for movement or the induction of ycgR. This was observed independent of proton-motive force (PMF) utilization by flagellar rotation. However, when the two methyl-accepting chemotaxis receptor genes tsr and trg were knocked out, persister frequencies increased. While it is unclear how trg is related to persistence, the knockout of tsr likely enables antibiotic survival by inhibiting chemotaxis towards serine, thereby starving cells of serine and conferring tolerance. The current study concludes that stochastic cellular motility promotes persister formation, while chemotactic motility mediated by tsr and trg acts as a moderate persister repressor.

Loss of Hippocampal Day-Time Inhibition in Alzheimer's Disease and its Contribution to Cognitive Impairment and Amyloid-*β* Pathogenesis

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High School Mentor: Rebecca Thrash

University of Alabama At Birmingham (UAB) PI: Dr. Karen Gamble

Lab Mentor: Allison Fusilier

When diagnosing Alzheimer's disease, doctors look for pathogenic amyloid-β (Aβ) plaque accumulation, tau tangles, and cognitive impairment. In the early stages of Alzheimer's disease, subclinical epileptiform activity or seizures, which are typical of network hyperexcitability, can be detected. Circadian rhythms are intrinsic predictable changes in physiology and behavior occurring over a 24-hour period. During the inactive phase of the circadian cycle, seizure thresholds are lower and epileptiform activity is greater in general in Alzheimer's disease. Previous literature suggests that decreased inhibition during the day plays a role in observed hyperexcitability and cognitive impairment, but the role of loss of day-night differences in hippocampal inhibition in cognitive impairment and Aβ pathology has not been studied. To begin this study, the point at which plaque buildup is seen in the J-20 mouse model must be determined. From the preliminary findings of the project, we see that by the age

of 4 months, Aβ pathology is not detectable in the J20 mouse model of Alzheimer's disease. By 12 months of age, hAPP(+) J20 mice exhibit Aβ plaque pathology.

Will Waxworms consume and decompose plastic at the same rate as a natural food source?

Emily Goodwin
Musselman High School
West Virginia

Teacher:
Cindy Raines

The purpose of my project is to see how efficient waxworms are at eating plastic. My hypothesis is if 100 Waxworms are placed in one cage with polyethylene plastic and another 100 waxworms are placed in a cage with honey, honeycomb, and bedding then the waxworms with the natural food may eat more than the waxworms with the plastic. The constants and controls in my experiment are the amount of food temperature, light, container, and worm are the constants. Wax, Honey, and bedding are the controls. The independent Variable is 100 waxworms in each cage. Dependent Variable is the amount of food that will be eaten from both cages. The way the Dependent Variable was measured is the foods were carefully weighed. The results are what I expected them to be. The experiment is worth doing because it is important to me.

Multiwavelength Identification of Black Hole Candidates in M13

Ashley Granquist (1st Place Physical Sciences)
William H. Hall High School
West Hartford, CT

Mentors: Dr. Jay Strader
Dr. Laura Chomiuk
Ms. Laura Shishkovsky
Michigan State University Department of Physics and Astronomy

Finding black holes in globular clusters helps fine-tune models for the causes of gravitational wave events which have been recently detected by the Laser-Interferometer Gravitational-Wave Observatory (LIGO) and helps predict the abundance of black holes in globular clusters. I present the identification of the most promising black hole candidates in the Milky Way globular cluster M13. I utilized source-finding programs in conjunction with X-ray catalogs and radio data from the Karl G. Jansky Very Large Array (VLA), as well as a *Hubble Space Telescope* image of M13, to identify candidates and determine the likelihood of each being a black hole. The sources I identified most closely match the LR/LX (radio luminosity/X-ray luminosity) correlation of black holes, and the most likely sources also have optical counterparts (which would signify the presence of a companion star in an X-ray binary, indicating the likelihood of the radio/X-ray source being a black hole). These sources have radio luminosities between 5.3×10^{27} and 1.3×10^{28} erg s^{-1}, and have X-ray luminosities between 4.4×10^{30} and 2.6×10^{32} erg s^{-1}, rendering the candidates too X-ray-faint to be neutron stars and too radio-bright to be white dwarfs. Additionally, several radio sources without X-ray matches were observed in both the 5 GHz and 7.4 GHz basebands of the VLA observation; their spectral indices close to zero indicate the possibility of them being black holes.

A Novel Function for Osteoclast Differentiation and Bone Resorption

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Teacher: Katharine Metzner-Roop
Academic Magnet High School

Mentor: Dr. Sakamuri Reddy
Medical University of South Carolina

Osteoclasts (OCL) are bone-resorbing cells that differentiate from macrophage precursors in response to receptor activator of nuclear factor kappa-B (NF-κB) ligand (RANKL). Although NFAT (nuclear factor of activated T-cells) activating protein with ITAM motif 1 (NFAM1) signaling is known to enhance OCL formation and bone resorption activity in Paget's disease of bone, the regulation of NFAM1 in OCL differentiation and bone resorption remains unclear. Here, I show that the activation of RANKL enhances NFAM1 expression and signaling in vitro in RAW264.7 cells. We first transduced RAW264.7 cells with NFAM1 shRNAmir recombinant lentivirus and stable cells with NFAM1 knockdown (KD) and control wild-type (WT) were established. Condition media obtained from RANKL-stimulated cells showed a significant inhibition of in the levels of cytokines IL-6 (2.5-fold) and TNF-α (2.2-fold) and chemokine ligand 5 (CXCL-5) (3-fold) in NFAM1-KD cells compared to WT. Further, RANKL-stimulation significantly increased p-STAT6 expression (5.5-fold) in WT cells but it was decreased to 2.5-fold in NFAM1-KD cells. In contrast, no changes were detected in STAT3 phosphorylation in these RANKL-stimulated cells. The expression of tartrate-resistant acid phosphatase (TRAP) was remarkably inhibited by NFAM1-KD in pre-OCL cells. Furthermore, the expression of NFATc1, a key transcription factor associated with OCL differentiation, is significantly inhibited in NFAM1-KD cells. Remarkably, lentiviral knockdown of NFAM1 inhibited OCL formation and bone resorption activity in mouse primary bone marrow nonadherent cell cultures. Taken together, these studies identified a novel functional role for NFAM1 in attenuation of osteoclast differentiation and bone resorption.

Does Feeding Time Affect Lambing Time of a Ewe?

Everlee Harvey
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Donnellson, Iowa

Teacher: Mrs. Alicia Schiller Haynes

For lambs to have the optimal survival rates, it is best to have someone around everyday to keep an eye on the ewes. Without someone not being there to keep an eye on them, you could take the risk of loosing the lamb, but also the ewe. My project was based on conducting research on the feeding times of pregnant ewes. I believe that the feeding time will affect when a lamb with be born. I fed six of the ewes in the morning would make them lamb during the hours of 6 p.m and 6 a.m. Feeding the other six ewes during the evening would make them lamb during the hours of 6 a.m to 6 p.m. They would all have the 12 hour time difference. With the continuation of watching and running this test it could possibly help out other farmers, other sheep productions, and simply people who raise them for a hobby. With being able to control the birthing time of a ewe, this could mean the difference between a live lamb and a dead lamb.

Previous research has concluded that feeding cattle at night causes them to calve during the day, and if they were fed during the day they would calve during the night. With feeding the cattle during the day you run the risk of not being there to assist if needed. This kind of research has not been conducted on Sheep.

Removal of Particulate Matter Using Carbon-Based Charcoal from Simulated Emissions of Smoke by Burning Organic Materials

Tori Hemstreet
Greyhills Academy High School
Tuba City, Arizona

Teacher: Mrs. Reny Mathew

The purpose of this experiment was to determine whether natural wood-based charcoals such as pine and juniper are just as effective at air filtration as activated charcoal. For our experiment, we had a controlled environment that consisted of a metal box, a plywood box, and a 3-foot stove pipe that connected the two boxes. We built an air filter that uses charcoal. Once everything was built, we tested the pine, juniper, and activated charcoal by having them filtrate smoke. A fire is made in the metal box and the stove pipe allows the smoke produced by the fire to transfer to the plywood box. Inside the plywood box is the air filter that contains one of the three charcoals and a Purple Air Sensor that measures the particulate matter (PM) in the air due to the smoke. As the smoke is being filtrated by the air filter, the sensor collects the data of the PM levels as they decrease. After all of the charcoals were tested, we studied the data collected by the Purple Air Sensor. The data showed that juniper filtrated the most smoke in a less amount of time compared to pine and activated charcoal. Pine filtrated the second-most amount of smoke from the air while activated charcoal filtrated the least amount of smoke.

Engineering a Biodegradable Surfactant via Production of Glycolipids

Weston Henning
Mid Buchanan High School

Mentor: Tereasa Freeman

The costs and production of synthetic surfactants have slowly become more and more of a problem. Surfactants have to be refined from petroleum explaining the costs of these chemicals. Surfactants, an ingredient largely used in soap and other cleaning supplies, allows oil and water readily, providing a convenience for everyday tasks industrially and residentially. Unfortunately, commercially-made surfactants, sourced from petroleum are not environmentally-friendly. The expected population explosion, without a doubt, will exponentially amplify the demand and use of such products. This study involved an alternative method for the creation of bio-surfactants. Biowaste from corn and wheat were used to create a biosurfactant, with the aid of a common bacteria, *Pseudomonas fluorescens.* Several tests were performed to compare the eco-friendly surfactant to a common commercial surfactant. It was hypothesized that the biosurfactant would work efficiently and with fewer adverse effects to the environment. The data revealed fewer deaths for *Daphnia magna* exposed to the biosurfactants. Also, Tukey HSD did not calculate a statistical difference in the heart rate comparisons between the control and each type of bio-surfactant. The surface tension test for efficiency revealed promising results.

Modeling Tet2/Npm1 mutant disease using CRISPR/Cas9 to construct a step-wise acquisition model of AML development

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Acute Myeloid Leukemia (AML) develops in progenitor cells and is believed to result from a step-wise acquisition of mutations. Current murine models lack sequential mutagenesis; this inaccuracy has the capacity to have altered our understanding of AML. This research created a more accurate ordered mutation AML model of *Tet2* and *Npm1*. Novel *Tet2*-targeting sgRNAs for CRISPR/Cas9 genome editing were engineered to elicit the knockout of *Tet2* mutations as observed in AML patients. Lentiviruses were produced in 293T/17 cells and used to infect murine Ba/F3 cells. Efficiency of delivery was measured. Three of four tested sgRNAs functionally edited the *Tet2* gene. Following lentiviral functionality confirmation, the lentiviruses were used to induce *Tet2* loss-of-function *in vivo* in a CreERT inducible Npm1 mutant mouse where mutations were induced at varying timepoints to determine the importance of mutation sequence. When *Tet2* mutations were primarily induced, cohorts developed more severe hematopoietic disease with shorter latency than *Npm1* primary mutation cohorts. The "*Tet2* first" cohort showed 1) changes in blood tissue cell counts 2) an expansion of hematopoietic progenitor cell populations into the blood stream, and 3) the capacity to be serially transplanted, consistent with AML formation. The "*Npm1* first" cohort has not yet shown these changes. These results indicate importance behind mutation order toward AML tumorigenesis. This research will provide insight into the mechanistic, molecular, and cellular synergy and impact of *Tet2* and *Npm1*, and could also change how AML is characterized and modeled leading to more individualized and more successful treatment options.

Fabrication of Lead Zirconate Titanate Piezoelectric Thin Films through Sol-Gel Deposition

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Considering the popularity of lead zirconate titanate (PZT) for its desirable piezoelectric properties, this study was focused on the fabrication of PZT thin films with improved qualities and reduced cracks. PZT thin film recipes were developed and tested by optimizing the thickness and heating/cooling processes of the film and without utilizing a seed-layer. Thin films were deposited through the sol-gel method and spin-coated onto a substrate. The films then underwent pyrolysis and annealing to remove organics and crystallize. Light microscopy and image processing were used to analyze the quality of the thin films by measuring the average area of the largest crack-free regions in each thin film. It was found that multi-layered PZT thin films contained less cracks but exhibited rougher surfaces. It was also found that raising pyrolysis temperatures gradually to annealing temperature was optimal to decrease thermal stress and the amount of cracks. Upon observing the films directly after pyrolysis, it was concluded that

the annealing stage was a major source of the film cracks and should be improved to decrease the amount of cracks. A completely crack-free PZT thin film was not fabricated, but future work should focus on improving the annealing stage, improving multi-layered thin films, and testing piezoelectric properties of fabricated thin films.

An Active Role for Machine Learning in the Diagnosis of Atrial Fibrillation

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Atrial Fibrillation (AF) is a cardiac disease affecting over three million Americans, with a prevalence of 1% (above 6% in the elderly).[1] AF is an irregular heartbeat that can lead to blood clots, stroke, heart failure and death. Annually, AF is responsible for over 750,000 hospitalizations and 130,000 deaths in the U.S.[2] Accurate and early diagnosis is key, however, the disease is significantly under-diagnosed. Monitoring devices can acquire large amounts of real-time ECG images but evaluating this big data remains a challenge. Diagnostic accuracy with current technologies is high but false positive rates are between 27-90%. There is a growing need for automated image analysis. This study aims to create a supervised machine learning algorithm that will reliably identify AF and reduce the false positive rate. 5,761 pre-classified ECG images were collected, augmented and classified as either AF or NOT for binary analysis. It was hypothesized that a machine learning algorithm could be built to diagnose AF that maintains sensitivity while significantly reducing the false positive rate. The optimal model included seven convolution neural networks, four dense layers and nine epochs. Testing the final model on the validation images resulted in sensitivity of 94.7%, specificity of 95.1% and a false positive rate of 4.9%. With a consecutive-image trigger, the false positive rates are dramatically reduced (< one per 10 years). Using this algorithm to diagnose AF can potentially achieve similar accuracy and a significantly lower false positive rate than the reported algorithms used today.

Deciphering Tumor Heterogeneity in Breast Cancer using Single-Cell Analysis

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Breast cancer is the most common form of cancer and the second-leading cause of cancer-related death in U.S. women. Up to 70% of all breast cancers are driven by the hormone estrogen. Hormone therapies that block estrogen from binding to cancerous breast cells have proved very effective, leading to high survival rates at 5 years. However, beyond 5 years, increased mortality rates are observed due to therapeutic failure. Literature has identified tumor heterogeneity as a major obstacle for effective hormone therapy. As cancer progresses, the breast tumor becomes more heterogeneous and consists of more diverse cells with distinct molecular signatures and differential levels of sensitivity to treatment. It is essential to decipher tumor heterogeneity to overcome therapeutic resistance and ultimately combat breast cancer. The purpose of this project is to decipher breast tumor heterogeneity and its underlying mechanisms through single-cell analysis. Analysis of single-cell RNA-sequencing data revealed that cancerous breast cells recapitulate healthy breast cell types and cycle between them. This plasticity allows the cancerous breast cells to escape hormone therapy. Through analysis of epigenetic

data, transcription factor KLF4 emerged as a master regulator of this heterogeneity. By inhibiting KLF4, tumor cells can be prevented from evading hormone therapies through their plasticity. These previously undiscovered mechanisms of breast cancer heterogeneity and the corresponding putative master regulator KLF4 can help create the next generation of effective hormone therapy for breast cancer.

The Intelligent Medical Stapler: Ending the Emergency Room Crisis

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Teacher: Jennifer Berry

Emergency rooms are overcrowded with patients who have lacerations, the most common injury after broken bones. Such cases require a simple treatment, sutures or staples; yet, a doctor must complete the procedure. As a result, doctors spend valuable time on stitching for sometimes half their day. The goal of this project is to design a robot to perform medical staple autonomously. Overtime, the design of a delta robot with six axes of rotation and camera tracking was selected. The base is a rotary delta system, which uses three motor powered arms, with three joints per arm, all of which are connected to a parallel end effector. This end effector holds a rotational plate; this component allows the robot to follow curved lacerations. A tilting platform is offset from the rotational plate to perform staples along the side of a patient. Most of the components are 3D printed, with some CNC-machined metal and MDF parts. The tilting plate is the final effector and can move along six different axes. A USB camera and a medical stapler are attached to the plate. During testing, the robot held up to significant stress testing, and the motors achieved a twenty percent margin over the desired range of motion. The computer vision software identified most skin and lacerations effectively, and the kinematics of the delta robot translated effectively into Cartesian motion. In the future, through further development to increase precision, the Intelligent Medical Stapler can transform overcrowded, overworked emergency rooms into hubs of medical innovation.

The Pancreas Detective: A Novel Artificial-Intelligence-Based Post-Biopsy Tool to Screen Genetic Mutations Towards Personalizing Pancreatic Cancer Treatment

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Mentor: Aditya Kumar
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Pancreatic cancer is a devastating and incurable disease with a 5-year survival rate of just 10%. Due to genetic alterations known as mutations, certain cancer-inhibiting and cell vitality genes are affected, allowing cancer to rapidly metastasize across the body. Today, three main treatments exist for pancreatic cancer: radiotherapy, chemotherapy, and immunotherapy. Precision medicine aims to tailor treatments to patients based on their genetic mutations; this yields better survival-rates than conventional methods. However, for pancreatic cancer, current diagnostic tools can lose up to one month of valuable treatment time in turn-around procedures. My research aims to solve the problem of lost treatment time and provides a highly confident artificial-intelligence tool enabling precision medicine treatments for pancreatic cancer. By classifying genetic mutations of patients, this research enables doctors to use targeted treatments potentially improving patient survivability by 13%. My invention, Pancreas.ai, utilizes deep learning to accurately predict the genetic mutations of patients, based on the tissue from their biopsy. Using over 450 pancreatic cancer biopsy images, radiomics allowed me to quantify

imaging features such as density and texture from cancer tissue. I utilized the MATLAB environment to train a "custom build" of the Inception-v3 deep learning network on the dataset. The network was able to successfully predict five pancreatic cancer mutations including KRAS, TP53, and CDKN2A. Pancreas.ai will allow oncologists to recommend targeted therapies yielding a higher probability of success -- while saving up to 30 days of turn-over time. Future work will explore feature-based prediction of progression for pancreatic cancer.

Wastewater Purification: Fabrication of a Low-Cost Water Filtration System to Remove Heavy Metal Ions in Wastewater Using Waste Tea and Coffee

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Water contamination has been one of the world's leading issues for the past few decades, with the problem only growing worse through industrialization. Over 6 billion pounds of tea (Tea Fact Sheet) and 19 billion pounds (The World Counts) of coffee are produced each year, and most of it goes directly to our overfilled landfills. The waste-tea leaves and coffees that are tossed into landfills are a real-life gem mine that present the opportunity to purify water not only once, but multiple times, as a low cost and low economic value adsorbent. The pollution of heavy metals such as copper (II) and nickel (II) affect townships and cities across the world. In order to assess the capabilities of waste tea and waste coffee to purify contaminated water, boiled waste teas and waste coffees were stirred into a heavy metal ion contaminated water (nickel(II) and copper(II)) for various times. The concentrations of the heavy metal ions were monitored in real time using commercial copper(II) test kits or using Lambert Beer's Law spectroscopy. Additionally, the waste biosorbents were tested in a prototype model filtration system that could be applied into a real world scenario in third world countries that cannot afford proper equipment. This study examines the abilities of five different types of waste teas (Assam, Tulsi, Darjeeling, Oolong, & Lipton) and waste coffee in removing heavy metal ion contaminants and their applications in a low-cost filtration system

A Mission-Critical Communications Planning Over Contested RF Spectrum with Deep Reinforcement Learning Aided Artificial Intelligence

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Mission-critical communications (MCC) refer to those that support operations involving high risk to human life and property. As RF spectrum becomes highly contested, ensuring mission-success with MCC requires intelligent planning policies. This project develops a novel game-theoretic model for MCC and a Deep Q-Network (DQN) implemented Deep Reinforcement Learning (DRL) based Mission-Critical Communications Protocol (MCCP) to learn to complete a mission within given resource-constraints against an adversary.
An example critical mission is defined as two radios exchanging messages within a given time constraint over two oppositely-directed communication links in the presence of an adversarial jammer. Mission-planning requires the radios to learn when and how to switch directions vs. channels based on the behavior of an adversary. Through extensive-form sequential game modeling, the problem was found too complex to solve analytically and beyond

traditional reinforcement-learning due to uncountable state-space. DQN-implemented DRL is shown to be an ideal approach to learn effective policies for such MCC planning. Results on an actual wireless network showed that the DQN-implemented DRL could achieve mission-success with 0.9 probability. A new DRL algorithm called Deep Policy Hill Climbing was developed that outperformed the original DQN-DRL algorithm by 30%. Developed abstract game-theoretic model applies to a wide-range of critical mission scenarios including crop-planning and resource-allocation in management. Hence, the developed DRL mission planning framework can be utilized for ensuring mission-success in a wide-variety of fields, far beyond MCC. This makes the case for adapting DQN-powered AI techniques to mitigate the risk of human errors in high stake missions.

Using MobileNet and Long-Short Term Memory Neural Networks to Help Correct Speaking Mouth Poses of Children with Cleft Palate

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Children with cleft palate often suffer from speech disorders. Children need guidance from professional speech therapists to teach them to pronounce correctly. Speech therapists and similar organizations are hard to find in many regions of the world. Even with the opportunity to receive surgeries, kids may still not be able to change their way of speaking. I realize the difficulties in completely altering the process of speech therapy, but I can use technology in the field of deep learning to increase the efficiency of it. The aim of my project is to construct a neural network that takes inputs from the patients, determine whether the input matches the correct mouth poses or not, and finally gives the patient feedbacks on each word. One of the most important aspects of speech therapy is to train kids to pose their mouths correctly while speaking. Even though the main process remains personal training with therapists, the duration of training can be shortened if children can practice on their own and gain immediate feedback on their performances. The main approach of this project is using convolutional neural networks and recurrent neural networks to process the data inputs, mostly video clips of patients speaking, and output to the patient if the input corresponds with correct poses that the model is trained on.

The Bees Knees Pesticides: Formulating Bee-friendly Pesticides from Innocuous Ingredients

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Mentor:
Allyson Andrews

The purpose of this project is to determine which of the three pesticides I created is the most effective in deterring pests while maintaining the functionality of commercial pesticides. If I test 3 pesticides made with castile soap, neem oil, or essential oils, then the pesticide made with neem oil will be the most effective in deterring pests while still preserving the bees' health. For my experiment I placed two different plants favored by bees (pentas & lantana) as a control group with no pesticide alongside a set coated in pesticide. I placed the control simultaneously with my test group and allowed my bees to follow their usual foraging route for 5 days before I returned to examine the condition of my control and test groups. I repeated this for all 3 of my formulated pesticides and made sure to keep the amount of pesticide on each test group even and monitor the bees during the 5 days with the beekeeper assisting me. During my experiment I found that the results supported my hypothesis-- neem oil was the most effective pesticide. After putting a grid on my result images and comparing the

average number of bite marks and pests for each pesticide group and comparing these averages with the control group numbers I was able to come up with my conclusion confidently. While it did not improve the condition of the bees per say, the effects of clothianidin and thiamethoxam (NNIs) were avoided.

A Biotechnology Approach to Desalinate and Purify High Salt Water for Sustainable Farming in Arid Regions from Earth to Mars

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Mentor: Dr. Vijayapalani Paramasivan
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Permanent drought is fueled by adverse effects of climate change and global warming, which is a critical problem worldwide. Consequently, shortage of fresh water challenges agriculture and food security. Vast water resources (oceans) and briny (high salt) water near arid regions are unfit for use due to high salinity. Emerging water management technologies have limited applications as they consume high energy. Therefore, using natural resources, I developed energy and cost-efficient strategies to convert high salt water to near fresh water for agricultural purposes. I cultured *Synechococcus* (cyanobacteria) strain PCC 7002 in briny water under white light or sun light, which resulted in desalination of the briny water to 68%. I filtered this biodesalinated water through basalt type volcanic rocks (which are commonly found in arid regions) and removed (purified) a significant amount of the PCC 7002 biomass. Surprisingly, this gravity filtration method using the naturally available rocks further reduced the salinity of the biodesalinated briny water to 9% due to adsorption of inorganic ions onto the rocks. Utilization of the purified biodesalinated briny water boosted the growth and biomass of crop plants in arid region (basalt type) soil. Thus, I identified a potential biotechnology strategy to convert high salt water to near fresh water, which will be highly valuable to combat drought and sustain farming in arid regions. Furthermore, this strategy will find potential applications to desalinate briny water on Mars to raise crops for NASA's Mars Mission in near future.

Tissue Transplantation Along the Anteroposterior Axis of Dugesia dorotocephala as a Model for the Treatment of Liver Cirrhosis via Stem Cell Therapy

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Teacher:
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Liver cirrhosis is a complication of various liver diseases, which are leading causes of worldwide morbidity and mortality. Currently, the only treatment for late stage liver cirrhosis is liver transplant, which leaves patients at risk for many complications. However, stem cell therapy, especially using induced pluripotent stem cells, is being investigated as a potential treatment for liver cirrhosis. This experiment attempted to model the treatment of liver cirrhosis via stem cell therapy by transplanting tissue along the anteroposterior axis in planarians. Planarians were irradiated and then received either head, midsection, or post-pharyngeal transplants from healthy donors. The amount of days it took for planarians to heal completely was then determined following transplantation. It was concluded that planarians only regenerated after receiving a head transplant, whereas midsection and post-pharyngeal recipients did not survive.

Additionally, recipients of head transplants regenerated faster than irradiated planarians without head transplants (ANOVA p =3.64 x 10^{-10}), allowing for the rejection of the null hypothesis. More research is needed to explain the survival of the head transplant recipients compared to the other groups in order to properly apply this data to the treatment of liver cirrhosis via stem cell therapy.

A Machine Learning Based Diagnostic Tool for the Early Detection of Colorectal Cancer

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Colorectal cancer (CRC) is not only one of the most common non-sex-specific cancers, but also one of the deadliest. There is thus the need to develop more comprehensive and less invasive methods to diagnose CRC. Previous studies have established the role of the human gut microbiome in CRC carcinogenesis and progression. In this study, the efficacy of gut microbiome data in detecting CRC was investigated. This was done using six publicly available datasets, comprising a total of 621 gut microbiomes. Utilizing robust feature selection methods, a total of 121 potential biomarkers for CRC were identified and were subsequently used to develop machine learning models for the detection of CRC. To evaluate the predictive capabilities of these models, the area under the curve (AUC) of the receiver operating characteristic curve and the accuracy on testing data was calculated. The top performing model in this study was a random forest model, obtaining an AUC of 0.9238 and an accuracy of 90.16%. Ultimately, this paper demonstrates the viability of metagenomics data in machine learning to enable the development of a diagnostic tool for the early detection of CRC, facilitating improvements in both treatments and patient prognosis for CRC. Moreover, this study represents one of the largest meta-analyses of metagenomic data performed to date. In the future, further investigation of relationships between the biomarkers identified in this study and the pathogenesis of CRC could aid in understanding the etiology of CRC and gaining insight into potential therapeutic targets for CRC.

FRK1-LUC Arabidopsis thaliana: Novel Endotoxin Assay Harnessing PAMP-Triggered Immunity

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The current practice of harvesting *Limulus polyphemus* (horseshoe crab) to use in the Limulus amoebocyte lysate (LAL) assay for the detection of bacterial endotoxins in medications and medical devices is ravaging coastal ecosystems. Pharmaceutical standards require these products to have an endotoxin concentration below specified thresholds to avoid human septic shock. This project creates an endotoxin assay with similar specificity and sensitivity to existing methods while minimizing cost and environmental impact. The PAMP-Triggered Immunity (PTI) response of *Arabidopsis thaliana* to pathogen-associated molecular patterns (PAMPs) allows quantitative

determination of endotoxin presence based on induction of the FRK1 promoter. Transgenic FRK1-LUC Arabidopsis thaliana were germinated to express luciferase upon activation by exposure to gram-negative bacteria. Luciferase control was first tested via plate reader, luminescence recorded with varying enzyme quantities. This provided expected luminescence levels based on the amount of luciferase produced. Next, E. coli ranging from $6*10^5$ to 10^3 CFU/mL, as well as flg22 peptide (positive control), were infiltrated into the leaf apoplastic space of FRK1-LUC and wild-type plants. Luminescence of infiltrated leaf discs from plant samples was measured after adding luciferin substrate to treated tissues to reconstitute functional luciferase. This determined correlation of infiltrated bacteria concentration and luminescence, a product of the luciferin-luciferase reaction. Data suggests this assay achieves endotoxin detection specificity down to ~20 endotoxin units (EU)/mL. This provides a promising indication that this method can be further investigated to yield results for lower endotoxin concentrations as well as to demonstrate greater specificity.

Feedback Training Improves Compliance with Sternal Precaution Guidelines: Implications for Optimizing Recovery in Older Patients After Cardiac Surgery

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Mentor: Dr. Kimberly Cleary
Professor, Eastern Washington University

Patients often need to use their arms to assist with functional activities, but after open heart surgery pushing with the arms is limited to < 10 lb to help minimize force across the healing sternum. The main purposes of this study were to determine: 1) how accurately older patients (> 60 years of age) can estimate arm weight bearing with 10 lb or less of force and 2) if feedback training is effective for improving ability to estimate arm force and reduce pectoralis major muscle contraction during functional activities. An instrumented walker I designed was used to measure arm force during walker ambulation and sit-stand transfers. Pectoralis major muscle electromyography (EMG) activity was measured simultaneously in study participants (n = 30). After baseline testing, study participants underwent a brief session of visual and auditory concurrent feedback training. Results showed that self-selected arm force was greater than 10 lb for all tasks (20.0-37.7 lb) but after feedback training it was significantly lower (10.6-21.3 lb). During most trials (92%), study participants used more than 12 lb of arm force. Pectoralis major muscle EMG values were less than 23% of maximal voluntary contractions and were reduced (9.8-14.9%) after feedback training. Results indicate that older patients may not be able to accurately estimate upper extremity force used during weight bearing activities, and that visual and auditory feedback improves accuracy. Results suggest that an instrumented walker and feedback training would be very clinically useful for patients recovering from open heart surgery.

Using a New Mathematical Model to Study the Formation and Development of Comet 67P/Churyumov-Gerasimenko

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This project examines the thermal properties of Comet 67P/Churyumov Gerasimenko through mathematical modeling. The goal of the project was to analyze differences between separate regions of the comet, comparing their absorption rates and conductivities, as well as analyzing the density of the comet as a function of its depth. Finding distinctions between thermal properties of regions of Comet 67P provided insight into how the comet initially formed.

Three programs were used to create the mathematical model. The first program was a PDS file reader, which read through data files retrieved from the MIRO instrument on the Rosetta spacecraft and filtered out data that was not taken from the examined region. The second program used data from the PDS file reader to create a thermal model of the expected temperatures over a comet day at that region. The third program was a radiative transfer reader, which accepted data from both the thermal model and the PDS file reader and calculated the amount of radiation the MIRO instrument should be able to detect from the surface of the comet given the thermal model data. Conductivity and absorption of the thermal model were adjusted until the model fit MIRO's data.

Results did not show differences between regions across the comet, suggesting that the comet formed from colliding solid material that originated in similar areas of the Solar System. Due to the error bars of the MIRO data, the results cannot disprove the possibility that the comet formed from two or more completely different solid objects. Results also showed a uniformly higher conductivity and lower absorption in the millimeter layer of the comet.

These research findings provide insight into how comets and other celestial bodies form and develop over time. Research on the thermal and physical properties of comets will also assist in the development of new technologies to protect the Earth from future comet impacts.

Just Keep Swimming: A Study of if *Artemia salina*'s Activity Can Measure Water Toxicity

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In Okinawa, Japan, the American Military Air Stations will use JET-X 2.75, to extinguish fires on the airstrip. The runoff of this chemical, Perfluorinated Compounds (PFCs), has been found in concentrations exceeding the United States Environmental Protection Agency (USEPA)'s advisory level of toxicity for safe drinking water. This lethal chemical is known to cause cancer, neurological, and reproductive disorders. A common way to detect the presence of PFC in water is chromatography, which is very expensive. However, *Artemia salina* (*A. salina*), small invertebrates which are used in lethality bioassays to measure cytotoxicity, could be a less expensive substitution. Gasoline and Scotchgard were over the counter chemicals used to simulate PFCs. *A. salina* were grown to the average size of 10 mm and then exposed to different concentrations of Scotchgard and gasoline. The hypothesis was that the difference in swimming speeds of *A. salina* exposed to safe drinking water versus highly toxic water containing gasoline or Scotchgard are statistically significant. There was a statistically significant difference in the swimming speeds of *A. salina* when exposed to gasoline. However, there was no statistical significance found for Scotchgard. The PFC found in Scotchgard is less than 3% which could have impacted the outcome of this experiment. Therefore, the swimming speed of *A. salina* may be an effective way to measure high toxicity in water however more testing is needed to find the range of toxicity measurable by *A. salina*.

Applying a Novel Hot-Casting Technique to Increase Perovskite Solar Cell Grain Size, Stability, & Efficiency in Photovoltaic Application

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Solar cells mitigate the severe effects of climate change by directly converting light into electricity. In particular, perovskite solar cells (PSCs) have recently demonstrated fast-rising efficiency. However, the main limitation of PSCs is the issue of instability. The instability arises from formation of small-sized grains with a large density of grain boundaries (GB) and defects. These defects largely result from the conventional post-annealing method used in perovskite layer preparation.

To promote stability and efficiency, I utilized a new technique called hot-casting in which the perovskite precursor solution and substrate are preheated before spin-casting. Annealing and spin-casting at the same time provides an ideal environment for crystal grain growth.

In scanning electron microscope images, hot-casted PSCs produced an average grain size of 11.40 μm, nearly 60x greater in size than the average grain size of 194 nm obtained conventionally. Atomic force microscopy images showed that hot-casted perovskite demonstrated such vigorous crystal growth that neighboring grains collided at the edges, forming a uniform, fully covered, and highly crystalline film; in contrast, conventional perovskite produced a fine-grained film with a large density of GB. X-ray diffraction (XRD) confirmed that hot-casting didn't lead to any lead iodide impurities and ultimately enhanced the crystallinity. Most notably, PSC performance tests demonstrated an efficiency increase of ≈38% when using hot-casting, from 12.2% prepared conventionally to 16.8% prepared via hot-casting. Thus, hot-casting has demonstrated to be an effective method to increase PSC grain size, stability, and efficiency for wide-scale commercial photovoltaic application.

Identifying Key Pathways/Mechanisms for the Generation of Pancreatic Beta Cells by Trans-differentiation of Acinar Cells

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Insulin is produced in the β cells of the pancreas. Individuals with diabetes either lack insulin (T1D) or have a reduced insulin secretion or action (T2D). Therefore, preservation of β cell mass is crucial for treatment. Pancreatic β cell mass is maintained by several mechanisms, which include self-replication, trans-differentiation from stem cells, and trans-differentiation from non-β cells, for example, pancreatic acinar cells. Since acinar cells are by-products of islet transplantation, their utilization will be an interesting approach to supplement the current limited availability of islet cells. Trans-differentiation, however, requires extensive knowledge about the key regulators that control β cell development/growth, and maintain β cell function. Furthermore, to improve the overall efficiency of the generation of β cells from acinar cells, it is imperative to understand the underlying mechanism for such trans-differentiation. Here, we investigated transcription factors critical for β cell generation, and determined the combination of transcription factors that resulted in a more efficient generation of β cells from acinar cells. Results show that when compared to basal, Rbpjl and Ptf1a knockdown in 266-6 mouse acinar cells

increased the overall expression of essential β cell genes. Additional overexpression of Ngn3, Mafb, and Nkx6.1 further increased the expression of essential β cell genes including insulin. This is the first study, to our knowledge, to show that inhibiting Rbpjl and Ptf1a and therefore disrupting acinar cell characteristics may aid in the conversion of acinar cells to pancreatic β cells.

*This abstract has additional contributing author(s)

Discovering the Unclassified Suicide Cases among Undetermined Drug Overdose Deaths Using Machine Learning Techniques

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Objective: The Centers for Disease Control and Prevention (CDC) monitor accidental and intentional deaths to answer questions that are critical for the development of effective prevention and resource allocation. CDC's National Violent Death Reporting System (NVDRS) is a major innovation in surveillance linking individual-level data from multiple sources. However, suicide underreporting is common, particularly from drug-overdose deaths. This study sought to assess machine learning (ML) techniques in quantifying drug-overdose suicide underreporting rates.

Methods: Clinical, sociodemographic, toxicological, and proximal stressor data on overdose decedents (n=2,665) were extracted from Utah's NVDRS from 2012-2015. The existing well-determined cases were used to train and test ML models. We assessed and compared multiple ML methods including: Logistic Regression, Random Forest Classifier, Support Vector Machines, and Artificial Neural Networks. We applied a majority voting methodology to classify undetermined drug overdose deaths.

Results: Overdose suicide rates were estimated to be underreported by 33% across all years, increasing yearly from 29% in 2012 to 37% in 2015. The overall test accuracies for all models ranged from 92.3-94.6%.

Conclusions: This research identifies a cost-effective, replicable and expandable ML-based methodology to estimate the true rates of suicide which may be partially masked during the opioid epidemic.

Novel Measures of Terminal Ductal Lobular Unit Involution for Automated Deep-Learning Assessment of Breast Cancer Risk: A Large-Scale Epidemiological Study

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Mentor: Dr. Jan Heng
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Terminal ductal lobular units (TDLUs) are milk-producing glands in the breast. TDLUs shrink (involute) with physiological aging. Reduced TDLU involution is associated with increased breast cancer risk. Traditionally, TDLU involution is assessed manually, but this is both labor-intensive and highly subjective. We established and validated a deep-learning computational method to quantify TDLU involution.

We examined data from whole slide images of benign breast disease biopsies from a Nurses' Health Study (NHS) and NHS II nested case-control dataset (283 cases, 944 controls). We applied our computational method to obtain six TDLU involution measures: TDLU count per unit area, median acini count per TDLU, median TDLU span, median TDLU area, percentage of non-adipose tissue area inside TDLUs, and median acini density. Measures were placed into quartiles according to the control population. TDLU area percentage was significantly associated with breast cancer risk in Quartile 2 compared to Quartile 1. Median acini density was significantly associated with breast cancer risk in Quartile 2 and Quartile 4. No significant association was observed in other measures.

This study paves the road to using our deep-learning TDLU involution method to automate breast cancer risk assessment in other large epidemiological cohorts, a step towards the inclusion of automated TDLU involution measures in clinical breast cancer risk models for the management of high-risk patients.

An Integrated Microfluidic Device for Blood Plasma Separation and Biomarker Detection

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Arcadia CA

Mentor: Suraiya Rasheed
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Human blood plasma contains biomarkers associated with many diseases. Separation of plasma from blood cells is crucial for many disease diagnostics. The current centrifugation separation technology suffers from its bulky design and inability to be integrated with downstream detection. A microfluidic device for blood plasma separation, antigen/antibody binding, biomarker capture, and fluorescence detection was successfully developed. The device uses the principle of bubble-induced acoustic microstreaming to capture and separate the blood cells from the blood sample, resulting in a pure plasma solution. Bubble-induced microstreaming results from an acoustic field on oscillating air bubbles causing the viscous dissipation of the surrounding liquid in the microchannel. This device successfully demonstrated plasma separation, with a 31.8% yield and 99.9% plasma purity, comparable to a traditional centrifuge. The blood was spiked with fluorescent P24 antibody, which was then mixed with 7-µm diameter beads conjugated with P24 antigen in an micromixing chamber. The bound proteins were then captured by acoustic microstreaming and detected using a fluorescence microscope. The fluorescent detection of HIV1 P24 antibody from a whole blood control demonstrated a detection limit of 17 pg/µL. This device shows a potential of immunoassay-based disease diagnostics with high sensitivity and quantification.

Comparing Fungus and Bacteria to Improve Crop Production and Soil Fertility: Analyzing the Effects of Azospirillum bacteria and Mycorrhizal fungi for *Zea mays:* Phase IIII

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I tested how fungi and bacteria would affect *Zea mays* (corn). I also compared soil and tissue samples throughout growth to measure environmental impact on plant and soil conditions. Discovering methods to increase production is a critical task of the agriculture industry moving into the future. By producing a higher yielding crop, growers can feed the world's growing population. However, environmentally safe practices must be used to meet these production needs. A better understanding of the results of these biologicals can help reduce the dependency of fertilizers that run off into rivers and streams, harming the environment.

Previously I grew corn indoors, then moved outdoors researching the effects of macronutrients and fungi on

growth, health, and yield. This year I was striving to discover a natural solution to raise yield with biologicals while monitoring similar components.

I concluded the *Mycorrhizae and Azospirillum* in-furrow application combination created the healthiest plants, soil fertility, and highest yielding crop. These plants were able to utilize the most nutrients in the soil, allowing for less waste and decreased probability of soil leaching, detrimental to the environment. This was due to the increased root mass which allowed better utilization of water and nutrients in the soil.

Faster Region-Based Convolutional Neural Networks for Tumor Localization in Breast Thermograms: A Novel Approach

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Mentor: Dr. Murray Loew
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One in eight women in the United States will be diagnosed with breast cancer in her lifetime. Early diagnosis of breast cancer is key to effective treatment and an increased survival rate. Mammography, the current gold standard of diagnosis, exhibits a low sensitivity in younger women and women with dense breast tissue and has a high false positive rate. Alternate forms of screening include breast thermography, which does not require compression of the breast and is equally accurate regardless of age or tissue density. However, thermography has a much higher false positive rate and a much lower true positive rate than mammography. Computer Aided Diagnosis (CAD) systems can help reduce the false positive rate and increase the sensitivity of thermography while retaining its benefits over mammography. To date, there have been no CAD systems developed to identify tumors in breast thermograms. In this study, we aim to develop a CAD system to detect tumors in thermograms with a comparable sensitivity and specificity to that of radiologists. We develop a Faster Region-Based Convolutional Neural Network with a sensitivity of 0.906, a false positive rate of 0.232, and an AUC of 0.89. This system not only outperforms radiologists, but also is more sensitive than other algorithms designed to detect tumors in mammograms, ultrasound, or other modalities. This paper demonstrates that in conjunction with this CAD model, breast thermography can be used as a reliable method of screening and is a step forward in the field of computer aided diagnostics.

String Theory: A Tale of the Violin

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Sponsor: Mrs. Ahearn ER

I have enjoyed playing the violin for 8 years. I've observed that many violinists prefer strings made from different materials. I have noticed that when I play, a gold E string sounds very different from a tin E string. I wanted to find out what casues this difference. For my investigation, I compared the tensions, lengths, spectrum analyzer images, and frequencies of the two types of strings. I concluded that none of these factors were the cause of the sound variation, so I investigated further. I then identified and measured the timbre of the two strings using a frequency analyze program. I was able to visually see that the difference in sound is caused by how the harmonics of each string vibrate. Some harmonics are more pronounced on the tin E string, and others on the gold E string. Finally, I wished to discover what characters of the string caused the harmonics to vibrate the way they do. I did this by

testing a platinum E string (which has similar characteristics and plating density to a gold E string) and another brand's tin E string to confirm if the density of the plating material is what causes specific harmonics to be heard over others. Though I was excited to discover that different harmonics were more prominent in different string materials, I was unable to confirm whether the plating density causes the difference.

Magnetic Nanoparticle (MNP) Assisted Mitochondrial Respirometry

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Mentors: Dr. Proshlyakov
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Mitochondria are the cornerstone of biological energy transduction and their dysfunction is linked to many diseases such as diabetes, cancer, Parkinson's and others. Scarce biological samples are not amenable to current methodologies for studies on mitochondrial function. Furthermore, existing techniques require specialized sample preparation calling into question their physiological relevance. We are developing a novel platform to study mitochondrial metabolisms by simultaneously measuring oxygen consumption and electrochemical currents. This approach requires that mitochondria are located in close proximity to the sensor as they are subjected to various reaction conditions, which cannot be achieved in classical assays. The goal for this project is to determine the effects of the magnetic nanoparticle (MNP)-mitochondria interaction on mitochondrial function and to explore strategies for their improvement. This project will involve isolation of mitochondria from ARPE-19 cells, characterization of mitochondrial fitness with and without bound MNP, and the citrate synthase assay. We observed that our microfluidic respirometer was able to measure changes in oxygen concentration and reproduce respiration rates data using a single sample of mitochondria. In addition, the project attempts to establish an ideal ratio between MNPs and mitochondria to create optimized protocols for further experimentation on mitochondria samples. We hope to implement our device to studying mitochondria from diseased tissue to ideally understand more about certain pathologies and create treatments.

Highly Concentrated Alcohol-based Solutions as Novel Electrolytes for Safe Li-ion Batteries

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Mentor: Kang Xu, Ph.D.
ARL Fellow
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Highly concentrated electrolytes have gained attention for their unusual behaviors in improving ion transport, safety, and electrochemical stability. In this work, a series of super concentrated alcohol-based solutions—

isopropanol (IPA), ethanol, and methanol—were evaluated for the first time using lithium bis(trifluoromethane sulfonyl)imide (LiN(SO2CF3)2, LiTFSI) as the salt.

Despite the flammability of each individual solvent, at high concentrations, none of the solutions are flammable due to intensified ion-solvent interaction. ^{1}H NMR and FTIR data reveal the desired suppression of the active proton on the -OH group of each of the alcohols, suggesting Li^{+} is the preferred ion for transport. Ionic conductivity data confirms this claim. Most importantly, the electrochemical stability window of these electrolytes is significantly expanded from ~1.6 V of diluted electrolytes to ~2.7 V, raising the possibility of supporting meaningful battery chemistries at high rates and non-flammability. The "methanol-in-salt" electrolyte (MiSE), 18 m LiTFSI in methanol, outperformed both IPA and ethanol electrolytes in conductivity and LiTFSI solubility, suggesting a new frontier for practical material design of safe liquid electrolytes. The results presented provide an interesting system for a fundamental understanding of how solvent molecules and ions interact in protic solvents in general.

A Novel Approach to Determining Cost-Effective Federal Spending On Urban Homelessness

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Background: The federal government spends $5 billion annually on homelessness. Prior approaches to studying effectiveness of programs have relied on analyzing data from a single city, region, or funding source. Because of a lack of data, a national approach hasn't previously been attempted. In 2007, Housing & Urban Development (HUD) started collecting Point-in-Time (PIT) homelessness counts through continuum of care (CoC) organizations. As such, there is now a decade of publically available accurate data.

Hypothesis: When controlling for total spending, of the four categories of HUD spending, investment in permanent housing will yield the greatest decrease in homelessness numbers in urban settings.

Methodology: A merged database was created from documents obtained from HUD for individual CoCs (2007-2017). Merging this database with other publically available data allowed per capita normalization. Difference-in-difference (DID) statistical analysis was used to compare a treatment group (effect of HUD spending on homelessness) and a control group (baseline change in homelessness independent of HUD spending).

Results:

- A regression of total homelessness counts on total spending showed where the homeless problem is bigger, more money is spent.
- DID analysis showed that all categories of spending, across all grouping of homelessness, are statistically significant ($p<0.01$), suggesting a collinearity problem.
- Multivariable regression was used to address collinearity, and showed some types of spending caused increases in homelessness, suggesting potential data heterogeneity.
- CoCs were cohorted into 'large' and 'small' based on size.

Key Finding: Spending on 'supportive services' has the biggest impact on decreasing homelessness counts for 'large' urban CoCs.

The Engineering of a Biomimetic Airfoil to Reduce Cavitation and Reynold's number in Micro Aerial Vehicles (MAVs) for Commercial and Military Applications

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Teacher: Christopher Reeves

Aerial technologies such as micro aerial vehicles and drones have drawn more and more attention due to their ability to efficiently perform aerial feets typically impossible for humans. Some of the limitless applications of micro aerial vehicles include revolutionary research, security, and defense for both military and commercial operations. The purpose of this study was to identify and engineer the most effective biomimetic design to increase lift, improve the lift to drag ratio, and Reynolds number for micro drones. By utilizing a water tunnel, six different airfoils were tested based on designs currently used in aerial technologies and inspired by organisms with evolutionary designs such as the humpback whale, American cicada, and the dragonfly. The resulting airfoil was engineered using three-dimensional software to improve the aerodynamic qualities of micro aerial vehicles or micro drones.

Cellular Mechanisms for TIM Protein-Assisted Viral Adhesion and Entry

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Mentor: Professor Anand Jagota
Lehigh University

Virus infections pose significant global health, economic and social challenges, especially with the emergence of new resistant viral strains like Ebola and Corona. Mechanistic understanding and characterization of how viruses manipulate our cells during the initial attachment in the cellular adhesion process is critical to slow down the infection and develop effective anti-viral therapies for treatments. Introduction of small molecules or functionalized nanoparticles as bioactive agents to neutralize virus ligand domains or adhesion receptors before the viral entry has created an opportunity to customize and enhance the therapeutic efficacy of anti-viral treatments.

This research focuses on developing a meso-scale coarse-grained mechanistic model and conducting three-dimensional dynamic simulations to characterize the interactions of the virus as it approaches the host cells. T-cell Immunoglobulin-Mucin (TIM) family of protein receptors play a vital role in cellular adhesion and viral entry by binding with phosphatidylserine (PS) domains on the virus surface. Reducing receptor density or strength of interactions with virions can be effective in slowing down the attachment process. Simulations show that increase in temperature makes adhesion harder and eventually leads to complete detachment of virions. Inducing a bit of tension in the membrane can compensate for thermal fluctuations, however, further increase in osmotic tension will impede the viral attachment. Spherical virions take longer to attach compared to the cylindrical virions, confirming the importance of size and shape effects. This was leveraged in demonstrating the potential of

functionalized nanoparticles as sizeselective inhibitors for reducing risk of infection against a specific family of viruses.

Cooperative Relaxation in Supercooled Liquids: Kadanoff's Block Construction and Wilson's Renormalization Group Transformation

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Dr. Udayan Mohanty
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The relaxation time of supercooled liquids diverges as the temperature approaches the Kauzmann temperature. The Adam-Gibbs model of relaxation in supercooled liquids relates the relaxation time to the configurational entropy by introducing the idea of cooperatively rearranging regions. We developed the renormalization group transformation by decreasing degrees of freedom and increasing scale length of the cooperatively rearranging regions. The fixed point of the transformation is determined and the Adam-Gibbs relationship between size of rearranging regions and entropy emerges, explaining the non-analytic behavior of relaxation time at the Kauzmann temperature. The renormalization group transformations provide new insights on the universality of Adam-Gibbs' relationship of different liquids as they all start from the ridgeline of the renormalization group manifold and converge to the same fixed point. Finally, we predict the configurational fraction for certain polymer liquids. This work provides an unexpected route explaining how kinetics and thermodynamic properties are related to the molecular motions of these glass-forming liquids, as well as fueling developments in real life applications.

Dynamic of Phobia in Neural Circuitry: Possibilities of Behavior Extinction

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Academia María Reina
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Mentor: Rubén A. García Reyes
Scientific Caribbean Foundation

The anxiety disorder known as a phobia mostly develops in the amygdala due to the pathological changes in the excitability threshold in fear circuits. The amygdala displays an increased activity in response to a threat stimulus. This investigation aimed to decrease the degree of a situational or specific phobia by creating a new memory through electric convulsive therapy (ECT) and stimulating sounds (during a subconscious level), using the program Simbrain. Even though, scientists do not fully understand why or how electric convulsive therapy works, the treatment seems to reverse the symptoms of several psychiatric disorders. A small amount of electrical current was passed through the brain during a partly unconscious sleeping-stage known as REM (rapid-eye movement) when the amygdala, the part of the brain responsible for memory consolidation and emotions of fear, was highly active. This current caused a seizure which provoked chemical changes in the brain. Thus, creating a new memory which consists on the confrontation of the phobia where a secure outcome is presented. The memory was created through stimulating/triggering sounds related to the situational phobia. For example, in regard to aerophobia (fear of flying), sounds such as the voice of a flight attendant, the buckling of a seat belt and an airplane taking off, were incorporated as increased decibels in Simbrain. The electric shocks were conducted during REM because this sleep-stage is considered important for memory consolidation, and during it, the part of the brain responsible for the feeling of pain is notably inactive. Consequently, the electric shocks and sounds did not create a hurtful memory. In addition, sections of the brain that are important in memory – the hippocampus, neocortex and amygdala –are

active during sleep. A dreamer's brain becomes highly active while the body's muscles are paralyzed. The electric shocks along with the stimulating sounds were successful in unconsciously creating a new memory related to the phobia without provoking any kind of pain or discomfort. Although phobias are often disregarded, they can result in serious social withdrawal and depression. If we are successful in creating a therapy that does not involve direct confrontation, patients that suffer from phobias will be more open to receiving treatment thus bettering their quality of life.

A Novel Method of Monitoring the Health o f our Global Fresh Water Supply using DNA Barcoding of Chironomidae (Diptera)

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Mentors:
Dr. Cristina Fernandez

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The Watershed Institute

It is forecast that 66% of our population will experience water scarcity within a decade, leaving us more dependent on surface water for drinking. This requires more filtration infrastructure, and monitoring of surface water sources. Current methods rely on expensive and technically challenging manual identification of biological samples. Macroinvertebrates spend their larval lives within a small a rea of water, showing cumulative effects of habitat alteration and pollutants that chemical testing and field sensors do not. Molecular methods enhance biomonitoring programs. This project explores deoxyribonucleic acid (DNA) barcoding, to measure waterway health with larval Chironomidae (order Diptera), the most widespread macroinvertebrate family. Their complex taxonomy makes manual morphological identification difficult. A statistical sampling plan was designed that represents variation in geological, ecological, and land use factors. Four methods of isolation and amplification were compared. Statistical analysis shows DNA Barcoding of Chironomidae results in more accurate and precise waterway health data, adding significant value for monitoring scarce water resources. The learnings from these data are being applied building microbiology capability a t a nonprofit scientific water study institute.

The Comparative Analysis of the Intraspecies and Interspecies Relationships of Lemur catta
Research Category: Environmental Science

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Teacher: Arleen Lewis

Mentor: Holly Hummel
Duke Lemur Center

Lemurs exhibit unique behavioral characteristics, some of which are uncommon to other species in nature; however, the display of such attributes offers more insight into the analysis of species relationships and patterns than ever imagined. Thus, closely examining a plethora of contrasting behavior types is essential to characterize the roles that social structures and other behaviors provide for the reasoning behind why they may arise within a

lemur group. No research has been completed that has drawn distinct comparisons among the different behaviors that Lemur catta (*L. catta)* may engage in with and without the presence of an unlike species of lemur due to the experiment's complex nature. Therefore, the research conducted stemmed from the question, "Does the fact that a captive lemur is held in an environment with other lemurs affect its behavior?"

Scan sampling and focal sampling were both utilized to track *L. catta* relationships and behavior. Over three days, the frequency of a predetermined set of behaviors (ethogram) was observed during thirty-second-time intervals. The *Duke Lemur Center (DLC)*, where this study took place, is the only site currently supporting the stabilization, conservation, and examination of lemurs. The Natural Habitat Enclosures (NHE) closely mimicked the lemurs' original environment. Two NHEs were observed, NHE2 and NHE4. Studying interactions in two NHE's generalized the results to larger populations. The hypothesis that more affiliative interactions would occur in an intraspecies group of *L. catta* was proved by data from two enclosures. This study and supporting data provide insight into what these behaviors mean while revolutionizing the path for fellow researchers and satisfying the conclusion of the behavioral structures that exist.

How Does Ambient Particulate Matter Induce Lung Cancer?

miR-21 is Involved in Malignant Transformation of Human Bronchial Epithelial Cells by Particulate Matter Exposure

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Supervising Scientist
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Several epidemiological studies have shown that long-term exposure to ambient particulate matter (PM) is an important and independent environmental risk factor for lung cancer. However, the mechanisms are still unclear. The hypothesis of this study is that PM may cause DNA damage in human lung epithelial cells through PM-induced oxidative stress, which may further induce DNA damage response. Long-term exposure to PM may cause DNA repair deficiency and microRNA-21 (miR-21, a cancer-promoting onco-miR) upregulation, resulting in increased genomic instability and cell transformation. To test this hypothesis, urban particulate matter SRM 1648a (U-PM) was used to treat normal human bronchial epithelial cells BEAS-2B. The results showed that exposure of BEAS-2B cells to non-toxic doses of U-PM caused generation of reactive oxygen species (ROS) and increased phosphorylation of histone H2AX (H2AX), a sensitive marker for DNA double-strand breaks (DSBs). Long-term exposure to UPM caused upregulation of miR-21, downregulation of PDCD4 (a tumor suppressor gene), and increased level of anchorage-independent growth of lung epithelial cells, indicating the phenotypic conversion of lung epithelial cells from normal to malignant characteristics. Oxidative stress and the miR-21/PDCD4 pathway may be involved in this cell malignant transformation process.

A Search for Exoplanets in High Solar Metallicity Open Clusters Using a Large-Scale Photometric Algorithm

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Teacher: Mrs. Kris Clements
Mentor: Dr. Saeed Salimpour

Open clusters can contain about 100 to 1,000 stars, with the stars being relatively young. These conditions make open clusters suitable for exoplanet formation, for new stars harbor a lot of dust and gas in their surrounding: two main factors in the process of new planet formation. However, the stars' close proximity to each other creates a harsh environment for exoplanet formation, which is why scientists have not widely searched for exoplanets in open clusters. The purpose of this project was to observe whether exoplanets can form in open clusters with high solar metallicity, to further the understanding of planetary formation and evolution. For my research I operated the 0.4m optical telescopes affiliated with the las cumbres global telescope network (LCO). With these telescopes I took observations of open clusters NGC 6791, NGC 2112, and NGC 6253. A code was written which created 1,071 light curves to be analyzed for transits. As of now, five potential exoplanet candidates have been identified. Those exoplanets candidates are in the cluster of NGC 2112. 88 uncatalogued stars were also identified. My observations and analysis have shown that exoplanets may be cosmic extremophiles that are able to form and remain around stars in open clusters. Because exoplanet candidates were only found in the youngest cluster of NGC 2112, it suggests that planetary ejection may occur later in their lifetime, furthering the scientific understanding of planetary formation in crowded environments. Further observations with a larger telescope will be used to confirm these exoplanet candidates.

Ivermectin Induces Apoptosis, Cell Cycle Arrest, and Senescence in C4-2 Prostate Cancer Cells.

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Ivermectin, awarded the Nobel Prize for Physiology or Medicine in 2015, was originally used as an anthelmintic. Ivermectin was invented by William Campbell and Satoshi Omura to treat parasites, mainly onchocerciasis. Ivermectin has been FDA approved for use in humans and has no side effects on human safety. Due to this, Ivermectin has been researched in multiple cancer cell lines and was found to have anticancer activity in various types of cancer. This project focuses on the effect of Ivermectin on the C4-2 prostate cancer cell line, which has not been researched with Ivermectin. The C4-2 prostate cancer cell line is a human castration resistant cell line derived of the LNCaP cell line. Multiple experimental procedures were used to test the effect of Ivermectin on the C4-2 cell line. For all experiments C4-2 cells were treated with a DMSO control and various concentrations of Ivermectin. It was found that Ivermectin induces apoptosis, cell cycle arrest in the G1/G0, and cell senescence. Lastly, ivermectin was found to decrease the FOXA1 protien which is necessary for AR binding to DNA, thus causing decreased AR expression and AR activity which is important in DNA damage repair. Therefore, increased DNA damage was detected in Ivermectin treated cells. The effect of Ivermectin on RPMI myeloma cells and HCT colorectal cancer cell lines was also tested. It was found that Ivermectin can decrease the cell density of RPMI myeloma cells without causing cell death, but no clinically relevant effect was found in HCT colorectal cancer cells.

Dollar Store Forensics

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Teacher: Mrs. Hamrick
Liberty High School

To begin with, forensic ink fingerprinting when used in law and criminal cases is very expensive. We are working on finding a cheaper option to use fingerprinting for forensic detectives on the go. Some of our materials could seem cheap, but they could be more effective and easier to use than the traditional methods.

First, an ink fingerprinting kit, according to Stem Supplies, can cost anywhere from $100-600. "[For the] fingerprinting to be admissible in court" (All Criminal Justice School). Although these prices are high we thought that there has to be an easier way to make legible fingerprints that could be used in court cases. So we pose our question to you, "Is there a cheaper way to make fingerprints that are legible enough to use in court?"

Secondly, for this experiment we will use materials such as ketchup, paint, flour, and other household materials. For our control group we will use normal ink on white paper. These materials are cheaper than court issued fingerprinting because their prices range from $1-10 (Walmart.com).

Thirdly it is now time to state our hypothesis. Our hypothesis is, the best material for forensic fingerprinting will be the pencil lead. We believe this because this because the pencil lead is the closest to the ink. It is made to stick to paper and to make outlines of materials like ink.In conclusion, our experiment is an effort to help forensic scientists and make their job easier and cheaper. This experiment will be contained and done precisely.

*This abstract has additional contributing author(s)

Developing EDTA-Polymerized Cyclodextrin as a Drug-Delivering Polymer For Use in a Coronary Drug-Eluting Stent Coating

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Drug-eluting stents (DES) release anti-proliferative drugs to prevent in-stent restenosis. However, current DES do not have sufficient periods of drug release to treat long-term restenosis. Cyclodextrin polymers (pCD) can slow drug release due to unique affinity for small hydrophobic drugs. Ethylenediaminetetraacetic acid (EDTA)-crosslinked pCD, which can chelate to metal stent surfaces, were tested as drug delivery polymers for DES coatings. This study looks at the attachment of these polymers to stent surfaces and compares the drug release patterns of various EDTA-crosslinked pCD particles to verify affinity-based release. It was expected that CD

particles with higher degrees of crosslinking would slow release the most due to tighter concentration of cyclodextrins. Chelation tests with $CoCl_2$, FTIR, SEM, and EDS were used to characterize particles and coatings. Drug release studies were carried out using drugloaded particles, and UV-Vis spectroscopy was used to quantify released drug. Sirolimus was used as a model drug. Color change and FTIR data confirmed chelating activity of EDTA-pCD. SEM indicated a texture difference between coated vs. uncoated stents, and EDS showed an increase of 4% in carbon composition, which comes from the coating. Cumulative drug release within 24 hours from highly-crosslinked EDTA-pCD was 82.4% lower than that of control nonaffinity EDTA-dextran particles, a reduction attributed to affinity. Compared to highlycrosslinked EDTA-pCD, however, less-crosslinked EDTA-pCD and control EDTA-dextran exhibited longer drug release. These preliminary results indicate that EDTA-pCD particles can chelate to metal stent surfaces, and that less-crosslinked EDTA-pCD particles and EDTAdextran particles have promising levels of extended drug release.

Creation of Novel Molecular Biosensors

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Molecular biosensors are essential in biomedical research as well as monitoring disease progression, environmental changes, drug discovery, and food control. Some are synthetically engineered and others utilize organisms' existing biochemical pathways, such as the amino acid Tryptophan's catabolic pathway. In the last case the TnaC molecular sensor detects the amino acid Tryptophan. If the TnaC sequence is changed to produce multiple variants, then these multiple variants would detect other molecules than L-tryptophan. Through the use of mutagenesis of this tnaC gene and selection, a total of 6 mutants were tested for these characteristics by using the TetR gene for selection and tryptophan to test for induction. The numbers of the mutants correspond to the variant number assigned to them. They were tested against the wild type of the the tnaC gene and their corresponding stop codon variants. tnaC2 and tnaC5 were indicative of detecting other molecules, but need additional testing. Additionally, it was found that tnaC4 is in fact a new molecular biosensor.

Multi-Analyte Precision Nanoparticle Sensor for Wound Management utilizing Lindenmayer Systems Research Summary

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Every year on average there are about 165 million injuries in the United States, both acute and chronic, which require wound treatment. Chronic wounds follow delayed healing patterns often due to preexisting medical conditions (Singer & Clark, 1999). Worldwide in excess of USD $50 Billion are spent on the treatment of chronic wounds alone (Fife & Carter, 2012). The number of patients with chronic wounds in the United States is greater than the number of patients with leukemia, colon, lung and breast cancer combined (AAWC, 2014). There is no cost-effective, precision, multi-analyte, mass manufacturable wound dressing which can monitor the conditions continually as well as keep the foreign pathogens out (Scognamiglio, Antonacci, Lambreva, Litescu, & Rea, 2015). Changing the dressing bed too early, or too late, can lead to the worsening of the wound and more frequent

dressing changes. Also, infection cannot be detected without opening the wound and doing a direct physical examination of the affected area (McColl, MacDougall, Watret, & Connolly, 2009).

This research has created a sensor where physicians will able to track the status of the wound through one or many variables including temperature, pH, moisture and oxygen level; quorum sensing regulation; and synthesized molecules such as pyocyanin. Continuously sensed, the detailed status is then wirelessly viewed over a smart-phone, and is connected to the Internet for remote monitoring and intelligent data analytics. Which subsequently allows for autoregulation of the wound condition in real-time. These sensors are created using inkjet printing, and are miniature, inexpensive, accurate, reliable and mass manufacturable. The approach uses biopolymer chitosan (Dai, Tanaka, Huang, & Hamblin, 2011; Muzzarelli, El Mehtedi, & MattioliBelmonte, 2014) in conjunction with single- and multi-layer carbon nanoparticles to effectively obtain all the required features including biocompatibility. The systematic ink formulations is further enhanced by making it capable of carrying quantum-dot nanocrystal to target complex analytes.

These sensors are optimized over four generations. A fully functional prototype is built to demonstrate the mobile and cloud connectivity. Precision enhancement for patterning and controllability is obtained by line fractals created using Lindenmayer systems (*L-Systems*)(Sagan, 1994). The data obtained through characterization in a controlled environment show successful meeting of all the objectives.

Identifying Tablets using Neural Networks

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According to the FDA, approximately 1.3 million people are injured due to medicine errors annually in the United States. A large percentage of these people are the elderly and people with multiple medical conditions. So, the purpose of my project was to utilize data analytics and machine learning methods to provide a simple way to identify tablets, thus reducing medicine errors.

First, I took pictures of different tablets and applied various filters to them in WEKA. Then, I ran the Decision Trees algorithm on features generated by each filter and selected the Auto Color Correlogram filter because its features resulted in the highest classification accuracy of 88.75%. The accuracy of this filter with Neural Networks (NN) was 97.5%. With this evidence of NN being a good classifier, I ran the algorithm available at Teachable Machine on my dataset to generate an NN model using TensorFlow Lite. I imported this model and embedded it into an Android app, which I named 'Tablet Identifier'. I downloaded this app onto a virtual phone, and connected a webcam to my desktop in order to test the app. It correctly identified tablets with 99% accuracy. When published, more medications can be added for numerous medical conditions. Thus, anyone with a mobile phone can download the app, and identify any tablet when their phone's camera is pointed towards it.

As a result, people will be able to use this user friendly app at home before taking their medication, which will lower the number of medicine errors.

Coral Grief: Machine Learning on Crowd-sourced Data to Highlight an Ecological Crisis

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Triggered largely by the warming and pollution of oceans, corals are experiencing bleaching and a variety of diseases caused by the spread of bacteria, fungi, and viruses. Identification of bleached and/or diseased corals enables implementation of measures to halt or retard the same. Benthic cover analysis as a standalone measure of reef health is insufficient for identification of coral bleaching and/or disease. Proposed herein is a solution that couples machine learning with crowd-sourced data - images from government archives, citizen science projects, and personal images collected by tourists - to build a model capable of identifying healthy, bleached, and/or diseased coral. The student researcher collected hundreds of images of corals with various health conditions from open sources such as the National Oceanic and Atmospheric Administration's records and the XL Catlin Seaview Survey and annotated these images using the image annotation platform Labelbox in order to highlight the regions of interest: healthy, bleached, black band disease, dark spot disease, white syndrome, or yellow band disease. These annotations were then used to build, train, and validate a Python-based model, adapted from an open source Mask R-CNN (region-based convolutional neural network) algorithm, within an Amazon Web Services EC2 remote computer. Use of the model on a test set of coral images yields over 85% accuracy in distinguishing healthy versus unhealthy coral. This machine learning-based model has the potential to rapidly analyze a large and growing database of images to identify coral bleaching and/or coral disease around the world, thereby enabling effective allocation of resources for preservation of our marine ecosystem.

Co-occurrence of Adolescent Depression and Substance Use Disorder and Access to Services in Pennsylvania

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Teacher:Julie DeLaurentis

Introduction: Recently, there has been an upwards trend among adolescents with depression. Adolescents suffering from Major Depressive Episodes (MDE) tend to use substances at higher rates compared to adolescents without a MDE. The purpose of this study is to explore co-occurring MDEs and Substance Use Disorder (SUDs) for adolescents in Pennsylvania and address the importance of early identification and prevention.

Methods and Results: The National Survey on Drug Use and Health for 2017 and 2018 was used for data analysis. A total of 896,000 PA adolescents were in the study. 10.9% of them had MDE and 10.42% had SUD (13.3% and 4%, respectively, nationwide). Alcohol, Marijuana, and Opioids, respectively, were the three most abused substances. The co-occurrence prevalence was 1% (n=9,000). More adolescents who are suffering from a MDE are using substances compared to adolescents that are not. 22% of PA adolescents suffering from an MDE are using Marijuana compared to 9.15% who do not have an MDE. Approximately 33% of Pennsylvania adolescents with co-occurring MDE and SUD reported receiving mental health treatment. Further studies are needed to determine the reasons for the limited treatment and to find the statistics for adolescents with MDE and SUD in the Philadelphia area.

Conclusion: The prevalence for SUD in Pennsylvania adolescents is over double the nationwide prevalence. Adolescents with MDE can lead to substance abuse. The lack of accessible treatment is especially harming adolescents. More accessible health treatments are needed for adolescents with the co-occurrence of MDE and SUD.

Developing Deep Learning Networks for Dynamic Traffic Light Control

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Mentors: Barbara Stewart
Cary James John
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The average Los Angeles commuter spends upwards of 20 work days per year in traffic. Though the rise of electric vehicles has reduced greenhouse gas emissions, “a green traffic jam is still a traffic jam”. Congestion is caused by a number of theories such as overcrowding, spontaneous generation, interaction with pedestrians, and road work. However, another large factor is inadequate traffic light management. Adaptive traffic light control in which light timings are biased based on the number of cars at each node at an intersection have been tested and shown to improve commute speeds by 10% in a 9x16 block section of midtown NYC. Many of these centralized systems use traditional algorithmic control. Recent studies using deep learning improved simulated wait times up to 25%. In this research, a real intersection was chosen to model in Python with observed traffic data. This simulation models vehicles on a grid as an environment to evolve neural network agents that control traffic light timings, whose goal is to minimize wait times. Neuroevolution was used to produce a neural network which reduced wait times 12% and increased throughput 2% on average as compared to the traditional algorithms. The implementation of this model has the possibility to reduce costs as it is open source and can run on an SBC, which can accept inputs from detectors such as cameras and can control the lights itself. Combining these controllers across a city can allow the software to find solutions to minimize waiting and increase efficiency.

The Effects of Fermented and Cultured Supplements on Dog’s Gut Microbiome

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The dog’s microbiome has emerged as the crucial moderator in the interactions between food and the body. Dogs have different strains of bacteria in their gut, which are directly connected to the dog’s brain via the Vagus nerve and control 80% of the dog’s immune system. The research hypothesis is to test if dietary intervention using fermented cabbage/unpasteurized, cultured kefir supplements would shape the gut microbiota increasing the diversity, richness, and evenness specifically. This study engaged dogs eating the same raw, dehydrated diet over a sixweek period with the addition of fermented and cultured supplements. All dogs’ microbiomes were baseline tested at the beginning and then retested at the end of the study to analyze whether nutrition influenced gut microbiome composition. Results were analyzed using Shannon Wiener Index calculations where patterns showed that (1) the bioavailability, due to the process of fermentation, increased (2) the diversity, depth, and evenness began trends to balance the gut biome landscape of the dog; and (3) there were slight variations in bacterial strains due to dogs’ living locations/regional differences over the six week studying comparing with and without

whole food supplements. These findings suggest a continuous, daily supplement of cultured/fermented supplements can play an important role in the dog's overall gut microbiome health.

A Headset Using Machine Learning to Aid the Visually Impaired in Pedestrian Navigation

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Mentor: Artur Ottlik
Siemens Software Architect

There are almost 39 million individuals who are completely blind, and almost 250 million others with low vision. For such individuals, seemingly simple tasks such as crossing the street, let alone walking to the nearest Starbucks, can be life threatening. Fundamentally, our project is a headset with a camera and accelerometer/gyroscope which allows for the pedestrian to talk to and receive natural voice command from a navigation assistant. The vision processing is built on the 3 most essential pillars of pedestrian navigation: crosswalks, sidewalks, and pedestrian traffic lights with additional safety features added through obstacle detection. Crosswalk detection uses color thresholding and contours to find bounding boxes in between the crosswalk, to then identify where the crosswalk is. generated on a crosswalk. Sidewalk detection utilizes a convolutional neural network to find the location of the sidewalk in an image and ensure the pedestrian is on track. Pedestrian traffic light detection utilizes a Histogram of Oriented Gradients and Support Vector Machine classifier. Lastly, obstacle detection utilizes the YOLO v3 Tiny network pre-trained on the COCO dataset to make predictions about the distances and velocities of obstacles in the frame. Together these different aspects of navigation work in conjunction with Google Maps Navigation and an accelerometer/gyroscope input, to allow for safe and reliable travel. In the end, this system proved effective and allowed me to travel blind foldedly down a 6 minute path with sidewalks, crosswalks, traffic lights, and people.

*This abstract has additional contributing author(s)

The impact of varying electrical stimulation parameters on neuromuscular response

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The World Health Organization estimates that 250,000 to 500,000 people suffer from spinal cord injury (SCI), and that patients with SCI are 2-5 times more likely to die prematurely. High density neurostimulation systems are being developed as a new approach for improving outcomes for SCI patients by restoring organ/muscle function. However, these require knowledge of stimulation parameters and corresponding responses for effective therapeutics. I was interested in developing a method to study how changing stimulation parameters impacts muscular responses, and the optimal range of parameters for maximal response. For this purpose, I built a prototype testbed using the earthworm as a model organism. My testbed consists of a 3-D printed raceway lined with a number of electrodes, which could be switched between stimulating and recording modes, and a digital camera synchronized with the stimulation system. Live, non-anesthetized earthworms were placed on the

raceway; contractile motion of the various segments of the worms, as well as the propagation of action potentials along the length of the worm were recorded for both non-electrically-stimulated and electrically-stimulated earthworms. I applied bipolar sinusoidal stimulation pulses of a range of voltages, pulse durations, and burst rates, at different locations along the length of the worm, and tracked the propagation of action potentials simultaneously at several distinct locations around the stimulation locations. These were then correlated to the contractile motion of various segments of the earthworm, demonstrating the feasibility of building a testbed to evaluate the impact of changing stimulation parameters on neuromuscular response.

Development of Polymer Composites Reinforced with Recycled Carbon Fibers

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Teacher: Mrs.Girtain

Today's industries are increasingly demanding high performance materials as substitutes for conventional materials. Polymer matrix composites(PMCs) combine two or more polymers resulting in unique properties that cannot be achieved with a single material. The purpose of this project was to prepare a Polyetheretherketone(PEEK) and carbon fiber(CF) PMC using recycled carbon fiber(RCF) and comparing the properties to virgin CF-PEEK. In this work, RCF-PEEK and CF-PEEK were prepared using injection molding, and the mechanical, structural, and thermal properties were characterized. Results reveal that RCF-PEEK has a higher flexural modulus but lower impact strength than CF-PEEK at similar concentrations. There is uniform distribution and strong fiber-matrix interaction for both RCF and CF in PEEK. CF-PEEK and RCF-PEEK are similar in their transition temperatures across fiber type and concentration. This comprehensive analysis of RCF-PEEK PMCs is beneficial in order to develop the full potential of PEEK and its composites for future applications in materials science. Overall, RCFs can be used in certain applications with similar effectiveness to virgin CFs. Optimization of carbon fiber recycling will lead to RCF becoming more prevalent and practical for industrial applications.

The Quest to Conquer Thermal Expansion: Non-hydrolytic sol-gel synthesis and characterization of $Al_{2-x}In_xW_3O_{12}$ Negative Thermal Expansion Materials

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Negative thermal expansion (NTE) materials have many potential applications given their unique properties to contract upon heating. Several families of materials show this interesting behavior; one of them is the scandium tungstate or $A_2M_3O_{12}$ family (A = trivalent metal; M = Mo, W). In this project, the substitution of $A_2M_3O_{12}$ compounds at the A-site was explored by creating various compounds in the structure $Al_{2-x}In_xW_3O_{12}$. This is expected to stabilize the NTE structure. Instead of the traditional $Sc_2W_3O_{12}$, the cations Al^{3+} and In^{3+} were substituted for the metal cation. To synthesize these compounds, a non-hydrolytic sol-gel route was used: $AlCl_3$, $InCl_3$, WCl_6, and diisopropyl ether were dissolved in acetonitrile solvent and heated to a powder, sealed in a glass ampoule, and heated for multiple days. After this, the ampoule was cooled and opened, yielding a raw sample. These were then subjected to various heat treatments and analyzed via x-ray diffraction, thermogravimetric analysis, and energy dispersive spectroscopy, to determine if a single crystalline phase with homogeneity of the two cations had formed. At this time, five compositions have been synthesized and tested, yielding promising

results for crystallinity and homogeneity. As this portion of the study focuses on optimization of synthesis conditions for phase-pure samples, it has been observed that longer reaction times and high-temperature heat treatments are essential for proper synthesis because they allow for increased crystallinity and the removal of organics. Once synthesis conditions have been fully optimized, the compounds will be tested for NTE behavior over a wider temperature range.

The effect of an alternative blood meal source from *Glycine max* root nodules on the eggs laid and successful larval birth of *Culex pipiens*

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Teacher: Michelle Spigner
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Mosquito-transmitted diseases have led to a vast increase in attempts to find a sustainable method to reduce the vector's population. The purpose of this experiment was to use leghemoglobin, a heme protein formed in nitrogen-fixing nodules, to reduce mosquito reproduction and offspring. It was hypothesized that leghemoglobin would lead to fewer eggs laid by the mosquitoes and the percentage of larvae that surface from the eggs would be lower since the structure of leghemoglobin contains less protein and iron, two essential nutrients for making eggs.

Leghemoglobin was isolated from *Glycine max* root nodules that were dried in a desiccator and ground to a powder. Both protein powders were dissolved and given in two specific concentrations to ten mosquitoes in an even gender ratio. Eggs were counted after two days, and two additional days were given for the larvae to emerge. The larvae were then counted by displacing them from the water. The leghemoglobin resulted in less eggs and larvae compared to hemoglobin. A two-way ANOVA was run to study the significance of the blood meal and concentration on the number of eggs and percentage of larval emergence. The Bonferroni test conducted for egg production at $\alpha=0.05$ resulted in a p-value of <0.001. The egg production results were deemed significant, whereas, the results for successful larvae ended up being insignificant. It was found that the mosquitoes were able to adjust to the meal, creating a lower quantity of eggs, but still providing enough nutrients for a successful hatch.

Classifying Magic Squares and Their Associated Symmetries Using a Chord Diagram Approach

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Mentor:
Dr. Vassilev
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Magic squares are defined as matrices whose rows, columns, and main diagonals all add to the same number. They have existed and have been a topic of great interest since as early as 190 BCE, appearing in several different cultures. Some of the greatest minds in mathematics dedicated time to their exploration and construction including Euler, Ramanujan, and Fermat. Even with their prevalence throughout the mathematical world, few general theorems have been proven about magic squares and their properties. Through the course of this project, a novel approach to studying the squares was developed that represents the matrix elements as connected points

on a circle with n^2 equally spaced points. Furthermore, this visual representation can be used to classify the squares by the symmetries they produce. Unlike previously used visual aids, this method of classification extends to all orders of magic squares. Using this method of circular graphing, generalized theorems about the reflection and rotational symmetries of magic squares were developed as well. It was also proven using these tools that the maximum number of possible axes of symmetry of a given $n \times n$ magic square is precisely $n/2$. Inconsistencies were found in prior work by other authors on classification of 4 × 4 magic squares using permutation matrices were discovered, and further relations to this theory were developed. Finally, techniques for magic square multiplication using Kronecker Tensor Products were applied to enumeration of magic squares - one of the largest existing problems related to magic squares.

A Novel, Low Cost Treatment for PNS Neurodegenerative Diseases: Ascorbic Acid

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Mentor: Mrs. Donna Leonardi

Neurodegenerative diseases are characterized by nerve impulse conduction anomalies and neuronal degeneration. Demyelination, a degenerative process that erodes away the myelin sheath which protects nerve cells, is often the underlying cause. Myelin production is orchestrated by the Schwann cell which wraps itself around the axon of the neuron and produces the protective myelin. Myelin associated glycoprotein (MAG), a myelin maintenance molecule, and collagen, a component of the Extracellular Matrix (ECM) are critical for healthy myelination. Interestingly, studies have shown that patients with demyelinating diseases have decreased levels of ascorbic acid in their blood serum. There is scant research investigating ascorbic acid's role in the myelination process, along with its mechanism in the peripheral nervous system. Therefore, this research examines the relationship between exogenous ascorbic acid application, collagen synthesis, and the upregulation of MAG in a Schwann - neuronal cell co-culture model. Data suggests that ascorbic acid application increases myelin by 210% ($p<0.001$), MAG by ~121% ($p<0.05$) and collagen by 494% ($p<0.001$) and decreases stress related signaling, compared to the control after a 7-day preventative co-culture model. Furthermore, a regression model was developed to predict the amount of myelin, and by extension, likelihood of developing a neurodegenerative disease based on potential biomarkers which can be measured non-invasively. Through this potential early diagnosis method, preventative treatment can be administered to those at high risk. This research suggests that ascorbic acid may represent a means by which the myelin sheath is maintained, both as a treatment and a prevention in demyelinating diseases.

Local Search Optimization and the Virtual Keyboard Design Problem

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Teacher: Mrs. Stephanie Dumont
Brunswick High School

Two main keyboard layouts are traditionally used for text entry in English -- QWERTY and lesser-known Dvorak. Both were designed around the turn of the twentieth century and were constrained by the mechanics of the typewriter. In this paper, I investigate keyboard design in contexts in which these restraints are eliminated, such as electronic text entry devices. I evaluate the relative efficiencies of traditional layouts with regard to the speed of text entry and propose new keyboard arrangements optimized for typing speed.

The speed of text entry relies on three factors: the frequencies of digraphs, or ordered pairs of keys, in a corpus of texts representative of what is being typed, the keyboard layout itself, and the facility with which the user can strike these pairs of keys consecutively. I collect data on the first and third factors, and use methods of computational mathematical optimization to determine the second. More specifically, I use three local search algorithms including simple hill climbing, steepest descent, and simulated annealing.

The layout produced when optimizing for stylus input and the layout produced when optimizing for touch typing input both achieve considerable gains in speed relative to the QWERTY and the Dvorak designs. Additionally, I investigate the robustness of my results with regards to the keystroke biometrics collected experimentally.

Exploring Position Specific Helmet Technology by Incorporating Biomimicry and Its Effects on the Reduction and Possible Elimination of Chronic Traumatic Encephalopathy (CTE)

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Teacher:
Cathy Boucvalt
John Curtis Christian School

The purpose of this research was to determine the possibility of reducing g-Force and acceleration of frontal impacts in a football player's position specific helmet design in an attempt to reduce the occurrence of concussions and long-term brain damage - Chronic Traumatic Encephalopathy (CTE). Biomimicry, in the form of an Experimental Facemask + Linear Dampers, was utilized to mimic the action of a woodpecker's beak to, potentially, dissipate the energy of impact before being transferred to the head.

Hypothesis: By incorporating biomimicry, in the form of linear dampers, into position specific football helmet designs, acceleration of human brains, during impacts, can be significantly reduced.

Independent Variables:

- Original Facemask (Control)
- Exp. Facemask + 5lb. Linear dampers
- Exp. Facemask + 15lb. Linear dampers

Dependent Variables:

- g-Force----------N/kg
- Acceleration---m/sec

Data was analyzed using a one-way ANOVA and Tukey HSD. Both experimental designs resulted in significant ($p < .01$) reductions in g-Force and acceleration compared to the Control. Also, 15 lb. dampers significantly ($p < .01$) outperformed 5 lb. dampers.

Further testing will be performed using dampers larger than 15 lbs. Also, multidirectional dampers will be used to allow the face mask to articulate while preventing it from being used a lever. Thus, reducing axial rotation when the facemask is impacted from the side.

Since results showed significant ($p < .01$) reductions in g-Force and acceleration for each experimental design, this suggests that the experimental designs have potential to reduce the incidence of concussions and the cumulative effect of repetitive impacts - A leading cause of CTE.

Testing for the Effectiveness of Different Solar Tracker Designs

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Teacher: Mr. Steele
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The purpose of this experiment was to compare the power output capabilities of a prototype single and double axis solar tracker. An artificial light source, used to simulate the sun, was constructed with a rotating wood piece and a solar simulating bulb. The solar tracker was designed and constructed to rotate on one axis or two axes depending on the position of a switch. A photoresistor as a light sensor was placed where the solar panel would be positioned to simulate the solar panel's power output. Eight tests were conducted for each tracker orientation.
The amount of time the tracker adjusted itself and the resistance of the photoresistor were used to determine the total power output for a simulated twelve-hour day, even though the tests lasted only around 10 seconds. A t-test was used to compare the power outputs for the two groups in watt-hours. The data was found to be significant as the t-test returned a p value of 9.959×10^{-9}, significantly less than the alpha value of .05. The double axis tracker provided more power which supported the hypothesis: if I use a double axis tracker, then it would produce more power than a single axis tracker even though it consumes more power to operate itself. These results can be used to engineer more efficient solar farms for harvesting solar power, which could replace traditional fossil fuel methods. This change could slow down or reverse the pollution of the environment that fossil fuels have caused.

Effect of Persulfates on the Prevalence of Bacteria on Removable Retainers

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DuPont Manual High School

Teacher:
Alexis Rich
Dupont Manual High School

The purpose of the project was to determine if persulfates had an impact on the prevalence of bacteria found on removable retainers. Persulfates are a known allergen, and it is important for oral hygiene to know if persulfates have any effect on this prevalence. It was hypothesized that if the presence of persulfates increases, then the prevalence of bacteria will decrease. Three sets of retainers were placed into a solution of artificial saliva. The control set of retainers was not cleaned, the persulfate set was cleaned by Retainer Brite, and the persulfate-free set was cleaned by DentaSOAK. Samples were collected by swabbing each surface of the retainers: the top interior, top exterior, bottom interior, and bottom exterior. These samples were plated. The plates were then placed in an incubator, and after eight days had passed, the plates were taken out and the available data measured. Mold had grown in most of the plates, with an abundance of bacteria growing in the control plates. However, the t-test values were lower than the required values for the specified degrees of freedom, and thus the data was not statistically significant enough to support the research hypothesis. The null hypothesis was accepted, and the research hypothesis was rejected. It was concluded that there would be no statistical impact of having persulfates

as an ingredient of commercial retainer cleansers with the intention to help reduce the number of bacteria found on removable retainers after cleaning.

GC-MS Analysis of Polyester Polyurethane Degradation Products Identifies Degradation and Enzymatic Pathways

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Teacher: Dr. Isabelle Cohen
The Potomac School

Mentor: Jason Howe
Chemist, U.S. Consumer Product Safety Commission

The rapid acceleration of plastic production and the accumulation of debris is a global crisis, as plastic takes over 400 years to degrade. This study examines the biodegradability of polyurethane (PUR), polypropylene (PP), high-density polyethylene (HDPE), polycarbonate (PC), and polyvinyl chloride (PVC) by four endophytic fungi that all digest Impranil DLN (a soluble polyester polyurethane dispersion). The study identifies the byproducts of Impranil DLN digestion by all four fungi via Gas Chromatography–Mass Spectrometry (GC-MS) and proposes potential degradation and enzymatic pathways. Halo assays were utilized to determine the efficacy of fungal digestion. Fungi were placed in liquid cultures containing minimal medium and Impranil DLN to visualize digestion and prepare samples for GC-MS. After 2 weeks, samples were extracted with 1-butanol and derivatized. GC-MS analysis examined the presence or absence of compounds after digestion compared to the control. The study identifies hydrolysis as a means of digestion. These findings highlight forward progress in finding fungi that can biodegrade plastics, but demonstrate significant limitations as many industrial plastics like Impranil DLN do not disclose formulas. These findings could be used to elucidate the formula of Impranil DLN and the previously unidentified enzymes in the four fungi.

The Comparison of the Efficiency of two Ion-Exchange Resins In Filtering Chromium-6 From Water

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Teacher: Ms. Kathleen Tait

Mentors: Dr. Jeffery Field
Jessica Murray

Chromium-6 is a highly carcinogenic metal that is commonly used in industrial processes to make textile dyes, anti-corrosion products, paints, and steel. The accumulation of Chromium-6 waste has increased the risk for numerous digestive and respiratory cancers as well as developmental disorders. This cancer-causing metal is found above health guidelines throughout the United States in utilities that serve a total of 232 million people. In recent years, scientists have discovered that Chromium-6 can be effectively removed through a reverse osmosis process and an ion-exchange process. The purpose of my project was to expand upon this knowledge, and determine whether a

mixed bead resin or a pre-swollen, microgranular cation resin would be more effective in removing Chromium-6 from water. Since Chromium-6 is a positively charged metal, I hypothesized that the cation resin, containing solely negatively charged ions, would be more effective. Throughout my experiment, I ran 5ml of my Chromium-6 stock solution through each resin using column-chromatography tubes. Afterward, I dyed each filtered solution, adjusted their pH and tested their absorbance in a UV-visible spectrophotometer. My results showed that the mixed-bead resin had 100% filtration efficiency, while the cation resin was only capable of filtering approximately 50% of Chromium-6. In the future, I believe that ion-exchange filtration methods using mixed bed resins will be very useful in filtering out harmful compounds such as Chromium-6 from water. This implementation will make tap water safer to drink and potentially lower the risk of digestive cancers as well as reproductive and developmental complications within the American population.

Synthesis of Human Urine into Carbon Dots for Implementation as a Visual Arsenic Assay in Water

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Mentor: Christopher Reeves

Arsenic contamination of drinking water poses an acute threat to human health, which is especially compounded in regions with limited resources. Though it is detectable, conventional tests for arsenic are expensive and time consuming, rendering them useless in underdeveloped regions.

A method for visual representation of arsenic presence ameliorates the issue of delay by providing immediate results, and an inexpensive test would eliminate economic obstacles. Such a combination would enable regions in all stages of development to readily and cost effectively test for arsenic and allow water consumption directly after sampling.

Quantum dots are nanomaterials with fluorescent abilities that make them useful as probes for heavy metals, but they are toxic or harmful to the environment and comparatively expensive. However, the dots can also be synthesised from carbon, creating less economically and environmentally straining nanomaterials. Urea, found in human urine, can be utilized as a base for these carbon dots, offering an easily accessible, nontoxic quantum material and ameliorating health and environmental concerns of excess runoff of unsterilized human urine.

This research synthesized carbon dots from human urine through microwave irradiation and tested fluorescence quenching of these dots in the presence of arsenic. The method created could be easily replicated by anyone with access to a microwave and possibly just a heat source.

Significant results (p-value$<.05$) found in this research support the effective use of microwave-synthesized, sulphur-doped carbon dots as a visual indicator of arsenic presence in water. These findings offer a viable solution to identifying safe drinking sources throughout all levels of global development.

Growth of Bird Vetch (*Vicia cracca*) with Varying Moisture and Competition Levels

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Mentor: Dr. Katie Spellman

Bird Vetch (*Vicia cracca*) is an invasive species in the interior of Alaska. We conducted a greenhouse experiment at UAF, to determine how moisture conditions and competition levels affect vetch growth. We grew bird vetch in 120 pots with vetch seeds in varying conditions, assigned either high or low moisture conditions with one, two, or three plants in each pot. We measured the differences in the number of nodules produced, shoot length and the number of branches below two centimeters. We found that the number of root nodules declined with competition, but not with soil moisture. Branches per plant declined with competition as well. The length of the shoot was not dependent on either moisture or competition. Soil moisture had a larger impact on vetch, these results will be beneficial in determining where vetch will grow in abundance and how it reacts to changing soil temperatures and the competition levels around the invasive species.

The Neuroprotective Effects of Ayurvedic Substances on β-amyloid Peptide Toxicity in Transgenic C. elegans

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Teacher: Mr. Brian Dempsey

Accumulation of β-amyloid, a sticky peptide, has been associated with the induction of Alzheimer's disease and Induced Body Myositis. The most common type of β-amyloid in Alzheimer's is β-amyloid 42, which causes paralysis in *C. elegans* worms. The transgenic *C. elegans* strain CL4176 has been genetically engineered with the addition of the dvls27 transgene to express β-amyloid 42 in its muscle cells, making it ideal to model the toxicity of β-amyloid.

The CL4176 and CL802 (control) strains of *C. elegans* worms were used in this experiment. The substances tested include alcohol, turmeric, and brahmi. Brahmi and turmeric are used in a branch of ancient Indian medicine called Ayurveda and have proven neuroprotective effects. Brahmi is a known choline acetyltransferase agonist, and turmeric is a known acetylcholinesterase antagonist. Alcohol is an NMDA antagonist meaning it indirectly decreases the amount of glutamate. Assays were performed for alcohol to determine an appropriate concentration to test on the worms.

Every substance tested in the experiment decreased the paralyzation of the CL4176 worms, with brahmi having the most profound effect on β-amyloid 42 toxicity. The implications of this project are twofold. First, it proves the effectiveness of ancient Indian Ayurvedic medicine. Secondly, the data indicates that brahmi, turmeric, and alcohol are promising treatments for both Alzheimer's disease and Induced Body Myositis.

Targeted Delivery of Immune Agonists for Antitumoral Response of the Tumor Microenvironment

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Mentor: Dr. Crystal Miller

Tumor-mediated immunosuppression allows tumors to hide from the immune system and avoid recognition. To reverse this suppressive microenvironment, antigen-presenting cells (APCs) and other innate/adaptive immune cells within the tumor can be targeted and activated from their senescent states. Cyclic diguanylate monophosphate (c-di-GMP), a drug that works within the cytosol of immune cells, is used to release inflammatory cytokines (IFN-) to recruit immune cells and initiate anti-tumor responses. However, therapy using freely injected drug is limited because c-di-GMP cannot easily cross cell membranes and is quickly cleared from the body. It is hypothesized that c-di-GMP loaded into a nanoparticle will more effectively deliver drug into the cytosol of immune cells, widespread within the tumor, resulting in more potent therapy. To demonstrate the therapeutic potential, macrophages were exposed to c-di-GMP loaded into nanoparticles in vitro. C-di-GMP nanoparticles boosted the secretion of cytokine IFN- from murine macrophages by 6-fold compared to free drug. To increase the particle specificity for suppressive immune cells, an antibody targeting the novel inhibitory immune-checkpoint protein V-domain Immunoglobulin Suppressor of T cell Activation (VISTA) was conjugated to the surface of a nanoparticle. Ongoing work looks to demonstrate the increased uptake of VISTA-targeting particles by a VISTA expressing cell line in vitro. This work demonstrates a potential new treatment that increases the efficacy of c-di-GMP by targeting and reversing immunosuppressive cell subtypes. Future work includes in vitro and in vivo studies optimizing the delivery of nanoparticles to tumor-associated immune cells and evaluating the therapeutic effects on tumor burden and overall survival.

"I Don't See Color": An Analysis of Racial Diversity within Prime Time Television

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Teacher: Mr. Daniel Coapstick

Mentors: Mrs. Kamisha Roedl
Mr. Kenneth W. Roedl

Racial representation on television has been changing ever since television was invented. This study aims to do three things: 1.) Track the trends television has been setting since the 1960s and showcase what the future of television might look like; 2.) Identify the audience's opinions on the growing diversification within television as well as what racial groups believe about the past, present, and future of diversity on television; 3.) Understand the impact that diversity (or the lack of) on television has had on viewers based on their perception on past shows as well as their self-confidence after watching tv. Using the research of Riva Tukachinsky and Dana Mastro, this project aimed to dive more deeply into the presence of people of color on television since the start of television and less on their portrayal. The study looks to answer two questions: "Is diversity within primetime television becoming more mainstream?" and "What are primetime television viewers' opinions on diversity within primetime television?". This is done by creating an examination for television shows on primetime television (ABC, NBC, and CBS). The survey also shows how minorities agree that representation is necessary, as opposed to Caucasians, and how they felt underrepresented on television as a child while whites believe they were represented on television as a child and that they are still represented now. The research will potentially serve as a blueprint for further studies to look into race portrayal and the future of racial representation on television which could be extended out to other countries and point out differences in television representation.

Counting With Entropy
Using information Entropy to Detect Colloidal Particles in Holographic Video Microscopy Images

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Supervising Scientist:
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Holographic Video uses lasers to visualize and track colloidal particles in solution. The video can track the particles' 3-dimensional position on a focal plane. Holographic images of microscopic polystyrene spheres provide an assortment of data, including sphere size, refractive index, depth of field, volume and entropy. This data can be used to characterize a large variety of microscopic particles. Prior to this study, the ability to determine the density of a solution was primarily limited to dynamic light scattering and machine learning methods. This research has produced a new technique for determining density, which is far more efficient than Dynamic Light Scattering (DLS). However, conventional methods of particle imaging and recognition (such as DLS, and Machine Learning) have proven difficult and the data is costly to analyze, often requiring prior training. Using entropy measurements as means of calculating the number of particles per image is proposed as an efficient method. The entropy and particle count can be determined using a Python based code. This code looks at the information content of individual images, and has been successful as it can determine how many images in a data set are blank and possibly determine density. This advance has implications in biopharmaceuticals, semiconductor processing and wastewater management.

Predicting Intensity Maps of Cosmic Neutral Hydrogen from Dark Matter Using Convolutional Neural Networks

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One of the main goals in cosmology is to constrain the values of the parameters in the ΛCDM model. This is achieved by comparing observational data from cosmological surveys with theoretical models of the universe generated in hydrodynamic simulations. However, the computational cost of these simulations limit the data that scientists have access to. An alternative would be to use machine learning to generate the simulations of a particular detectable constituent of the early universe, neutral cosmic hydrogen. In this paper, I showed that neural network algorithms can be used to accurately and efficiently predict the intensity maps of HI in all regions of the cosmic web given the input of dark matter density field. Specifically, the UNET architecture can generate HI maps with speeds up to a hundred times faster than the traditional method of creating Illustris simulations. Moreover, I found that the statistical properties of the predictions are similar to those in the Illustris maps with the use of validation metrics such as the power spectrum and 1D Probability Distribution Function. This work is an important step towards the goal of obtaining fast and accurate models of our universe that can be used with the upcoming 21cm cosmological surveys. Furthermore, this efficient approach is crucial for the future of cosmology when analysis of the physical properties of the universe is needed on a faster and more accessible scale.

The Effect of Recycled Glass Cullet on Heat Transmittance in Shingles

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Bealeton, Virginia

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The purpose of this experiment was to determine whether the replacement of asphalt granules on shingles with recycled glass cullet would decrease the amount of heat transmittance through the shingle. The glass shingles were constructed by pressing crushed multicolored glass into the sticky tar of a shingle. Glass shingles with a white Titanium Dioxide coating were made using the previous glass shingles and dusting a thin layer of the powder onto it. These were used to test if a change from dark to light color on shingles would also affect the heat transmittance. Thirty shingles were made for each of the three trial groups and tested using a heat lamp and a thermometer probe that was placed under the shingles. The data exhibited significance through a p-value of less than 0.00001. The means of the trial groups differed by almost ten degrees Celsius between trials with asphalt shingles at 63.57°C, glass shingles at 52.73°C, and glass shingles with Titanium Dioxide at 42.75°C. Standard deviations remained under 4.5 degrees Celsius for the three groups. In conclusion, the significance between the asphalt and glass granule shingles was demonstrated in this experiment as well as the significance between plain multicolored glass shingles and glass shingles with a white Titanium Dioxide coating. This research could prove vital in sourcing green roofing to urban area to mitigate the Urban Heat Island effect and reduce energy used to cool houses in the warmer months.

Determining Cost-Efficient Indicators of Alzheimer's Disease Using Neural Networking

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Comparison of methods used to diagnose Alzheimer's Disease (AD) via imaging, mental, and genetic data remains an open area of investigation. In this investigation, it was hypothesized that after designing and creating a full feed-forward neural network that accurately classifies cognitively normal (CN), mildly cognitively impaired (MCI), or Alzheimer's Disease (AD) patients, the top indicators of AD will include ApoE ε4 and structural volumetric measures. A key public AD Neuroimaging Initiative dataset containing 68 potential indicators for 14,037 patients was cleaned, one-hot encoded, and normalized to 25 potential key indicators and 2,646 patients. A full feed-forward network was carefully designed, which employed a categorical cross-entropy loss function and Adam Stochastic Gradient Descent Optimizer, to determine the most accurate indicators of AD. After more than 1,000 trials were run, Principal Component Analysis and BigML Analysis were conducted to cross-verify the results of the neural network. A cost analysis was also conducted to assess the practicality and accessibility of these top indicators. The results partially supported the hypothesis, suggesting that ApoE ε4, Clinical Dementia Rating Scale Sum of Boxes, the 11 and 13 item versions of ADAS-Cog, ADASQ4, the Mini-Mental State Examination, hippocampal volumetric measurements, and intracranial volume adjustment measurements most accurately indicate AD. Based on the cost analysis, getting a Mini-Mental State Examination ($79.35) and ApoE ε4 testing ($99-$199) are the most cost-efficient and accurate indicators of AD.

Investigating the Cause of the Cosmic Ray Background in IBEX-Hi

Paxson Swierc (Poster Peer Awardee)

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Mentor: Dr. Paul Janzen
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Interstellar Boundary Explorer (IBEX) is a NASA satellite designed to solely measure energetic neutral atoms (ENAs), however, its high energy detector (IBEX-Hi) has also observed a significant rate of cosmic ray particles. In this study, a qualified triple-coincidence event background rate was estimated for the IBEX-Hi detector and analyzed in relation to high energy and high mass cosmic ray data provided by the Cosmic Ray Isotope Spectrometer (CRIS), housed on the Advanced Composition Explorer (ACE). Results using the CRIS dataset, with specified energy ranges, show that the shape of the IBEX-Hi background over time most closely matches that of the Z = 26, 431 MeV/nucleon cosmic ray flux. As a cosmic ray's energy increases, its rate of change decreases towards the estimated IBEX-Hi background rate. It is likely that other cosmic rays above Z = 2 are able to generate background once they reach a sufficiently high energy. The reason for this may be that once cosmic rays reach a
high mass and energy, they have a high enough stopping power to knock loose electrons within IBEX-Hi that trigger the detector.

Ground-based Follow-up Observations of TESS Exoplanet Candidates

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The goal of this study was to further confirm, characterize, and classify LHS 3844 b, an exoplanet detected by the Transiting Exoplanet Survey Satellite (TESS). Additionally, I strove to determine the likeliness of LHS 3844 b and similar planets as qualified observation candidates for the James Webb Space Telescope (JWST). These objectives were accomplished by analyzing the stellar light curve, emission spectroscopy metric (ESM), and Planck spectrum of LHS 3844 b. I remotely obtained ground-based images of LHS 3844 b from the El Sauce Observatory. Through the Python programming language, I developed a novel pipeline to convert the calibrated images into a fitted light curve, and through my best-fit light curve model, I classified LHS 3844 b as a terrestrial planet. The calculated ESM of LHS 3844 b surpassed the projected threshold for simulated planets deemed qualified for JWST spectroscopic follow-up, and the Planck spectrum of LHS 3844 b revealed that the observed wavelengths between 6,000 and
10,000 nanometers would produce the highest signal-to-noise spectroscopic observations of LHS 3844 b. These findings will improve the accuracy of spectroscopic follow-ups done by the JWST; I intend to apply these methods to study a variety of exoplanets.

Deciphering the Vaping Epidemic: The role of α5 single nucleotide polymorphism on Nicotine Dependence

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Nicotinic acetylcholine receptors, or nAChRs, form the basis of nicotine addiction. The $\alpha4\beta2\alpha5$ nAChR is the focus of this study. When an individual uses, either a cigarette or an e-cigarette, nicotine is released, rapidly moving from the bloodstream to the brain. There it binds to the nAChRs and results in the opening of the receptor, sodium, and calcium enter into the receptor and potassium exits. The effect of calcium entering releases the neurotransmitter dopamine. Once this transmitter is released the user experiences a pleasurable feeling, which reinforces continued

use of the substance to achieve more pleasure, thereby strengthening the addiction. This process is known as the "Dopamine Reward Pathway." Thus, defining the nicotinic receptor subunit composition in vivo remains a critical issue to be addressed in characterizing the mechanisms underlying addiction. Two tests were conducted to help both characterize and reverse the role of the α5 receptors. Electrophysiology allowed me to distinguish between the α5(D) and α5(N) nAChR subunit variants through ACh stimulated whole cell patch current. After measuring the desensitization rate of both, I was lead to two hypotheses. The new tool that was used to help with the knockdown of the α4β2α5 nAChR is the gene editing tool called CRISPR-Cas9. After finding the correct antibody, I was able to with the help of the pX330 DNA plasmid knock-down the α4β2α5 nAChR. And to help visualize the knockdown, western blots were performed, allowing me to identify the presence of specific proteins.

An Analysis of Various Fibonacci-Type Sequences and Sums

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Teachers: Barbara Stewart
John Cangelosi

Mentors: Jonathan Bayless
Paul Kinlaw

The Fibonacci Sequence (1,1,2,3,5,8...) is well-known for its recursive definition. Although simply defined, its complexity grows when considering its applications to nature, finance and the general field of mathematics. One interesting characteristic of the Fibonacci Sequence is its reciprocal sum, defined as the sum of the reciprocals of each term in the sequence. However, the closed form of this sum is unknown, and the most accurate values are computed with techniques that are too complex for the realm of this project. Despite this, previous research has indicated simpler numerical bounds of 0.096% and 0.887% above and below using the sequence's counting function. The aim of this project was to obtain more accurate bounds, and investigate the counting function to more detail. In addition to these elements, other functions and sequences, such as compositions of the counting function with itself, were analyzed. A variety of analytical and computational methods were studied, including Partial Summation, which uses the counting function, and a direct approach, which uses a mathematical description of the sum itself. The most accurate method was found using the Wolfram Language, chosen because of its computational abilities and expansive library of functions. The results of this research were novel analyses of several different sums and functions related to the Fibonacci Sequence. With this came a deeper understanding of this sequence stemming from the concept that these aspects allow a more detailed analysis of the behavior of the sequence, which could advance the widespread applications of the Fibonacci Sequence.

The Effect of STN1 Knockout on the ATR DNA Damage Repair Pathway

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Mentors:

Dr. Jason A. Stewart

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This study was undertaken in order to determine the effect of the removal of STN1 on the ATR DNA damage repair pathway. STN1 is one of the structural proteins in the newly discovered protein complex CST, which consists of CTC1, STN1, and TEN1 in humans and has been found to play a role in rare genetic diseases Coats Plus and dyskeratosis congenita. As CTC1 was discovered to play a role in DNA damage repair, it was hypothesized that STN1, a related protein in the complex, may also play a related role in this pathway. In order to test this, an induced knockout of STN1 was created in a HeLa cell line using a Cas9 complex. The knockout and a wild type of this cell line were collected and frozen on even numbered days 2-12. The protein from these cells was extracted and quantified to run in a Western blotting procedure, testing for the presence of ATR downstream products and preliminary factors. The resulting blots showed an identifiable decrease in the presence of inducers early on (days 4-8), with a rescue of the tested preliminary factor in days 10 and 12. Downstream product levels were unable to be identified, as the tested cell line showed a p53 and consequently a p21 deficiency. It was thus revealed that STN1 has an effect on the ATR DNA damage repair pathway, though further research is needed to fully confirm and investigate the specific role of the STN1 protein in this pathway. Given the importance of DNA damage repair in cellular maintenance and reproduction, the understanding of specific mechanisms in this pathway opens up the possibility of specific treatments for the failures of the pathway.

Hierarchical Attention Neural Networks for the Detection of Advertising and Promotion in Texts

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As news consumption shifts to be based more and more online, there is also a growing trend of deceptive advertising practices in this area. Native advertising, as an example, consists of adverts written as an editorial or news article, and is, as a result, difficult to differentiate from organic content. In addition, more malicious forms of advertising have been growing in prevalence recently, with spam emails reaching an all time high in 2019. It is for this reason that a method to accurately detect and filter promotional texts is necessary. This paper proposes a novel, largescale natural language dataset built for the purpose of advertising detection, consisting of human annotated multi-class labels for 5 types of promotional language and a negative class for unbiased texts. In addition, this paper proposes a method to detect promotional texts through the use of a deep learning architecture that effectively models large texts by capturing a hierarchical feature structure, looking at both the word-level representation of a document and the overall sentencelevel representation. Evaluated using accuracy, precision, and bias as metrics, this method was found to be effective for the detection of promotion within texts.

A Novel Approach to Improving Crop Yields via Waste Application: Analyzing Effects of Soybean Curd Residue on Soil Productivity

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Teacher: Jesse Nims
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This project explores the potential of utilizing soybean curd residue (SCR) to improve soil productivity and drought resistance by analyzing its effects on the nitrogen and potassium concentrations, water-holding capacity, and permeability of soil. A few hundred million tons of SCR are generated annually as a byproduct of soybean manufacturing. Currently, this waste material is dumped into landfills, which poses environmental problems because it is highly susceptible to putrefaction and releases greenhouse gases. In this study, different concentrations of SCR and two types of SCR, wet and dry, were analyzed to determine effects on soil productivity. Experiments revealed that adding SCR to soil raises nitrogen and potassium levels from Depleted to Sufficient, with an estimated five to six times higher nutrient concentration than the control. SCR lowers soil permeability and significantly increases water-holding capacity. Compared to the control, soils with SCR retained over triple the amount of water for up to ten times longer. Higher water-holding capacity assists in relieving drought and prevents leaching; lower permeability inhibits rapid water drainage, giving plants more time to absorb moisture. The elevated levels of nitrogen and potassium, which are limiting nutrients, in soils with SCR substantially enhance soil fertility and allow for greater productivity. SCR presents a practical, cost-effective method to improve crop yields and agricultural sustainability while reducing wastes that negatively impact the environment. This novel application method redefines the potential of waste and finds a synergistic solution in the complex waste-food-environmentenergy nexus with the potential to alleviate food crisis.

An Integration-Free Accelerometer Based Approach for Estimating Peak Knee Angle

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Mentor: Mrs. Stacie Massie

Knee angle tracking has important applications in rehabilitation and sports training. In this project, a wearable sensor system is developed for using inertial measurement units (IMUs) to track knee angles. It consists of two IMU sensors, an Arduino Nano board, and a Micro SD module. In addition, a new integration-free accelerometer-based method for tracking peak knee angle is proposed. The method takes the advantage of the fact that gravity is the only acceleration at the peak of stride. The peak knee angle is the angle formed by the thigh and shank when the knee reaches its peak position in a walk stride. It is an important parameter for measuring the range of motion. Experiments were conducted with three different users to evaluate the accuracy of the developed sensor system and the proposed peak knee angle tracking method. Two additional tracking methods, an optical tracking method and a conventional gyroscope-based method, were also used in the experiments for comparison purposes. Experimental results show that the developed sensor system and the proposed method can accurately track peak knee angles. The average root-mean-square (RMS) error of the three users' peak knee angles obtained by the proposed method is 7.6 . It also shows that the proposed method is more robust than the conventional gyroscope-based method.

Minimizing Error in Machine Learning Algorithms by Adjusting Model Hyperparameters

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Machine learning (ML) allows a computer system to detect patterns in a set of data and make predictions. ML techniques can be applied to many fields both inside and outside of computer science, such as economics or healthcare. The researcher's focus in this study is not on the prediction of specific data but rather on the optimization of the machine learning model itself in order to produce more accurate predictions based on any data set. The researcher analyzed the resulting error of twenty-seven combinations of the values of three hyperparameters or setup parameters (batch size, step size, and learning rate) when applied towards the prediction of median house values given the population in a compact geographical area using data from the 1990 U.S. Census. While the researcher hypothesized that each individual variable would have a direct, independent effect on the resulting error, the data demonstrated that this is partially true, but also that two of the input variables are interdependent in producing ideal results. This study produced nine combinations of the three variables that yielded optimal predictions, while simultaneously demonstrating the complexity of the optimization of machine learning models.

Identifying Optimal Panobinostat Treatment Regimens Utilizing Reverse-Engineered Concentration-Time Curves

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Mentor: Praneeth Sudalagunta
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The Ex Vivo Mathematical Malignancy Advisor Model (EMMA) is a support tool for treating Multiple Myeloma. A biopsy is taken, and patient plasma cells are cultured in plates to which chemotherapies are applied. These plates are imaged, and an algorithm produces a cell viability curve for each plate. EMMA is fit to these curves, and parameterizes patient-specific models of chemosensitivity to each tested chemotherapy. For EMMA to predict patient response to a specific chemotherapy, the model must incorporate that chemotherapy's concentration-time curves (CTCs). These describe the average temporal variation in concentration doses of a specified chemotherapy will undergo in humans. Because CTCs aren't readily accessible to the public, a novel mathematical model was formulated to reconstruct the CTCs of orally-administered Panobinostat. Model parameters were fit by minimizing the residual between the 20mg model curve's cmax, t max, and AUC inf metrics, from those publicly provided about Panobinostat's 20mg CTC. For the reconstructed CTCs of different doses, the model was solved using a different dosage value, and cmax, t max, and AUC inf were checked to ensure they fell within the reported range. Model CTCs were concatenated to create alternative treatment schedules. Using each logged patient's chemosensitivity model, alternative treatment schedules were substituted and EMMA was run to produce best response: the predicted largest percent reduction in tumor volume that patient will experience. For 51.4% of patients, treatment scheduling produced best response metrics varied such that they were not all >50% or <5%. This indicates for half of patients, Panobinostat scheduling can be optimized.

Investigation of Green Energy in the Process of Fermentation

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Teacher: Christopher Benshoof

Mentor: Wang Xu

Energy is vital in providing heat and electricity for the world, but often, its waste byproducts harm the environment. Hence, green energy is long sought for because it is generated through a natural cycle in ecosystems. The energy yield of dough fermentation was tested to see whether it could be converted into a substantial source of green energy, as a potential alternative to chemical batteries. The temperature of leavened and unleavened dough was recorded over the span of three and a half hours to quantify the heat produced during this reaction. After improving the experimental design multiple times, the results showed a significant temperature difference, which was directly proportional to the heat produced from the leavened dough through fermentation. The average power of the heat was measured to be about 2.2 kJ/h, thereby indicating that 900 grams of a leavened dough would produce a similar amount of power to a 1.5 volt AAA battery supplying a current of 1.0 amp. However, an AAA battery supplying a current at that rate would become discharged in less than an hour, while the dough could easily supply that power for more than three and a half hours. To disseminate the use of leavened dough as a green energy battery, a thermoelectric generator of high efficiency would be required to convert the heat into electricity in order to harness this energy. Also, further studies would need to be conducted to increase the efficiency, portability, and convenience of extracting energy from a leavened dough.

Automated Computer Vision and Machine Learning Workflows in Radiation Treatment Planning

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Mentor: Dr. Shulan Tian
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Brachytherapy, the use of radioactive implants placed near tumors, is a vital part of cervical cancer treatment. However, the lack of automated workflows makes brachytherapy planning susceptible to time constraints, human error, and inconsistencies in radiation dose quantities. This project proposes a fully automated software that does not require manual interaction with patient images, with the goal of reducing planning duration and variability. The software is equipped with a three-dimensional interface for clinical usage and features a novel assemblage of 3D computer vision tools. Tandem and ovoid applicators, the titanium catheters that ferry radiation into the body, are segmented by thresholding CT images. The isolated high-density voxels are assigned to catheter and non-catheter structures through HDBSCAN, an unsupervised machine learning algorithm that uses density-based linkage clustering. The algorithm recognized seven structures, including three catheters and four gold seeds. After clustering, the applicator contours were traced through finding the centroid point of the applicator voxels on each image slice. The contours, along with treatment reference points and ovoid surface lines, were written to a treatment plan file. Through comparing manual and automated planning, retrospectively, for 10 cervical cancer patients, the software demonstrated clinically viable results in geometric and dosimetric accuracy. The average execution time for the algorithm was less than 30 seconds. The implementation of this automated workflow, the first of its kind for tandem and ovoids applicators, can lead to safer radiation delivery and reduce the duration and variability of high-dose rate treatment planning.

An ATP analog DIMA elicits a synthetic lethal effect in cells overexpressing the MYC oncoprotein by acting as a dual inhibitor of MKLP2 and Aurora-B kinase

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Mentor: Jing Zhang
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Synthetic lethal therapies represent an emerging direction of anticancer drug development. We have recently identified a mitotic regulator, the motor kinesin-like protein MKLP2, as a synthetic lethal target in cells overexpressing the Myc oncoprotein. Currently, the Myc oncoprotein lacks effective pharmacological inhibitors. Based on the structure of MKLP2, we used a computationbased approach to design an ATP analog that elicits the dual inhibition of MKLP2 and Aurora Kinase B, named DIMA, as a potential inhibitor of the mitotic regulator. Upon exposure to the chemically synthesized DIMA, cells were initially arrested in early mitosis and then developed polyploidy or underwent apoptosis. Immunofluorescence staining of drug-treated cells revealed that DIMA efficiently inhibited both MKLP2 and Aurora-B kinase without much discrimination. This inhibition apparently led to a failure of cytokinesis because both MKLP2 and aurora-B are pivotal regulators of cytokinesis. Cells suffering cytokinetic failure underwent repeated runs of DNA synthesis in the absence of cytokinesis, resulting in polyploidy. In contrast, Aurora-A was not inhibited. Collectively, these data indicate that DIMA is a novel dual inhibitor of MKLP2 and Aurora-B. This compound has great potential in furthering the field of anti-cancer drug development as a synthetic lethal therapeutic that kills cells overexpressing MYC.

Reducing the Impact of Dust Accumulation on Photovoltaic (PV) Solar Panels by providing Vibration and Airflow

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Mentor: Dr. Nate Brady
The Walker School

This engineering study, Reducing the Impact of Dust Accumulation on Photovoltaic (PV) Solar Panels by providing Vibration and Airflow, was developed to discover new solutions for the prevention of dust accumulation on solar panels to promote more solar energy harvest in desert regions. To reduce the pollution on our environment by fossil energy, engineers are developing technologies to harvest sustainable clean energy, such as solar energy. Deserts receive the most solar energy; however, the sandy condition stops people from utilizing deserts to harvest solar energy. Sand and dust accumulations on solar panels can cause the efficiency of solar panels to drop by 40%. Common cleaning methods, such as water spray and manual wiping are not viable in desert regions because of the scarcity of water and expensive labor. In this study, we developed two novel solutions to solve this issue: Vibration and Airflow, needless water or labor. Vibration motors were attached to the back a PV panel to shake the sand and dirt off the panel's surface. A plastic tubing with a cut slit attached to a squirrel cage fan was designed to blow away dust and sand. As a result, vibration motors are able to bring the efficiency of the PV panel back from 50% to 98% after a minute of vibration; after 25 seconds of blowing by the fan, the panel's efficiency can be recovered to 99%. The results showed that these methods were highly effective in increasing the efficiency of PVs under dry, sandy conditions.

Testing Different Aromatic Urethane Acrylates and Properties of Boron Nitride Nanotube for Use in Fabrication of Ion-Selective Nanotube Membranes

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Supervising Scientist:
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One largely untapped source of clean energy is to use the osmotic gradients where freshwater and saltwater are mixed, for example at estuaries. To harness such energy, chargeselective membranes are needed to separate the anions and cations in saltwater, establishing an electric potential like a battery. This objective of this study is twofold: to investigate the creation of the polymer matrix, and test the properties of boron nitride nanotubes, as both are essential in the creation of a ion selective membrane. The proposed polymer layer has many attractive properties: controllable thickness allowing nanotubes (typically 5-10 microns long) to pass through, being rapidly curable with a UV lamp, easily mounting on other substrates, resistance to O2 and SF6 plasma gas etching, and structural strength to prevent tears. Out of three polymer samples tested in this study, the mixture known as Soltech 704 showed the best resistance to etching, as well as the highest UV cure rate. To allow such nanotubes to be aligned, magnetic iron oxide particles were attached, and then a magnetic field was applied. This study shows a linear relationship between the magnetic dipole moment and the magnetic field strength, and a linear relationship between the magnetic dipole moment and the length of the nanotube. This study can be used to optimize the alignment procedure for the nanotubes, as well as the curing polymer.

Synthesis and Characterization of Si(bzimpy)$_2$ Analogs for Application in Organic Light Emitting Diodes

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Supervising Scientist:
Margaret Kocherga
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Organic electronics have various advantages due to their flexibility, light weight, and low-cost material fabrication. OLEDs were first made in 1987, utilizing Alq3 as their emitting element. Alq3 and its substructures have been the most commonly used materials in electroluminescent devices. However, they exhibit a few drawbacks: poor fluorescence quantum yield, redox instability, chemical instability in water. Ideal OLED materials are expected to have these key characteristics: high luminescence efficiency, redox reversibility, chemical stability, and simple stereochemistry. In 2017, research on the Si(bzimpy)2 complex began, focusing on creating proof of concept organic electronic devices. Si(bzimpy)2 has a higher fluorescence quantum yield, does not degrade in water, and exhibits most of the ideal characteristics for electroluminescent materials except for redox reversibility and chemical stability in the reduced state. Thus, the new effort is to develop Si(bzimpy)2 analogs that improve on the weakness of Si(bzimpy)2 complex. This project synthesized multiple Si(bzimpy)2 analogs; characterized the structure, optical, and electronic properties of these molecules; and fabricated the OLEDs based on these molecules. Preliminary results show that Si(pincer)2 complexes are potential candidates for efficient OLED applications, with improved properties over Alq3 since they are non-toxic, environmentally friendly, abundant (no rare earth elements), and exhibit color tenability.

Real-Time Prediction of Vehicle Steering Angles using Convolutional Networks and Computer Vision on Dashcam Video

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Virtually all existing self-driving vehicle solutions require a myriad of expensive cameras, LIDAR, and radar equipment. The few camera-only systems are problematic, soley utilizing Convolutional Neural Networks (CNNs) that cannot accurately emulate continuous human driving behavior or Recurrent Neural Networks (RNNs) that, when used alone, do not work in real-world scenarios due to small errors compounding over time. In response, I present an accurate, self-correcting, real-time autonomous driving solution that predicts steering angles using frames from a single camera. Individual images are fed into an ensemble of three different models, and the results are combined using an innovative function that generates safe, accurate predictions. An RNN is the primary steering factor, which takes a camera frame as input and outputs the predicted steering angle. Computer vision techniques like color thresholding and perspective transformation are used to detect left and right lane markings in order to calculate the vehicle's deviation from the center of the lane, preventing compounding errors. A Fully Convolutional Network (FCN) performs semantic segmentation to identify areas that are part of the road, verifying the other inferences. This novel algorithm significantly outperforms state-of-the-art solutions in terms of accuracy and efficiency for both simulated and real-world scenarios.

Cost-Effective and Facile Production of Foamed Aerogel

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Foamed aerogels merge the properties of aerogels' high porosity, extremely low density, and high specific surface area with foams' closed-cell macroporous voids by constructing macroporous foams with aerogel walls. They are a relatively new class of materials that demonstrate potential applications in cleaning oil spills, fractionating blood, and controlling the release of time-sensitive drugs, but existing procedures require prefabricated polymer templates, resulting in extremely specific and costly procedures not suitable for industrial scales. This paper presents an innovative procedure for synthesizing foamed aerogels without the usage of chemical foaming agents or polymer templates, resulting in a less expensive, more efficient, and less specific process. The proposed process induces gas dissolution into the solution to form a foam-like structure within the aerogel under a highly pressurized environment during the gelation process. Polyurethane aerogel was synthesized to test the procedure, creating foamed aerogels and their non-foamed counterparts for comparison. A desirable combination of pressure, volume of solution, and apparatus orientation was determined. These foamed aerogels exhibit lower bulk densities, higher porosity, and macrovoids. Because the procedure does not require additional chemical processing steps, it is 50.6% less expensive than existing procedures and scalable for industrial production. In addition, the foamed aerogel demonstrated a 144° contact angle with water, displaying its near superhydrophobicity.

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Tunable Plasmonics Based on Dynamic Voltage Simulated Nanostriations

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A growing issue of modern technology is the computational limit of silicon electronics. As society continually attempts to shrink their transistors it will eventually reach a quantum limit, preventing further advancements in computing power. The limits of electronics create the need for a new information medium beyond the electron. A prominent proposed solution for this issue is to use light. However, light is limited by its ability to couple with devices, requiring much larger wavelengths in order to function. In recent years, however, heavy research has been done in the field of plasmonics, which potentially provides an alternate solution.

Surface plasmons are quantized charge density oscillations that propagate at metal-dielectric interfaces. They are quasiparticle oscillations that resemble optical behavior, although they can be used on a much smaller scale. These plasmons, however, are limited by the very precise resonance conditions needed to create them. This results in devices being engineered for specific fixed functions and limits their practical usage in circuitry and computation. This project seeks to address this issue through the creation of a tunable plasmonic device. This device will be built around a unique dielectric material known as Barium Strontium Titanate(BST). BST is a tunable dielectric, being able to adjust its permittivity on account of an applied voltage. By inducing a standing wave voltage pattern within the dielectric material, it is theorized to simulate the effect of conventional resonance structures and create for a new tunable device, paving the way for potential plasmonic-optical signal processing and computation.